CONTEMPORARY TECHNOLOGY

Innovations, Issues, and Perspectives

Fifth Edition

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Introduction

Contemporary Technology: Innovations, Issues, and Perspectives is written for college and university courses related to technology and society. This book is intended to introduce you, as one of its readers, to the pervasive nature of technological innovations and to increase your awareness of both the promises and the uncertainties associated with the use of technology as a creative human enterprise. The chapters are organized under three headings. Section I, "Innovations," contains five chapters discussing recent developments and breakthroughs in the following technical disciplines: biotechnology, information systems, space exploration, medicine, and manufacturing. Section II, "Issues," includes four chapters focusing on some of the public controversies associated with significant international and global issues in technology transfer, appropriate technology (AT), environmental policy, and defense strategy. The final three chapters make up Section III, "Perspectives," and address a variety of diverse sociological viewpoints regarding humankind's effective use of technology and the projected stability of our "pseudotraditional" social institutions.

Contemporary Technology presents technical facts and figures and scientific theories in a general way to provide you with an overview of the innovations, issues, and perspectives on the topic of technology in your everyday life. We acknowledge that it is impossible, in these few pages, to cover all the bases, investigate all the angles, or delve into all the topics with the thoroughness everyone might desire. This book will prove, however, we believe, to be a useful starting point in your study of technology and technology's impacts on society. The text presents cases, both pro and con, to be considered in the application of technology. We provide explanations for many key technical concepts and periodically define words with which you might be unfamiliar. The lengthy lists of suggested readings at the end of each chapter will enable you to further study areas of particular interest. Our desire and optimistic expectation are that the course or activity for which you are reading *Contemporary Technology* will teach you to actively think, analyze, question, criticize, and ultimately search out new sources of information. Our primary objective is to motivate you to take a strategic role and participate in current and future technological ventures.

Linda Rae Markert

Patricia Ryaby Backer

About the Authors

Dr. Linda Rae Markert and Dr. Patricia Ryaby Backer are well qualified to write this newest edition of *Contemporary Technology.* Dr. Markert is the author of the first three editions of this textbook. Dr. Backer joined the writing team with the release of the fourth edition.

Dr. Markert is presently the Dean of the School of Education at SUNY at Oswego. Prior to this administrative post, she chaired the Department of Technology at SUNY Oswego, where she continues to hold a professorship. As chair, she taught courses and supervised technology-education student teachers. She held a professorship in and was the Graduate Coordinator for the Division of Technology at SJSU. Employed at that institution for 15 years, she taught a variety of graphics and professional courses, including a graduate seminar in international technology. Dr. Markert holds her doctorate in educational administration from the University of the Pacific. She received an appointment as a Visiting Scholar in the Science, Technology, and Society Program at the Massachusetts Institute of Technology (MIT) and participated in the Institute for Management and Leadership in Education at the Harvard Graduate School of Education. Dr. Markert is published in a number of professional journals, oversees research grants, serves on educational boards, and is a sought-after speaker.

Dr. Backer is presently the Director of General Engineering at SJSU. She holds a Professorship in the Department of Aviation and Technology and has taught courses in many technical areas, several of which include technical illustration, multimedia production, manufacturing organization and communication, and statistical quality control. Prior to joining the faculty at SJSU, she held instructor appointments at Tennessee Temple High School; Tennessee Temple University; and Thomas Jefferson High School for Science and Technology, a Governor's Magnet School in northern Virginia, where she taught courses in geometry, computer science, physics, business statistics, and philosophy of education. At Tennessee Temple University, she also evaluated the pre–student teaching observation program for preservice elementary and secondary teachers. Dr. Backer holds her doctorate in neurocognition from the Ohio State University. She received a Fulbright Scholar lecturing award in Peru, where she taught and consulted on the topics of computer-based multimedia and Web teaching materials. Dr. Backer also received fellowships from the National Endowment for the Humanities and the Army Research Institute. She has given numerous national and international presentations on many topics, all of which have been published in professional proceedings, and she is a successful research-grant recipient. Both authors have taught courses for which this textbook is selected and used. Working and teaching in central New York and in the heart of Silicon Valley keep Dr. Markert and Dr. Backer in focus with emerging trends in technology and the impacts of these trends on society.

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Chapter 1

Science, Technology, and Society (STS)

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DATELINE

Dresden, Germany

The German Federal Police conducted a robust field test of Cognitec's FaceVACS® face-recognition software at the main railway station of Mainz, Germany. Their project confirmed that it is technically possible to use biometric face-recognition systems in police-investigation scenarios and obtain highly accurate results. This test used parameters to achieve a false alarm rate of 0.1% or less.

Police and private organizations have deployed automatic face-recognition systems in airports, shopping malls, school campuses, and other locations in many countries around the world. Cognitec Systems, headquartered in Dresden, Germany, is a face-recognition company. According to the National Institute of Standards and Technology, Cognitec is currently leading research and development (R&D) efforts to perfect 3-D recognition algorithms. Applications for use of its impressive product portfolio range from the issuance of national identification (ID) cards to automated border control to the search for unwanted persons in sports stadiums and casinos. The use of cameras and computers to look at every citizen attending a sporting event or playing a video slot machine or card game while on vacation is a bit unsettling and might mark the end of public anonymity....

Introduction

What better way to open the first chapter of a book about contemporary technology than to relate an incident about the highly pervasive nature of technological systems in our everyday lives? In all likelihood, most people attending football games or enjoying a restaurant meal are entirely unaware of the fact that they might be under investigation or being recorded. See **Figure 1-1.** Reasonably, most of us have become accustomed to being filmed while using a bank's automatic teller machine (ATM), but we are less keen about having our attendance at a sporting event videotaped without our knowledge or consent.

In recent years, we have begun to take greater notice of the importance of privacy, since a significant portion of it has been or is threatened to be taken away. Privacy is viewed as a personal right we assume we have, yet we take it for granted until something or someone infringes on it. In reality, our current technological-surveillance capacity makes personal privacy, in many aspects of our lives, a thing of the past. At the same time, however, our society guards against antisocial conduct through these same surveillance technologies, in order to protect personal and group rights and enforce social rules and regulations.

Philosophically, *privacy* can be viewed or defined in any number of ways. *Privacy* can be regarded as an entitlement of a person to determine what personal information about himself is communicated to others, or it can be defined in relation to control over access to information about oneself and the intimacies of personal identity. Another definition of *privacy* identifies the word with a state or condition of limited access to a person, the intimacies of life, one's thoughts, or one's



Figure 1-1.
On an ordinary Saturday afternoon in early winter, thousands of spectators are casually watching a basketball game inside a large college dome stadium. Unbeknownst to them, surveillance cameras might have been installed. (Michael Poirier)

body. In each of these instances, control over information about oneself is relative, as is control over one's bodily security and personal property. The more we venture into the public realm to pursue interests with others in our lives, the more we inevitably risk privacy invasion and perhaps identity theft. It stands to reason that, if we want medical doctors to cure us or if we choose to conduct our private business over the Internet, we must be willing to relinquish what might be considered private or personal information about ourselves.

Without question, as these ideas illustrate, we are living in an age of cyberspace, in which computerized information storage and retrieval systems have become the rule, rather than the exception. Many of us have actually become quite accustomed to the idea of record-keeping redundancy and various other forms of technological surveillance. Many agencies around the world electronically store all kinds of personal statistics, credit references, academic records, annual-earnings figures, health reports, and even grocery-store purchases. These bits and bytes of what was once considered to be private information are transmitted back and forth among banks, universities, government offices, and detective agencies in a matter of a few seconds.

For a while, it seemed as if the grand advancements in communications technology and electronic-database management would result in what literary observers called a

paperless society. To date, not many people seem willing to completely relinquish their right to have a hard copy of most documents being reviewed. In fact, the advent of computerized information systems, coupled with the ever-present electrostatic copier, has led to a society more full of paper, as opposed to one that uses less of it. Electronic mail (e-mail) has made its mark here as well. Many people routinely print their e-mail messages, along with an array of e-mail attachments, in order to read them at a more convenient location away from the computer screen (such as while riding the subway home from work or sitting in a lounge chair at the beach).

More often than one might expect, most people insist on having multiple copies of everything they write or transcribe for someone else. These oversimplified examples of contemporary daily living illustrate the point that technology pervades every business transaction and every individual's life. For this reason, it is no longer possible, if indeed it ever was, to be casual about science and technology. See **Figure 1-2.** Large and small, banal and impressive, scientific innovations and technological improvements pour out at an increasingly accelerated rate of speed. A great portion of such technological change, modification, and improvement is hardly even noticed these days. Many of us have become numb to novelty, unless it is formidable, majestic, or entertaining in its outward appearance.

The types of breakthroughs receiving the greatest amount of media attention and the subsequent interest of the public seem to take place most often under the guise of exotic, distant, or new high-tech industries. Among these disciplines one might list biotechnology, computers, robotics, artificial intelligence, lunar mining, fiber optics, pharmaceuticals, supersonic transport, lasers, glass ceramics, satellites, and space shuttles. Behind all the glitter of high tech, we find a

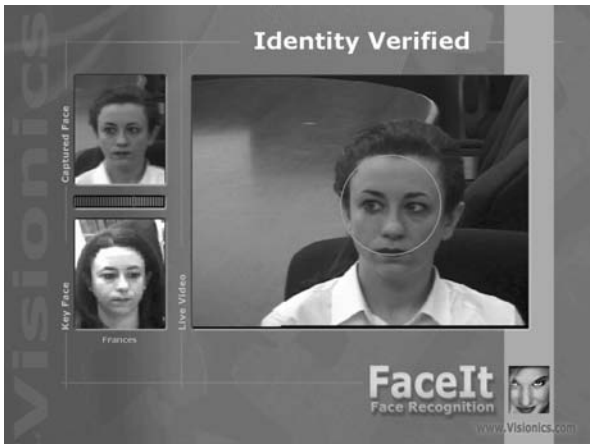


Figure 1-2.
Similar to FaceVACS computer software, FaceIt® computer software allows police officers to search for the faces of unwanted or suspicious persons in public locations.

gamut of new, but somewhat unremarkable, technologies that cut across a wide range of businesses, including sporting goods, convenience foods, household appliances, tools and gadgets, clothing fabrics, children's toys (often also enjoyed by adults), video games, soft drinks, music, and art. Contemporary scientific and technological advances range from tiny improvements in devices that we take for granted (such as coated frying pans, flat-screen monitors, or the shape of the buttons on the remote control devices linked to an entertainment system) to heroic leaps forward that have far-reaching impacts on the status of life on the planet (for example, nuclear weapons, space stations, the Human Genome Project, artificial organs, and global communication networks).

Who has the authority to say any one of these changes is any more or less important than any other? This is one of the most important rhetorical questions of the era. Technologies that one social group favors are simultaneously abhorred by other groups. Some people's lives are hanging in the balance of whether or not a medical

breakthrough will be made before it is too late. Others believe too much money is already being spent on medical research only benefiting those who can afford it. Some people profess to be antitechnologists, while others are avid supporters of technology. Still more people find themselves somewhere along this continuum of extremes.

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

science
technology

The Nature of Science and Technology

Over the past several decades, academic leaders around the world have developed a well-regarded discipline given the label *science, technology, and society (STS).* Through curricular proposals, scholarly papers, annual conferences, and hundreds of articles and books, these professionals have garnered a great deal of respect for an area of study that is, in every sense of the word, *interdisciplinary.* The principles, theories, and objectives of this area pervade the many circles of physical scientists, life scientists, humanists, business analysts, educational specialists, engineers, technology educators, and industrial technologists. Across the nation, schools of engineering have started to develop required courses seeking to achieve a balance among technical, social, and ethical issues throughout the design process. These courses help ground the education of university science, technology, and engineering students, with the ideals of social and ethical responsibility as an integral part of their intended professions. Through interdisciplinary projects, students are taught the relevance of social, environmental, ethical, cultural, and political factors to their work. One of the aims of STS research has been to investigate the relationships (both historical and contemporary) between science and technology, in an attempt to reveal how the developments in both fields influence the nature of social institutions. STS researchers encourage us to think about the social, political, and environmental influences on and consequences of science and technology.

Can *Technology* Be Defined?

The word *define* is a variant of the Latin term *definire,* which translates to mean "to set bounds to." In order to define a word or concept, one must, therefore, be able to limit its meaning through the establishment of boundaries. A definition not only explains the true or accepted meaning of a term, but it also delineates what is not true about the term. In this day and age, *technology* is one of those words (similar to *engineering*) that has been used, overused, and misused to the extent that it almost defies definition. If one has difficulty explaining what technology does not include, it must be everything else. By definition, a definition should exclude something, since it cannot include everything.

In many cases, the word *technology* has become so diluted that a secondary modifier is demanded for further clarification. Thus, we have expressions such as medical technology, military technology, household technology, manufacturing technology, biotechnology, information technology, computer technology, agricultural technology, and industrial technology. The list continues as a greater number of specialized permutations become evident. From this perspective, technology seems to make reference to the procedures

and artifacts aligned with a particular discipline. On the other hand, the degree to which the research foundations for each discipline are interrelated makes it hard to say exactly where an exclusive product of technology fits. For example, is a solar-heated grain elevator part of agricultural technology, or does it belong under the energy-technology heading or even in the manufacturing-technology category? Modifiers enable us to focus on a certain discipline, but they do not really define the term *technology* very effectively.

It has also become fashionable to abbreviate the term *technology* to its shortened *tech* version. Thus, we have high tech, low tech, and no tech. We commonly use the prefix *techno-* to refer to a host of social conditions and products of technology, such as *technophobia, technostress, technocrat, technotoys, technoworld, technodummies, technowizards,* and *technolifestyle.* Once again, since we have become conditioned to these modern-day expressions, they are implicit in their use, and we say these expressions without giving them a second thought. Each of these terms has something to do with either the level of technological development or society's behavioral or psychological response to technology.

Perhaps it is easier to explain the meaning of technology by generating a list of technology's profile characteristics. Review the following inventory. Place a check mark next to any features you honestly believe are not true about this concept.

- ❑ Technology creates new economic opportunities and social benefits and, at the same time, produces new social problems.
- ❑ Technology is a powerful force that improves human productivity.
- ❑ Technology is an extension of human physiological capabilities and biological potential.
- ❑ Technology involves inventing new things and modifying the old ones to make them more efficient.
- ❑ Technology is evident in every culture, regardless of the culture's level of sophistication or stage of development.
- ❑ Technology enables humans to exert control over the natural environment.
- ❑ Technology liberates us from demeaning and demanding labor and, therefore, creates more leisure.
- ❑ Technology has increased the human life span by conquering many debilitating diseases.
- ❑ Technology incorporates human knowledge into physical hardware that will eventually respond to some human need or desire.
- ❑ Technology is intrusive to our lives and threatens our right to privacy.
- ❑ Technology is a process for transforming raw materials into useful goods and services.
- ❑ Technology is human made and desire driven.
- ❑ Technology creates uselessness by displacing people and trivializing their work.
- ❑ Technology has made many people apprehensive about the future.
- ❑ Technology is fundamental to the survival of civilization.
- ❑ Technology is destructive to nature.
- ❑ Technology is making the world increasingly incomprehensible.
- ❑ Technology is future oriented and, therefore, progressive.
- ❑ Technology is motivated by a pragmatic interest or an instructional interest.
- ❑ Technology utilizes the methods, tools, and skills typically characteristic of the process we call *innovation.*

Now, if you made a number of check marks in the margin as you scanned through this very partial list of modern technology's features, go back to those items and read them over a second time. While each of these ideas can certainly be debated to some extent, convincing examples can also be cited to validate every one of them. Consider for a moment the FaceVACS software technology described in the opening Dateline story, in relation to the first item in the list above. Surveillance cameras might be viewed as an invasion of individual privacy (social problem), but this technology has the potential to also be used to locate missing children (social benefit).

Technology is not a simple word to define. This word is used over and over again in this book within a whole series of contextual arrangements. The following simple definition for ***technology*** is not any more correct or useful than any other, but it can be used to establish boundaries.

TECHNOLOGY
The cumulative sum of human means developed in response to society's needs or desires to systematically solve problems.

Is Science Different from Technology?

The terms *science* and *technology* are so routinely combined to form a single phrase that some people find it nearly impossible to distinguish between the two. What is scientific is also perceived to be technological, and vice versa. It was not always this way. For centuries, people regarded science and technology as distinct fields of study, entirely separate from one another. Science was understood to be the pursuit of knowledge that would enhance human understanding of the natural environment. Technology simply entailed making and inventing things humans could use to control or cope with the natural environment. Early scientists were not often concerned with practical applications of the knowledge they secured, and early technologists were happy with their tinkering and did not have an interest in understanding the reasons things worked the way they did.

Therefore, one of the early distinctions between science and technology made reference to the world of "know-what" and "know-why," on the one hand, and the world of "know-how" on the other. Throughout the twentieth century and into the twenty-first century, the line between scientific inquiry and technological application has become quite obscure. In fact, one of the chief characteristics of contemporary technology is it is based more on the scientific knowledge of the nature of things—why materials react in certain ways and which laws are in force at any given point in the process of development—than ever before. Some excellent examples of science-based technology are found in atomic energy, fiber optics, biotechnology, antibiotics, and microengineering. The traditional language clearly distinguishing science from technology began to break down several decades ago and has nearly vanished.

In the mid-1990s, shortly after the author Michael Shermer founded the Skeptics Society and published his first issue of *Skeptic* magazine, we were introduced to another novel concept—something he labels *pseudoscience.* In much of today's media, numerous claims are presented so they appear scientific, but they lack supporting evidence and plausibility. Pseudoscience (such as hypnosis) is built on these claims. It is often difficult for many of us to recognize the point at which valid science leaves and pseudoscience begins. To some degree, this level of confusion underlies the negative reactions or skepticism some people have toward contemporary scientific breakthroughs.

The authors of this textbook maintain that contemporary scientists are motivated by curiosity and the desire to improve social well-being, but these scientists also recognize the need for the results of their research to be industrially relevant. In this regard, a recent strategy within the scientific community has been an attempt to establish that a close link exists, via technology, between pure science and its application to economic ends (entrepreneurial science). Thus, science is what is, while technology is what can be, as a result of science. Scientists have been anxious to demonstrate that their apparently curiosity-oriented work can, ultimately, lead to critical profit-making technological innovations and business ventures. This book reveals numerous instances in which this strategy has been quite successful and illustrates cases in which technology is actually used to legitimize science. In sum, it is difficult to separate science from technology. To simplify the incomprehension, the following explanation for the term ***science*** is proposed.

SCIENCE

A stream of human events involving a mathematical or systematic study of nature, resulting in a body of knowledge that is practical, as well as theoretical.

Overview of the Text

The following twelve chapters are organized under three subheadings. Section I, titled "Innovations," contains five chapters discussing and explaining recent developments in the following technical fields: biotechnology, information technology, space exploration, medicine, and manufacturing. These areas have been selected to illustrate the dynamic interaction between seemingly disparate fields of specialization.

Section II, "Issues," includes four chapters focusing on the dilemmas and controversies commonly associated with technological change. The subject areas that have received a significant amount of public attention during recent years are presented here. These areas are technology transfer, appropriate technology, environmental protection and degradation, and defense strategy.

The final segment of the text is Section III, "Perspectives." This segment contains three chapters addressing several diverse sociological viewpoints. These viewpoints include the effective utilization and management of technology and the projected stability of our traditional social institutions.

The format for each chapter is consistent throughout the book. As you found with this first chapter, each chapter opens with a *Dateline* incident that is, in some way, pertinent to the subject matter covered. These brief vignettes are designed to illustrate that technology marches on throughout the world at all levels, without the least regard for time. They are meant to show you that a simple glance through today's newspaper or last week's national magazine will reveal some event (major or minor) in technology that is already or will soon be shaping or reshaping the way we live each day. Be alert as you read through each chapter, and you will note that the authors make reference to the *Dateline* story, in order to tie it into the material being discussed.

Scientific and technological facts and figures are presented in a general way in this book. Highly respected publications, entire series, and comprehensive CD-ROM databases have been written or developed on every topic contained here. This fact alone makes it a challenge to provide a brief overview making any sense. Informed readers will unquestionably react to our method of content coverage by saying something such as "The authors left this

out," "The authors forgot to mention an important historical fact," or "The authors don't provide enough examples to back up their ideas." For this very reason, a lengthy reference list of suggested readings for further study is provided at the end of each chapter. Your ongoing perusal of technical subject matter, either directly related to your career objectives or indirectly supportive of them, is strongly recommended.

Several publications to which you might want to consider opening a subscription in the future include *Technology Review, Computers and Society, Issues in Science & Technology, The Economist, Invention & Technology, The Wall Street Journal, American Scientist, Science, The Futurist, The Technology Teacher, Skeptic, Science Digest, Scientific American, Harvard Business Review, Fortune,* and *IEEE Technology and Society Magazine.* While this list is not exhaustive of the titles available, it is a representative sampling of highly readable and quite informative titles. In addition to these printed media, we can strongly recommend you listen to numerous programs broadcast on National Public Radio (NPR), including *Morning Edition, Public Interest, Talk of the Nation, Science Friday,* and *All Things Considered.*

The discussion questions found at the end of each chapter (with the exception of this first chapter) are designed to stimulate further creative thinking about the innovations, issues, and perspectives presented under each of the major subject headings. We encourage you to work through these discussion questions, which are essentially inquiry based and tied to authentic learning experiences. They can be completed individually, but we recommend using cooperative study groups and seminar discussions, which will facilitate the most effective interdisciplinary learning and dialogue. Since it is impossible for any one author or solitary instructor to cover all the bases or investigate all the angles, you must take some personal responsibility for the learning endeavor.

Toward this end, it is essential to recognize that the development of a technological vocabulary goes far beyond a rote memorization of terms and their meanings. If the formal study or informal activity for which you are using this book teaches you anything, it should teach you how to think, learn, and search out new sources of information. No single reference is ever completely infallible. A technological vocabulary changes and expands on a regular basis. In just a few years, a whole new set of terms will be "on the books," but not included in the lists of Key Concepts found at the beginning of each of our chapters. You will see a written segment at the beginning of each chapter where a number of key concepts are introduced. Collectively, throughout the textbook, these concepts provide the foundation for a contemporary technological vocabulary.

The list of technology terms you will have studied when you finish reading this textbook is, by no means, exhaustive. Furthermore, between the time of this writing and the time of your reading of the material, any number of new terms will have appeared in all technology-related disciplines. As you read through this textbook, please make an effort to expand your own technology vocabulary—endeavor to learn new words and avoid simply "glossing over" key terms in your reading. We hope our inclusion of definitions of scientific and technological terms, both in the chapters where they are discussed and in a comprehensive glossary at the end of the textbook, will be helpful as you learn about contemporary topics and issues in technology. Moreover, it is our expectation that our methods of introducing you to an array of science and technology innovations, issues, and perspectives will enhance and improve your personal level of technological literacy.

Suggested Readings for Further Study

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Chapter 2

Biotechnology

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DATELINE

Reykjavik, Iceland

deCODE® genetics announced recently that it has developed a deoxyribonucleic acid (DNA)–based test for assessing risk of prostate cancer. The discovery is a direct result of this company's decade-long effort to analyze the genomes among the population of Iceland. Iceland was the first country in the world to sell the rights to its citizens' genetic codes to a biotechnology company. The data gained from Iceland, because of the uniformity of its people—a largely blue-eyed, blond-haired populace—provides an invaluable resource for studying human genetics, leading to fundamental insights into many diseases, proponents say. Additionally, because Iceland has a strong health-care system, scientists can correlate diseases with environmental and social causes. According to the CEO of deCODE genetics, Kari Stefansson, "[The company] believe[s] that this is a test with significant clinical utility for improving and personalizing the screening and treatment of one of the most common cancers. At the same time, we will integrate today's discovery into the prostate-cancer module in our personal genome-analysis service, deCODEme®, enabling our subscribers to stay abreast of how the latest discoveries in human genetics may relate to their genome...."

Introduction

The practice of biotechnology has existed in science for thousands of years, but *biotechnology* has acquired a new definition and perception in the minds of the public over the last 30 years. The first use of the word *biotechnology* can be traced to the late 1910s. The word was then used to refer to the industrial production of materials, such as acetone used to make cordite, an explosive.

The traditional uses of biotechnology were mostly in the manipulation of agricultural products through the process of artificial selection. Different strains of plants and animals were crossed, in order to produce particular genetic traits. Many previously wild species of plants and animals were domesticated to suit the demands of the human population. Through this artificial selection, the genes of these species were irrevocably changed. Although we generally forget about these early uses of biotechnology, the results can be seen in the diversity of animals today. For example, thousands of years ago, all dogs were wolves. Today, however, there are thousands of breeds of dogs. Many of these breeds developed as dogs were crossbred to maximize certain traits. This process of breeding and crossbreeding a species is the essence of traditional biotechnology.

The modern era of biotechnology began in the early 1950s, when James Watson and Frances Crick discovered the structure of DNA. The actual birth of the biotechnology industry is generally marked in the mid-1970s. Modern achievements of biotechnology include the transfer of specific genes from one organism to another; human stem cell research; cloning; and the fusing of different types of cells to produce medical products, such as monoclonal antibodies (MAbs). *Biotechnology* has become accepted as the umbrella term encompassing all these techniques. We define ***biotechnology*** as follows:

BIOTECHNOLOGY
The manipulation of biological organisms to make products benefiting human beings.

Biotechnology has triggered a great deal of public scrutiny and interest over the years. Consequently, it represents many things to a variety of professional disciplines. Molecular biologists view it as a powerful scientific tool, while entrepreneurs and venture capitalists recognize its versatility as a novel and potentially lucrative technology. For agronomists (scientists who specialize in field crop production and soil management), biotechnology holds the promise of another "Green Revolution," similar to the one of the 1960s, in which there were dramatic increases in the production of cereals and grains in developing countries because of improved seeds and production techniques. For medical scientists, biotechnology harkens a future that will bring cures to dreadful genetic diseases. Of course, there are numerous critics of biotechnology who focus on the potential for its abuse in the environment, among people, and in society as a whole.

The widespread use of biotechnology today promises abundance for humanity, but it simultaneously brings with it a series of mysterious potential risks. Biotechnology has an additional difficulty for laypeople, in that the technologies involved are difficult for nonscientists to understand. It is easy to fear something one does not understand. As biotechnology affects us more in our daily lives, it will be subject to more controversy and discussion. Genetically engineered microorganisms in any application present an array of complex problems for the environmental ecosystem and the regulatory agencies commissioned to protect it.

The commercialization of biotechnology started in the mid-1970s, when a number of small entrepreneurial firms were founded in the United States. These companies were specifically formed to expand the ever-growing body of fundamental knowledge in molecular biology and exploit it toward a profitable end. The market for biotechnologically engineered products has grown exponentially and continues to do so. Large, well-established corporations in the United States, Japan, and Europe have expanded their R&D programs to investigate new techniques in biotechnology. Along with this expansion of research has come a renewed focus on the patenting of biotechnological products, including those derived from experimentation with human cells. A struggle is being waged to dominate a fledgling market whose lifeblood is found in basic scientific research.

Biotechnology is different from many other technologies. The growth and development of this technology have occurred under a climate of intense public scrutiny. This scrutiny has brought increasing pressure to biotechnology companies to justify their product developments and reduce the risks to people and the environment. This chapter describes a variety of biotechnology uses today. The broad spectrum of disciplines involved in biotechnology research is presented with an eye for both the associated promises and perils. The following questions will be addressed in this chapter:

- ❑ What is the science behind the biotechnology movement?
- ❑ What types of commercial breakthroughs will be made in the health-care field and in gene therapy?
- ❑ Will biotechnology use in agriculture lead to another "Green Revolution"?
- ❑ What are the ethical and business aspects of cloning?
- ❑ Why has the question of regulation in the biotechnology industry been so complicated to address?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

biomining
biotechnology
blastocyst
cell fusion
clone
deoxyribonucleic acid (DNA) chip
Escherichia coli (E. coli)
gene therapy
genetically modified (GM) food
genome
monoclonal antibody (MAb)
pharming
recombinant deoxyribonucleic acid (rDNA)
transgenic
xenotransplantation

The Critical Technologies

Politically, as well as economically, the United States is well suited to the continuing and extensive development of the biotechnology industry. Generally speaking, the laws and policies of our government have enabled industrialists and scientists to capitalize rapidly on biotechnology and apply it to many areas. Much of the basic research on biotechnology has been conducted within the university system and in government laboratories. In the United States, there is a symbiotic relationship between R&D efforts. It is usual, even expected, that a researcher will commercialize any discovery. This entrepreneurial spirit and the availability of financing for risky ventures have led the country to the forefront in the commercialization of biotechnology. Additionally, the U.S. industrial sector has exemplified its diversity and flexibility, with reference to making efficient use of numerous laboratory achievements in biotechnology. All these factors have facilitated the rapid commercialization of biotechnology in the United States.

What Is Deoxyribonucleic Acid (DNA)?

To understand biotechnology, a basic knowledge of DNA is indispensable. The actual structure of the DNA molecule itself is identical among all living things. See **Figure 2-1.** The structure appears as a three-dimensional twisted ladder, with two strands twisted into a long spiral—a double helix. The steps of the ladder are pairs of bases: adenine (A) with thymine (T) and guanine (G) with cytosine (C). In the process of reproduction, the two strands of DNA unwind and serve as the foundations for generating new strands. This process results in the duplication of DNA. The structure of the DNA determines what the organism is.

The set of instructions for making an organism is called the organism's ***genome.*** The genome contains the master blueprint for the organism and consists of DNA and the associated protein molecules organized into structures called *chromosomes.* You might recall from previous biology courses that the nucleus of each living cell hosts a number of chromosomes. Different species have different numbers of chromosomes. For example, humans have 46, corn has 20, and goldfish have 94 chromosomes in each cell. Strung along the chromosomes are the units of the genetic code, the genes composed of DNA. If all the DNA in a single human cell was uncoiled, it would stretch out over 5' (about 2 m). In these 5' of human DNA, there are some 100,000 genes, which vary in length, often extending over thousands of base pairs. Overall, the human genome consists of 3 billion units (the bases

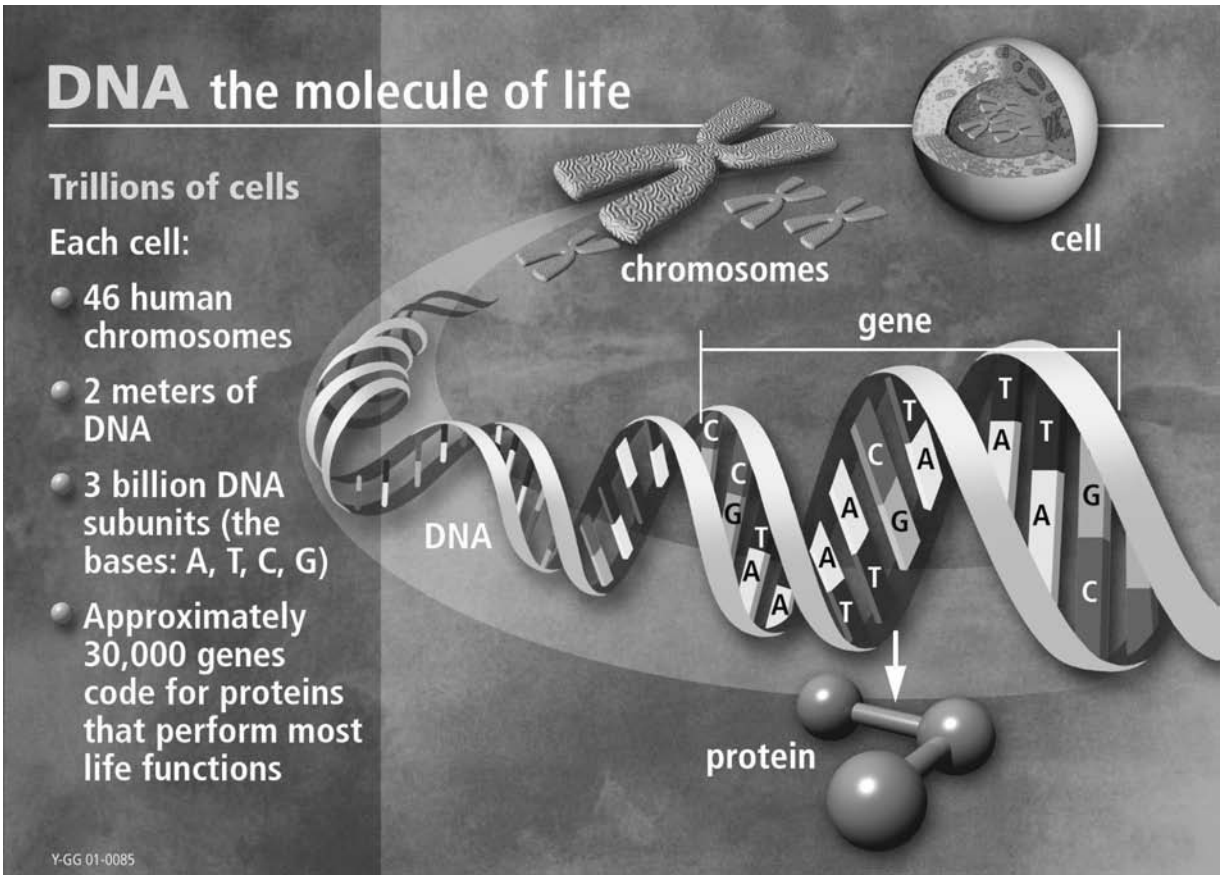


Figure 2-1.
The composition of DNA in a human being. (U.S. Department of Energy Human Genome Program)

A, T, C, and G). In each DNA molecule, there is the blueprint (genetic code) for bones, muscle, tissue, and blood. Every living being has its own unique genetic makeup. The DNA present in every cell of every living organism has the capacity to direct the functions of that cell.

Directly altering an organism by changing its genetic code requires that the specific gene (or set of instructions) along the DNA coil be modified and that this same set of instructions be changed in every cell of the organism. This task is not too difficult to accomplish in the contemporary research laboratory with single-cell organisms, such as bacteria. Remember, however, that the human organism is 100 trillion times as complicated, in terms of cell structure.

For the reason of simplicity, the most obvious candidate for the pioneer research in biotechnology was a single-cell bacterium. The organism scientists selected in the early 1970s was a bacterium commonly found in the human intestinal tract, ***Escherichia coli (E. coli).*** Besides chromosomes, the *E. coli* nucleus contains plasmids, which are small strands of DNA. A plasmid exists and reproduces as a circular molecule. The benchmark genetic-manipulation research Herbert Boyer (University of California—San Francisco), Stanley Cohen (Stanford University), and their colleagues conducted provided the information needed to engineer *E. coli.*

Recombinant Deoxyribonucleic Acid (rDNA)

Recombinant deoxyribonucleic acid (rDNA) consists of a DNA sequence artificially produced by joining pieces of DNA from different organisms. The rDNA experiment is considered successful if the desired traits are passed on to succeeding generations. This technique can also be used to develop useful microorganisms having the ability to degrade toxic wastes. New strains of agriculturally essential plants, such as wheat, corn, and rice, represent by-products of rDNA technology. Recombinant DNA technology can be used in a wide range of industrial enterprises to develop the following:

- ❑ Microorganisms that produce new products.
- ❑ More efficient methods of producing currently available products.
- ❑ Large quantities of products that are scarce in the natural environment.

The biological principle underlying rDNA technology is simple, but it is staggering. If genes from a higher organism are implanted in bacteria, the bacteria follow the genetic instructions of the higher cells. An *E. coli* bacterium's cells divide and reproduce every 25 to 40 minutes. They continue to do this even after the genes from another organism have been spliced into them.

Bacterial enzymes (called *restriction enzymes*) are used to transfer DNA from one organism to another. Restriction enzymes are used, similar to scissors, to cut the DNA at specific points, so new DNA can be inserted. There are well over a hundred restriction enzymes used in biotechnology, and each restriction enzyme cuts a specific and different part of the DNA molecule. After the restriction enzyme cuts the DNA, the result is a set of double-stranded DNA fragments with single-stranded ends, called *sticky ends.* The bases of the sticky ends can then form a bond with the foreign DNA molecules. The result is an edited, or recombinant, DNA molecule. The rDNA molecule then takes on the characteristics of the inserted gene. The first product made with rDNA technology was human insulin in the early 1980s, produced by Eli Lilly & Co.

The diagram in **Figure 2-2** illustrates the procedures used to clone the human protein interferon, using rDNA technology. Human cells invaded by viruses naturally produce small quantities of interferon. This protein is effective in fighting many viral diseases, including some forms of cancer. The gene for interferon production is mapped using sophisticated laboratory equipment and removed from a human chromosome. This gene is next inserted into the *E. coli* bacterium, which acquires the capacity to make interferon.

If the biotechnical engineer's objectives are fulfilled, a new organism has been created. The transformed bacterium possesses mixed, or recombinant, DNA, in which human and bacterial genes are present side by side. The bacterium is cultured under carefully controlled conditions, in order to allow the gene for producing human interferon to work in its new site with the *E. coli.* Once the bacterium has been correctly transformed, interferon synthesis can commence using huge vats, or fermentation chambers. The rapid reproduction cycle of the bacterium speeds this process. Finally, substantial quantities of interferon are extracted, primarily for use in the health-care field.

Human interferon is so potent that the body produces it in minuscule amounts. For this reason, its use in the medical field was extremely limited until recently. (In the past, it has reached costs of $70–$100 per millionth of a gram!) During the late 1970s, a Finnish laboratory, supervised by Dr. Kari Cantell, processed 90,000 pints of blood and produced

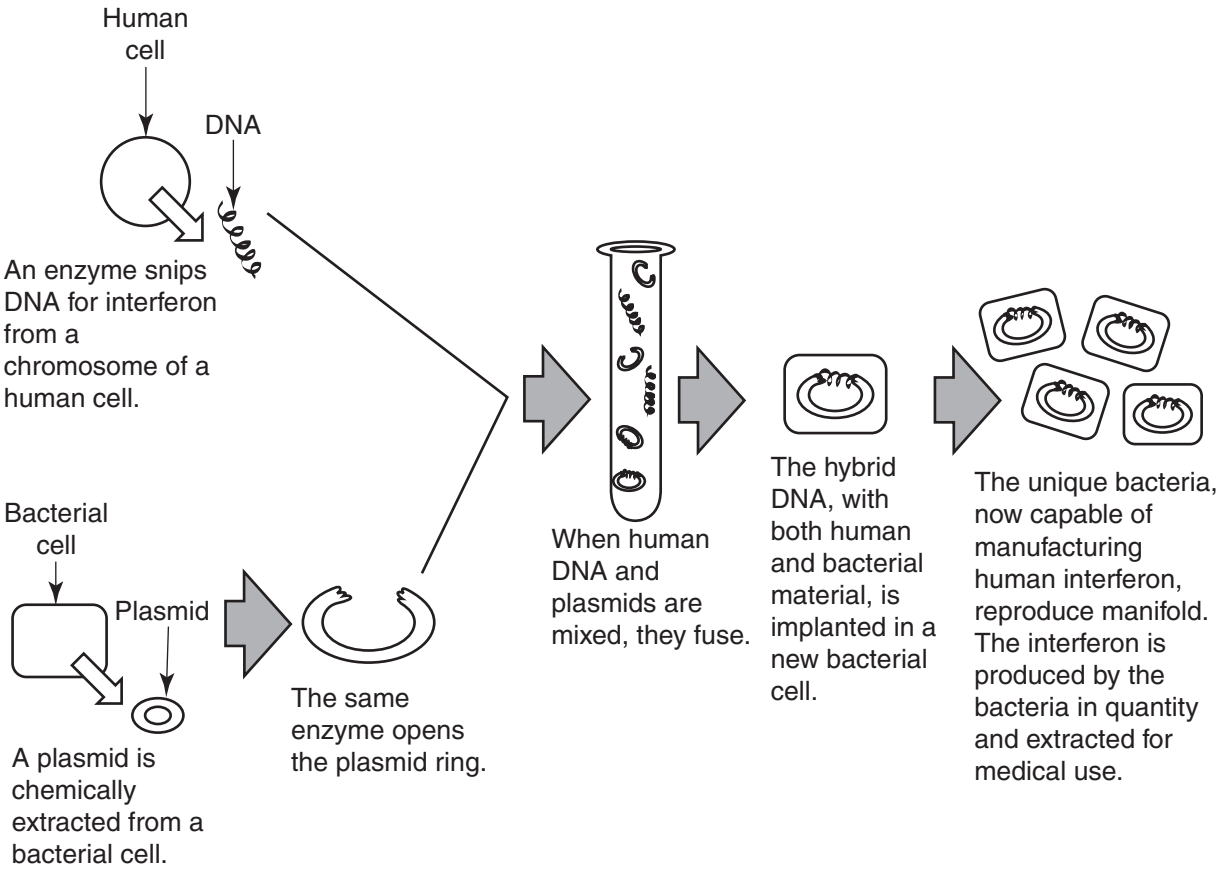


Figure 2-2.
The procedures used to clone the human protein interferon, using rDNA technology.

only 1/10 of a gram of pure interferon. Subsequently, to attack a common cold, doctors treating one patient in a clinical study needed to use about $2000 worth of interferon. Using rDNA, these newly engineered bacteria produce interferon as a metabolic by-product, and the same amount is acquired in the laboratory for about a nickel. Different strains of lab-grown bacteria and yeast are now used commercially to produce several dozen products, including human insulin, human growth hormone bovine growth hormone (used to increase the amount of milk a cow produces), and chymosin (a protein from calf stomachs used for cheese making).

Recombinant DNA is not the only form of biotechnology used to transmit DNA from one organism to another. In fact, using a variety of techniques, DNA has been transferred to bacterial, yeast, animal, and plant cells. In any transfer technique, the plasma membranes or cell walls must be penetrated without permanently damaging the cell. The removal of the cell wall allows the scientist to

introduce foreign DNA directly into the host cell. When working with plants, scientists produce protoplasts (plant cells, minus the cell walls) before introducing DNA through the plasma membranes. After the creation of the protoplast, the DNA can be introduced into the cell via infection with a bacterium; microinjection of foreign DNA, using a fine needle; or electroporation, using brief pulses of high-voltage electricity to form holes in the membrane of the cell. Protoplast fusion is another technique used in biotechnology (with limited success), in which the external walls of two different types of cells are removed, allowing their specific genetic materials to combine and mix. This fusion causes a natural (but random) genetic recombination. Once the new DNA, consisting of both foreign DNA and the inserted gene, is inserted into the cell, the foreign DNA becomes part of the genetic makeup of the host cell. The host cell now contains the gene transmitted by insertion, and it will pass this gene to future generations.

Monoclonal Antibody (MAb) Technology

MAbs are produced through ***cell fusion,*** using cells capable of forming antibodies and myeloma (a tumor of the bone marrow) cells capable of sustained division and growth. When myeloma cells are fused with antibody-producing mammalian spleen cells, the resulting hybrid cells, or hybridomas, produce large numbers of ***monoclonal antibodies (MAbs).*** The term *monoclonal* indicates that the offspring, or ***clones,*** of a single hybridoma cell produce them.

CLONE

An exact genetic copy. This copy is an individual grown from a single somatic cell of its parent. Clones are genetically identical to their parents.

The production of antibodies in higher life-forms is one aspect of a complex series of metabolic processes referred to as the *immune response system.* This system is located in the spleen, lymph nodes, and blood of the organism. Specialized sets of cells, known as *B lymphocytes,* are organized to detect and destroy foreign substances posing any sort of threat (for example, bacteria, viruses, and pollen molecules). As these foreign substances, called *antigens,* enter the body, the special cells churn out large numbers of complex molecules, called *antibodies.* The structure of these antibodies enables them to lock on to particular antigens. More importantly, specific antibodies fit only one kind of antigen. The foreign substances are, thus, blocked in their actions. The end result of this aspect of the immune response is the antigen's removal from the body.

Separate from their natural functions in the protection of life-forms via this immune response, antibodies have long been used in clinical research to identify particular molecules or cells. They also play a major role in the diagnosis of diseases. Antibodies that recognize known antigens are commonly used to detect the presence and levels of drugs, hormones, bacterial elements, and viral products in sensitive blood samples.

Actually, antibodies are large genetically specified proteins. Molecular biologists have devoted a great deal of research toward considering how the genes in antibody-producing cells are switched on and off to produce the correct molecule at the right moment. The conventional method to produce antibodies was to inject a laboratory animal with an antigen, allow a period of time for antibodies to form in the animal, and then collect the antibodies from the blood serum of the animal (antiserum). This method had problems. Since the antiserum was collected from animals, it contained undesirable animal extras. Also, this technique produced a relatively small amount of usable antiserum

per animal. This type of problem led to the development of the MAb technique.

In contrast to the conventional method, MAb technology allows scientists to produce large amounts of pure antibodies. A mouse is immunized with a foreign substance, or antigen, to stimulate the production of antibodies. A few weeks later, the spleen of the mouse is removed, and the antibody-producing cells are isolated from the spleen. Fusing the antibody-producing cells with myeloma (tumorous) cells produces MAbs. Antibody-producing cells cannot survive on their own in artificial cultures. They must be fused with another type of cell and cultured in a medium. The resulting cell is called a *hybridoma.*

The hybridomas resulting from this procedure are cloned, and each clone is tested for the production of the antibody desired. These clones can be established either in an in vitro (outside a living body or in an artificial environment) culture system or injected into mice, where the hybridomas grow in abdominal-cavity fluids. Either of these methods allows for the preparation of large quantities of very specific MAbs to counteract almost any available antigen. By allowing the hybridoma to multiply in a culture, it is possible to produce a population of cells, each of which produces identical antibody molecules.

Although prohibitively expensive at first, the costs of producing MAbs have continually dropped. New production techniques under testing include using ***transgenic*** plants and animals to produce antibodies more efficiently. In the past decade, scientists have developed new techniques for producing MAbs. In general, these new techniques reduce the amount of mouse antibodies used to produce the MAbs. Another new approach involves mice that are genetically engineered to produce humanlike antibodies. Depending on the percentage of mouse antibody used, these MAbs are referred to as *chimeric MAbs* or *humanized MAbs.* These humanized MAbs have a higher success rate in attaining Food and Drug Administration (FDA) approval. The number of MAbs has soared because of this. MAbs generate worldwide revenue over $20 billion and are the fastest-growing segment in the pharmaceutical industry. More than 160 MAbs are now in clinical trials to obtain FDA approval.

MAbs have been used for many purposes, including the diagnosis and treatment of disease and the purification of proteins. In the late 1990s, Roche Laboratories was approved to market a MAb to help prevent acute kidney-transplant rejection, Zenapax® immunosuppressant. This drug uses the body's own immune system to prevent the acute rejection that can make kidney transplants fail. Herceptin® pharmaceutical, a MAb that Genentech manufactures, has been used to treat metastatic breast cancer. Since the FDA approved it in 1998, over 30,000 women have been treated with the Herceptin pharmaceutical, which can dramatically improve the effectiveness of chemotherapy against some advanced breast cancers. MAbs are not limited to medical uses. The Agricultural Research Service, a unit in the U.S. Department of Agriculture (USDA), designed a MAb protein to screen new varieties of tomatoes, potatoes, and eggplants to ensure that they do not exceed safe levels of bitter-tasting natural compounds called *glycoalkaloids.*

Polymerase Chain Reaction (PCR)

Polymerase chain reaction (PCR) is a technique for making many copies of a specific DNA sequence—we can think of this technique as photocopying DNA. In nature, most organisms duplicate their DNA in the same way. PCR mimics this duplication

process in a test tube. There are three steps to the PCR process. The first step is to separate the two chains of DNA by heating. The second step is to cool the test tube and add a large quantity of the four bases (A, C, G, and T) and a primer to bind to the ends of the DNA strands. The primer is derived from the *Thermus aquaticus* bacterium, discovered in Yellowstone National Park. The final step is to make a complementary copy of the DNA strand by using a pair of short primer sequences matching the ends of the sequence to be copied. The three steps in the PCR reaction take less than two minutes, and since the cycle is repeated 30 or more times, 1 billion copies of DNA are produced in about three hours!

Following the discovery of the PCR techniques in the early 1980s, their use in molecular biology exploded. PCR has become a quick method for detecting mutations associated with genetic diseases. One diagnostic PCR test was developed to screen for adenovirus, one of the causes of the common cold. Adenovirus can lead to left ventricular dysfunction (LVD), which is a rare disease of the heart muscle. This disease often afflicts young athletes in their prime and has caused high school athletes to die suddenly while playing sports. PCR has made its greatest impact in the field of DNA fingerprinting for genealogical studies and forensics. This reaction allows the forensic researcher to take a minute portion of blood or semen and grow enough copies of the DNA to analyze. The use of PCR technology has revolutionized the analysis of data from crime scenes. By licking an envelope, you deposit enough DNA to trace your identity from the seal of the envelope. Police crime labs use DNA analyses to determine the likelihood a suspect is guilty. Although DNA analysis cannot prove someone is guilty of a crime, it can indicate the odds of someone else having the same DNA markers. This type of evidence is being used more frequently in court cases.

Bioprocess Technology

Modern bioprocess technology is an extension of ancient techniques using natural biological processes for developing usable products. The production of beer is a classic case of bioprocess technology. In beer production, the combination of yeast cells and cereal grains undergoes a fermentation process to make the beverage. Modern bioprocess technology is not exactly a genetic technique, but it allows the biological methods of production to be adapted to large-scale industrial use. Bioprocesses are systems in which complete living cells or their components (such as enzymes and chloroplasts) are used to create desired physical or chemical changes. Examples of industrial products created with bioprocess technology include polymers, plastics, chemicals, fuels, lubricants, newsprint ink, pharmaceuticals, cosmetics, and construction materials. Advances made in bioprocess technology could ultimately determine the commercial success of selected industrial applications for both rDNA and MAb techniques.

Commercial bioprocessing is currently done in single batches, allowing only a small quantity of the product to be recovered from large quantities of cellular components, nutrients, wastes, and water. In large-scale fermentation tanks, genetically engineered microbes are placed in a liquid solution of catalytic nutrients the microorganisms require to propagate. One method used to separate the desired end product (the protein interferon) from the fermentation solution entails running the mixture through membranes, collecting the larger protein molecules and allowing the smaller molecules to pass through. Another technique uses bioreactors, in which either the catalytic enzymes or the cells containing the rDNA genes are immobilized on a substrate. Improvements made in techniques for immobilizing cells or

enzymes, as well as in the design of bioreactors, have helped to increase production and facilitate the recovery of many substances (such as proteins, hormones, and wastes). More research in this area is still needed, however. Techniques are also being developed that can assist in the design of more efficient bioreactors, sensors, and recovery systems.

Current applications of bioprocess technology include the following:

- ❏ Production of cell matter, such as baker's yeast and single-cell proteins.
- ❏ Production of cell components, such as enzymes and nucleic acids.
- ❏ Production of chemical products, including ethanol, lactic acid, and antibodies.
- ❏ Catalysis of single-substrate conversions, such as glucose to fructose.
- ❏ Treatment of waste to allow recycling of garbage.

Present research in biotechnology covers a wide range of interests. Progress is continually being made in both solving the engineering problems unique to genetically modified (GM) organisms and identifying ways in which genetically altered organisms can be used to enhance the efficiency of certain bioprocesses.

The remainder of this chapter will consider applications of biotechnology in use today in different areas: agriculture, industry, and medicine. Also, we will cover international and regulatory issues related to the use of biotechnology today. The effects of biotechnology will only increase in the future. How these technologies will affect the quality of life is an open, and unresolved, question.

Biotechnology and Agriculture

Old style plant breeding was a slow process and an unreliable process. The biologist crossed plants with desirable traits, such as resistance to drought or pests, and hoped these desirable traits would be passed to the offspring. As with human genetics, however, where two brown-eyed parents can have a blue-eyed child, not all characteristics are readily apparent. Now, with modern techniques in biotechnology, scientists can identify traits by their genes and move those genes (and the traits) to create new and improved organisms.

Genetically Engineered Crops

The first two products of rDNA technology in agriculture were not actual food products. Rather, they assisted in the production of food. In 1990, Pfizer introduced an enzyme (Chy-Max® chymosin), which is an artificial substitute for natural chymosin, an enzyme cheese makers use to convert milk into curds and whey when making cheese. The traditional source of chymosin was found in the stomachs of slaughtered suckling calves. The use of the rDNA Chy-Max chymosin allowed cheese makers to have a consistent supply of this enzyme. This use also had another unexpected effect. Since traditional cheese was made with a product from a calf's stomach, certain vegetarians and kosher Jews did not eat cheese. The new cheese could now be eaten, making the vegetarians, and certainly the cheese makers, happy.

There was little controversy with the chymosin enzyme. This was not the case with the second rDNA food product—recombinant bovine somatotropin (rBST). Bovine somatotropin (BST) occurs naturally in cows'

pituitary glands and is related to the control of milk production. Injections of BST into cows increased milk production. In the early 1980s, Monsanto developed an rDNA-derived version of BST, and the company received approval in the early 1990s to market rBST to dairy farmers. When farmers inject rBST into a cow, it can increase milk production by 20%, starting at 60 days into the milking period.

The road to FDA approval for rBST was a long one and one fraught with controversy still existing today. To approve food additives, the FDA uses a standard called *Generally Regarded as Safe (GRAS).* Since rBST mimics a naturally occurring protein (except for the addition of one amino acid at the end), it easily met the GRAS standard. What was unexpected was the widespread opposition to this drug. During the late 1980s, there was extensive criticism of rBST and the FDA approval process from dairy-producing states, Congress, and the general public. Some critics were concerned that a drug was being added to the milk supply at all, while other critics based their concerns on economic reasons—rBST would further reduce the number of small dairy farms. Wisconsin even banned the use of rBST for one year, in 1990.

After rBST was in production, additional criticism arose over how ***genetically modified (GM) foods*** should be labeled. As we will see in this chapter, this criticism of biotechnology occurs again and again as companies develop and apply new biotechnologies. For rBST milk, the FDA concluded that, since rBST does not change the composition of milk, no extra labeling is required. Dairies can, however, indicate that their milk comes from non-rBST cows by adding a label.

There was considerably more scrutiny by the public and food activists about the next developments in GM foods after the debates over rBST. Interestingly enough, the next GM food was an actual food product. This food was the Calgene Flavr Savr® tomato.

Calgene genetically engineered the Flavr Savr tomato to allow the tomato to remain on the vine longer to ripen before harvesting. Most other tomatoes are harvested while green and firm so they are not crushed when shipped. After shipment, the green tomatoes are treated with ethylene gas to ripen them. The Flavr Savr tomato reduces the level of a ripening enzyme, polygalacturonase (PG), which normally causes tomatoes to soften as they ripen. Since Flavr Savr tomatoes have lower levels of PG than normal tomatoes, they can remain on the vine longer before they are picked, and they will be firmer when sold in supermarkets.

As the first GM food product sold, the Flavr Savr tomato received extensive scrutiny from the FDA. In the early 1990s, the FDA instituted a new policy requiring that biotechnology-derived foods meet the same safety standards required of all other foods. This was a critical juncture for the biotechnology companies. By its ruling, the FDA established a precedent that GM foods were generally going to be evaluated the same as normal foods. Therefore, if the new GM food is significantly the same as the normal food, the FDA does not conduct a comprehensive scientific review of the GM food. Instead, the FDA requests that the company provides a summary of the GM food safety and nutritional content to the FDA. Also, the company must discuss the results of the GM food properties prior to commercial distribution. The FDA calls this a *consultation process,* rather than a *review process.* By any name, the effect is to make it easier for U.S. companies to market GM foods in the United States.

The consultation process includes a safety assessment of new GM foods. This process includes evaluations of the effects of the genetic modification, the source and function of the introduced genetic material, analytical studies to determine whether or

not the genetic modification has any effects on the composition of the food, and the safety of new or modified substances in the food. Using these consultation criteria, the FDA reviewed the Flavr Savr tomato in the mid-1990s and found it to be as safe as a normal tomato.

Since then, there has been an explosion of GM foods. In fact, GM seed accounts for approximately 40–60% of all food planted in the United States. In 2006, approximately 40% of corn, 80% of soybean, and 70% of cotton in the United States were GM. Over 60 GM foods had finished the FDA consultation process by a few years into the twenty-first century. In addition to foods such as the Flavr Savr tomato, there are GM foods that include genes resistant to pesticides. Some of the most controversial GM foods are those whose seeds are resistant to Roundup® chemical herbicide (created by Monsanto). See **Figure 2-3.** Since these plants (soybeans, cotton, corn, and canola) have the Roundup herbicide–resistant gene, farmers can spray their fields with the pesticide, killing all plants (including weeds) except for the Roundup herbicide–resistant plants. Also, this way, farmers can use no-till agriculture, which reduces soil erosion by 70%. Some scientists, however, worry that this resistance to Roundup herbicide can spread to the weeds and using these seeds will lead to the creation of "super weeds."

Other biotechnology efforts have tinkered with the nutritional makeup of plants. A consortium of scientists from Germany and Switzerland created a new rice strain to improve the nutritional value of rice. Almost half of the world's population eats rice daily and is dependent on this food for much of its caloric intake. Dependence on natural rice, however, can lead to a vitamin A deficiency, which is already a serious health problem in at least 26 countries, including highly populated areas of Asia, Africa, and Latin America. Vitamin A deficiency, which can lead to vision impairment, affects around 70% of children under age five in Southeast Asia. The new rice, called *Golden Rice,* has three extra genes that increase the synthesis of beta-carotene, which people can use to produce vitamin A. Golden Rice, with its distinct yellow-orange hue, will be distributed free to government-run breeding centers and agriculture institutes in India, China, and other rice-dependent Asian nations. Local farmers in these areas will each be allowed to earn an annual $10,000, without



Figure 2-3.
Monsanto YieldGard Plus® technology, which is built into the seed, provides farmers with a new way to reduce the amount of pesticide used. (Monsanto Company)

paying royalties. Currently, 16 research institutions in seven developing countries (India, the Philippines, China, Bangladesh, Indonesia, Vietnam, and South Africa) are evaluating Golden Rice. Before Golden Rice can be planted in a country, the trait for vitamin A must be bred into a local rice variety suitable for planting in a particular country. The International Rice Research Institute (IRRI) in Los Baños, Philippines is evaluating the safety and use of Golden Rice. After this evaluation is completed, this GM food could be widely used in developing countries.

Golden Rice is not the only GM rice being studied. The Philippine Rice Research Institute has developed a rice strain with iron and zinc, as well as vitamin A. Also, the Chinese government has developed two new strains of GM rice that produce higher yields and require fewer pesticides. Researchers at the University of Tokyo in Japan have developed a strain of GM rice that includes a vaccine for cholera, which is a major and growing health problem worldwide.

For hundreds of years, humans have been changing the biological makeup of their food. Now, with biotechnology, these changes are coming faster. See **Figure 2-4.**

Global Area of Biotech Crops, 1996 to 2008: by Trait (Million Hectares)

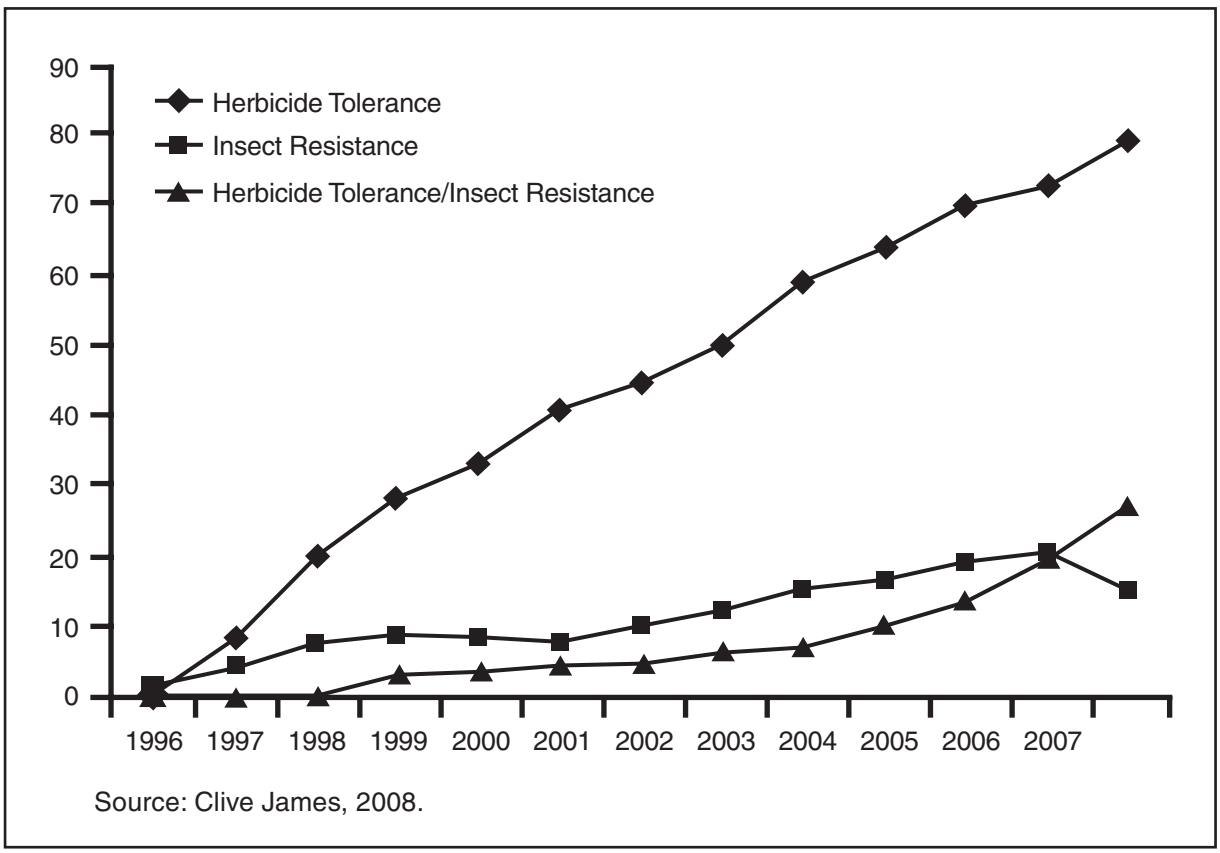


Figure 2-4.
The amounts of GM crops have dramatically increased over the past decade. Crops grown with imbedded herbicide tolerance had the highest growth rate—80 million hectares (about 200 million acres) of herbicide-tolerant GM foods are grown each year. (Clive James, 2008)

A new generation of GM foods will include traits that will improve a plant's taste, size, or nutritional content. Overall, GM foods hold the promise of increased yields with less pesticide use and more nutritional value. They promise a new "Green Revolution" to double production and nutritional content of key crops, such as corn, wheat, and rice.

Transgenic Animals and Plants

GM foods are considered to be transgenic if they contain genes outside their species. An example of a transgenic plant is Monsanto's NewLeaf Plus potato. The NewLeaf Plus potatoes include genes that give the plants resistance to infection by the potato leaf roll virus and the Colorado potato beetle. These potatoes contain the natural pesticide *Bacillus thuringiensis (Bt). Bt* is a group of naturally occurring soil bacteria, found everywhere on Earth. Results of the last few years of planting showed that the NewLeaf Plus potato is less susceptible to infection by the potato leaf roll virus than regular potatoes are. Also, farmers use fewer pesticides with this transgenic food. Both the FDA and USDA reviewed the NewLeaf Plus potato because it includes a gene from another species. This potato was deemed safe for human consumption.

Since the discovery of *Bt* (and genetic transfer of *Bt* into food), most GM foods have included transgenic genes. By far, the most important trait introduced into foods is pesticide tolerance (led by Monsanto, with its Roundup Ready® crops). See **Figure 2-5.** The next most inserted trait is for insect resistance. Papaya is a significant crop in Hawaii, but the yields dropped in the 1990s because of the papaya ring spot virus (PRSV), which many aphid species are rapidly transmitting. Overall, Hawaii's papaya production fell from 58 million pounds to 36 million pounds. Researchers began to investigate how to transform the papaya so it would resist PRSV. They decided to inoculate the papaya with a gene from the virus, with the hope that the new papaya would become resistant. The researchers used rDNA techniques to isolate and clone a gene in the virus that then was injected into the cells of the papaya plant. This plant inoculation worked, and the state's $16 million papaya industry was saved.

There is still debate about the environmental impact of transgenic foods. A small, but vocal, segment of consumers actively oppose the use of GM foods. There are three kinds of concerns. The first is that pollen from GM crops could contaminate organic crops. The second concern is that GM crops might negatively impact biodiversity. On this point, there is uncertainty even among scientists as to whether bioengineered traits can pass to other plant species. The concern is that, for example, insect-resistant *Bt* crops will crossbreed with weeds and other undesirable plants and cause an explosion of insect-resistant plants that, in turn, would

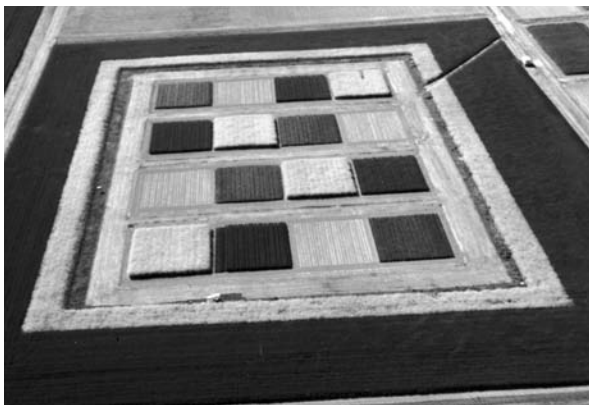


Figure 2-5.
This is a field trial in Dahnsdorf, Germany, with herbicide-resistant seed. The surrounding fields serve as a catch crop for transgenic pollen. (BBA/B. Hommel/H. Baier/2001)

cause more damage to the ecosystem. The third area of concern relates to terminator seeds—seeds biotech companies sell that result in sterile seedless plants, thus requiring the farmer to buy new seed each year. To differentiate GM foods even more from traditional foods in the minds of the public, they are acquiring the negative label of "Frankenfoods."

In 1995, when the first transgenic seed was available, farmers planted 4.3 million acres of the new bioengineered varieties. By a few years into the twenty-first century, 12 million farmers planted over 280 million acres of crops with transgenic seeds. In monetary terms, the global sales of transgenic crops grew from $75 million in 1995 to $7 billion in 2007.

Most scientists claim that eating GM foods is harmless because these foods are not significantly different from traditional foods. There is, however, growing concern about the effects of GM foods on animals and humans. International public reaction to a recent study of monarch butterflies trumpets this concern. At Cornell University, researchers in a laboratory fed monarch butterfly larvae milkweed leaves dusted with pollen from *Bt*-modified corn. Almost half the larvae died. This news was used in some countries to ban the development of new GM foods. Another study completed in an actual cornfield, analyzing the effects of *Bt*-corn pollen on black swallowtails, contradicted the famous monarch butterfly report, but the news contradicting the monarch butterfly report was not featured on CNN. Why? Many within the industry and government believe that opposition to GM foods stems mainly from a fear of the unknown, with most of the reasoning based on emotion, not fact. Coupled with the normal tendency of the media to highlight bad news over good news, it is easy to see how this story was overlooked. Whether any scientific data, no matter how credible, could sway the opponents to GM foods is certainly debatable.

Consumer response to GM foods in the United States, although significantly less negative than the response in Europe, has led some U.S. food companies to stop using GM products. Two large U.S. baby-food companies, Gerber and H. J. Heinz, announced in the late 1990s that they would switch to non-GM food ingredients in baby food. McDonald's asked its suppliers to stop sending GM potatoes, and Frito-Lay, the nation's largest snack producer, pledged to stop using GM corn in chips.

Current agricultural research will stretch the content of GM foods. In the pipeline are vegetables containing medicine to cure a range of medical problems. Imagine eating a banana or tomato to get vaccinated for hepatitis, skipping a pill and taking your morning's vitamins through your breakfast of eggs, or taking your contraceptive through a side dish of corn on the cob! All these GM foods are currently being developed, but fruits and vegetables are not the only GM foods being developed. Recombinant DNA techniques also are being used to transfer foreign genes to animals and to turn plants into manufacturing factories.

Why transfer foreign genes to animals? The simple answer is to produce drugs for human beings. Researchers realized they could use the normal functions of a goat, sheep, or cow to produce drugs during the normal production of milk. The milk can then be purified to obtain the pure drug, or the consumer can directly use the drug-enhanced milk. Although no transgenic animal product has been approved yet, there are a number of products in clinical trials.

Even more lucrative than GM foods are plants that could make materials for industrial products as they grow. Plant biologists at Monsanto are working on a plastic that

could be grown inside the plant in the field. Although the Monsanto work is still in the development stage, there already are biotech poplar trees planted in Oregon and China and biotech aspen trees planted in Michigan. If the bioengineering works, these trees will grow to full height in just six years, 10 times the global rate for poplars.

Despite the concerns and negative publicity, there is no doubt there will be an increase in transgenic crops and animals. According to the Biotechnology Industry Organization, the growth potential for GM foods is enormous and will lead to new developments in energy, food, and chemicals. The political climate for transgenic plants and animals is harder to predict.

International Concerns with Genetically Modified (GM) Foods

Much of the food we eat today contains GM products, and there is a real opportunity for biotechnology to lead to a second "Green Revolution" and produce more food for a growing world. The expansion of GM foods seems unstoppable, at least in the United States, but the United States is not alone in producing GM crops, despite being, by far, the largest producer of GM food. In 2007, the number of countries planting biotech crops increased to 23, with 8 countries (the United States, Argentina, Brazil, Canada, India, China, Paraguay, and South Africa) planting over 2 million acres each of biotech crops. Of all the transgenic crops planted, 57% were planted in the United States, while Argentina had 19%, Brazil had 15%, Canada had 7%, and India had 6%.

The number of small farmers planting biotech crops also is growing. There are now over 11 million small farmers in developing countries planting biotech crops. Both India and China have dramatically increased their total acreage of *Bt*-modified cotton, most of which is grown by small farmers. For example, India is the largest cotton-growing country in the world, and its use of *Bt*-modified cotton reached over 15 million acres in 2007. Both Brazil and Argentina have large acreages of both *Bt*-modified cotton and soybeans.

The production levels of GM foods are linked to the acceptance levels of these foods in these countries. In the United States, there is a high level of use of GM foods and a higher level of acceptance than in most of the world. Why Americans are more likely than Europeans to eat GM foods is not clear. Surveys indicate, however, that Americans have more trust in government and the regulatory process. So, when a government agency such as the FDA approves a product for sale, Americans generally believe the product is safe. In contrast, since the mad-cow disease scare in the mid-1990s, European consumers have been more distrustful of government experts. During that crisis, public-health officials in the United Kingdom gave people false assurances about the safety of eating beef from diseased cows. Although mad-cow disease has nothing to do with GM foods, the scare led to increased food anxiety. The memory of unsafe food is very fresh in the minds of European consumers.

Overall, European countries are generally opposed to the use of genetically engineered food—this opposition is the cause of a trade dispute between the United States and the European Union (EU). Despite assurance from the FDA as to the safety of GM foods, many consumers in the EU remain wary of the new technology, and the widespread press coverage of the monarch butterfly experiment that seemed to justify all the fears of using biotechnology in food heightened the normal wariness. In addition to banning GM crops, there have been many incidents, particularly in the United Kingdom, in which activists destroyed GM crop trials.

In the late 1990s, the EU halted the authorization of new GM foods until it approved new regulation. Also, the EU mandated labels on all foods containing GM ingredients. This, in effect, was a de facto ban on the commercialization of genetically engineered plants in the EU nations. Three large biotech countries sued the EU through the World Trade Organization (WTO). The WTO ruled that the EU ban on GM foods was illegal. The EU established a new policy on GM foods that allows them to be used in Europe because of the WTO ruling. Despite this, several European countries continue to have national bans on GM foods.

The Biodiversity Protocol, finalized in 2000, affects the transport of GM foods across international boundaries. The protocol allows individual countries to decide whether or not they are willing to accept imports of GM foods, and more critically, to allay consumer fears, all products containing GM organisms must be clearly labeled. Whether or not the labeling of GM foods will end this debate is difficult to see. There are significant economic benefits to companies developing new GM foods. Also, export of GM foods can enhance a country's world trade. GM foods, despite the controversy, will most likely be more widely used in the next decade.

Industrial Uses of Biotechnology

When we think about biotechnology, we forget that it is more than new food and medical products. Biotechnology also includes the development of new biomaterial products that reduce environmental waste. See **Figure 2-6.** Next time you are at your local grocery store, look at the plastic bag you carry to your car. Chances are, if the bag is recyclable, that the bag was made from potatoes, using new biomaterials.

Recent developments in genetic engineering have expanded the industrial role of biotechnology. In this section, we will discuss three different industrial applications of biotechnology. These applications are waste management, biomining, and DNA chips.

Waste Management

The first method of sewage treatment was to let the contaminated water flow along open ditches to clean it. Next came forced aeration—the insertion of air into wastewater to speed up the water's purification. After that came the use of biotechnology in waste treatment. Composting and wastewater treatment are some examples of older environmental biotechnologies. Today, the treatment of waste has moved beyond traditional cleaning techniques and uses biological microorganisms to remove pollutants from the environment. This biologically based treatment is called *bioremediation.*



Figure 2-6.
Eric Mathur, Senior Director of Molecular Biodiversity for Diversa Corporation, collects a sample from a geothermal vent in Yellowstone National Park, Wyoming. (Diversa Corporation)

The history of bioremediation starts more than three decades ago. During the 1970s, microbiologists developed anaerobic biodigesters to help clean waste. These biotechnology products ate the pollutants from the waste and allowed more thorough cleaning.

Most current biotechnology waste treatments are remedial. They attempt to clean what is already dirty. These waste treatments use special microbes that selectively eliminate certain pollutants. Interestingly, the use of microbes for waste treatment was discovered on accident. During World War II, in addition to the massive loss of human life, there was tremendous environmental damage. In particular, because of the many sea battles, there was a large amount of oil spilled into the ocean. When scientists began to study the worst oil-spill areas after the war, they discovered that there were petroleum-eating microbes that had broken the oil down into harmless compounds. This discovery was soon applied to other waste-treatment problems.

Bioremediation can be applied in one of two ways. Nutrients can be added to stimulate native microbes to clean the pollution. A famous example of this was the cleaning of the beaches along the Prince William Sound after the *Exxon Valdez* disaster that occurred in 1989. Workers noticed that petroleum was removed more quickly from beaches that received an application of fertilizer than from steam-cleaned beaches. The fertilizer stimulated the oil-eating microbes and quickened the removal of oil. See **Figure 2-7.** A second method has been used in the United States and Europe in the decontamination of toxic and hazardous waste sites. In this technique, samples are taken to a laboratory, where nutrients are added to enrich the selected microbes to remove the contamination. The samples are then returned to the waste site to clean it. Bioremediation has been successfully used to remove DDT, mercury, kerosene, and oil, among other pollutants, from soil. In one use of bioremediation in Great Britain, in just 12 months, most of the oil and heavy metal pollutants at a former tar factory were eliminated, after polluting it for more than 100 years!

Plants are also used to treat environmental problems. In this technique, plants act as filters for the contaminants by collecting and accumulating the waste in their roots and shoots. In another method, plants can stimulate microbe cleaners in the soil by releasing enzymes into the soil. Transgenic technology can enhance the ability of plants to function as soil cleaners. Both GM cottonwood trees and tobacco plants were used to clean methylmercury, a highly toxic chemical, from soil.

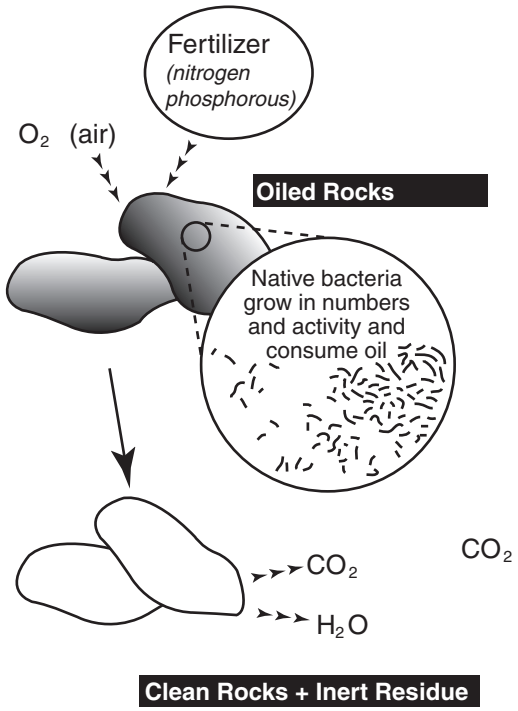


Figure 2-7.
Fertilizer acting to balance the amounts of nitrogen and phosphorus with the available carbon can enhance the natural biodegradation of oil. When the three elements are present in optimal amounts, microorganisms can fully utilize them to form carbon dioxide and water from oil.

Biotechnology applications can even change the end products of waste. A North Carolina State University scientist has developed a process for changing animal waste into various products, including methane gas for fuel, liquid nutrients for aquaculture, and feed additives for poultry and livestock. When demonstrated in China and North Carolina, it was estimated that a farm with 50,000 chickens could produce nearly 10 million British thermal units (Btu) of energy a day—enough energy to supply 200 homes!

Biomining

The pursuit of precious metals for jewelry, coins, and other finery has been the trademark of man since the beginning of time. In tombs traced to ancient civilizations, such as the Incas, Mayans, and Egyptians, we find many examples of gold and silver ornaments. Most of these metals were obtained by mining. Obviously, the first metals mined were the easiest to get. The techniques used to extract minerals from the earth have not changed significantly over the past few centuries. Ore containing the mineral is dug up from the earth. The ore is then crushed, and the precious minerals are extracted, either by extreme heat or by using toxic chemicals, such as cyanide.

In the last decade, mining techniques have been changing, and this change can be attributed to the use of new ***biomining*** techniques. There are two main biomining techniques used today: bioleaching and biooxidation. Both of these techniques rely on the behavior of certain bacteria that, at very high acidity levels, can eat away any unwanted iron and minerals, leaving the valuable mineral (silver, copper, or gold) behind.

Bioleaching uses the natural behavior of certain bacteria to drain (leach) precious metals from raw ore. In recent years, it has been used to successfully recover a variety of metals, including copper, nickel, zinc, lead, cobalt, gold, and uranium. Bioleaching is used widely in the extraction of copper, with approximately 20% of all copper worldwide, worth more than $1 billion annually, being produced through bioprocessing. This technique is particularly successful with lower-quality copper ore. In one method, after removal from the mine, the ore is treated with sulfuric acid. The acid stimulates the growth of *Thiobacillus ferooxidans* bacteria, which literally eat the ore. As the ore is eaten, the copper is released and collected in solution. To make the process even more environmentally sound, the sulfuric acid can be recycled.

Another technique used in biomining is biooxidation. Biooxidation is a type of priming technique used on gold ore imbedded in sulfur. Bacteria are added to the crushed ore to separate the gold from the sulfur. The gold can then be extracted using a traditional cyanide process. Since the ore containing gold is pretreated, more gold can be extracted with less use of cyanide. The first full-scale biooxidation gold mine was the Youanmi mine in Australia.

Integral to this use of biotechnology are bacteria and microbes assisting in mineral processing. There is a need to find bacteria that can resist heat because the bioprocessing of ore releases a tremendous amount of heat. Biotech researchers are now searching for new bacteria under the ocean near volcanic vents and geysers. The goal is to find bacteria that can be used for biomining temperatures up to 1000°C. One mine, Gold Mines of Australia, is using high-temperature (thermophilic) bacteria in their processes. The mine was able to process 98% of the available gold because of the efficiency of the thermophilic bacteria. This is compared to a gold-recovery rate of only 40%–60% with traditional cyanide processing.

Scientists are not trying only new bacteria. A new technique in biomining involves using plants to separate gold from ore. Researchers at Massey University in New Zealand (NZ) found that chicory and some mustard plants absorb the gold from the ore. After the gold is accumulated, the plant is burned, and the miner collects the gold from the ashes.

DNA Chips

The future is DNA. At least, this is what many companies hope. DNA's promise extends much beyond medical diagnosis and drug treatment. ***Deoxyribonucleic acid (DNA) chips*** can also screen for water quality, determine the identity of endangered species, and allow rapid ID of crime suspects in the field. A DNA chip is a wafer of glass (sometimes a wafer of nylon) onto which DNA strands are placed. The DNA is placed in distinct spots, and each spot contains a unique DNA sequence. Hundreds of DNA sequences are assembled in parallel rows onto the DNA chip.

When the test sample, such as a drop of blood, is washed over the DNA chip, a change occurs in only some of the DNA sequences. A machine then reads the DNA pattern and converts the results. DNA chips are attractive because they can be specially designed for a specific purpose. One chip, developed by Sandia National Laboratory, allows police, firefighters, and other emergency workers to quickly identify germs or chemicals at the scene of a terrorist attack. Another chip, GeneChip® Mapping 100K, manufactured by Affymetrix, allows scientists to understand the genetic differences between individuals. Researchers at Rockefeller University used the GeneChip Mapping 100K to do a comprehensive study of obesity in adults living on the island of Kosrae in Micronesia. Before World War II, obesity did not exist on this island. After Americans arrived, Kosrae residents stopped eating their traditional diet and starting eating fattier American food. After one generation, many Kosrae adults became obese, but some did not. The scientists are using the GeneChip Mapping 100K to compare the genetics of the two groups and hopefully identify genetic variations related to obesity.

Industry has only begun to explore the possibilities from biotechnology research. The future holds the promise of more specialized products, "greener" and cleaner technologies, and cheaper medical diagnostics. If this promise is kept, the potential applications are impossible to predict.

Biotechnology for Health

Genomics is the branch of biotechnology dealing with the structure and organization of DNA. Today, scientists have identified the DNA of many organisms, including human beings. Also, as human DNA is further defined and analyzed, the genes responsible for a number of inherited diseases, such as Huntington's disease and sickle cell anemia, will be identified. The largest initiative in genomics is the Human Genome Project (HGP).

The number of biotechnology applications in health is growing each year. These applications can be divided into several categories. Of these, the fastest growing category is genetics-based human diagnostic tests. Another fast-growing field is in the nonmedical diagnostics sector. Many companies have begun to develop tests for potential bioterrorism agents because of the increased funding for antiterrorism measures in the United States.

The Human Genome Project (HGP)

The HGP was an international research effort to map the DNA of human beings. In 2000, the then-President of the United States, Bill Clinton, announced the completion of the first draft of the survey of the entire human genome. This 13-year effort included scientists from the United States and several other countries. Decoding human DNA is not the end of the HGP—it is really the beginning. In order to understand the importance of the HGP, we must look back to what motivated this project. In the 1980s, there was a widespread belief among doctors and scientists that understanding human DNA would allow for better medical treatment and diagnosis.

The goal of the HGP was to discover all the estimated 100,000 human genes and make the information about these genes accessible to researchers for further study. Another goal was to determine the complete sequence of the 3 billion DNA subunits. (For an extended explanation of DNA, see the previous section in this chapter, "What Is Deoxyribonucleic Acid [DNA]?")

The U.S. HGP, managed by the National Institutes of Health (NIH) and the Department of Energy (DOE), coordinated the work on the human genome done in the United States. The work was completed at three DOE national laboratories: Lawrence Livermore, Lawrence Berkeley, and Los Alamos. Also, research was being conducted at numerous colleges, universities, and other laboratories throughout the United States. On average, the U.S. HGP funded about 20 separate researchers each year.

The original goals of the HGP were to identify and describe the complete sequence of the human genome; develop technologies for genome analysis; train scientists to use the tools of the HGP to improve human health; and examine the ethical, legal, and social implications of human-genetics research. The last goal of the HGP is particularly important and represents a shift in traditional scientific funding. Ethical analysis was imbedded in the HGP, and this type of analysis has received extensive support and attention. In fact, the DOE and NIH set aside 3%–5% of their annual budgets for this project to study ethical, legal, and moral issues.

In addition to studying the human genome, the HGP completed the genome for four other organisms. These were the bacterium *E. coli,* the yeast *Saccharomyces cerevisiae,* the fruit fly *Drosophilia melanogaster,* and the roundworm *Caenorhabditis elegans.* Also, a new goal added in the late 1990s focused on identifying individual variations in the human genome and seeing how these variations affect an individual's predisposition to disease, drugs, and environmental conditions.

Since the end of the HGP, the National Human Genome Research Institute (NHGRI) launched a public research consortium named the ENCyclopedia Of Deoxyribonucleic acid Elements (ENCODE). As part of the ENCODE project, 35 research teams have analyzed over 40 regions of the human genome. NHGRI plans to continue its work over the next few years to finish the analysis of the entire human genome. The commercial potential for the information derived from the HGP and the ENCODE project is great. As more of the human genome is analyzed, there will be more specific genetic tests developed to identify individuals with genetically caused diseases. Also in the future is the development of specialized drugs, with a sales projection exceeding $73 billion of all DNA-based products and technologies by the year 2014.

Genetic Testing

One of the likely by-products of the HGP is an increased availability of genetic tests to screen for various diseases. Thus far, HGP research has led to the location of genes responsible for a wide range of human diseases, including cystic fibrosis, Huntington's disease, some forms of breast and ovarian cancers, and some forms of Alzheimer's disease. Consumers now have the option of taking a test to determine if they have a genetically related condition.

Genetic testing usually involves taking a person's cells (frequently from a blood sample) and examining the DNA. The genetic test usually focuses on a particular portion of the DNA, in order to determine whether or not the person has the medical condition. A positive DNA test does not, however, mean one will ever get the disease. In some cases, it just means the person has an increased risk of eventually getting the disease, and the risk varies depending on the disease. One breast-cancer test determines whether a woman has a Breast Cancer 1 (BRCA1) or Breast Cancer 2 (BRCA2) mutation. A BRCA1 carrier has a 50%–90% chance of developing breast cancer in her lifetime. The inherited BRCA1 mutated gene is only responsible, however, for about 5%–10% of breast cancers. So, a woman might find out that she does not have the BRCA1 mutation and still get cancer, or she might have the BRCA1 mutation and not get cancer. Another genetic screening test available allows men to know their risk for early-onset baldness. More controversial genetic tests include deCODE's test for type II diabetes and the Alzheimer's Mirror® test, marketed by Smart Genetics. The Alzheimer's Mirror test shows the likelihood that a person could develop Alzheimer's in their old age.

A genetic test can give a false sense of security, and at the same time, it becomes a part of a person's medical history. Once an individual is tested, the result is a genetic blueprint. If the person has children (and for example, a genetically linked disease), this information can lead to finding genetic disorders for that person's children. This information can become part of their children's medical history, too. As the *Dateline* excerpt indicates, the people of Iceland are confronting these issues today. A company, deCODE genetics, has studied the gene pool of 275,000 Icelanders to find links between inherited illnesses and DNA. The company uses the medical records of the Icelanders, as well as the country's genealogies, which have been recorded for more than 1000 years. Several other countries, including Tonga, Estonia, the United Kingdom, and Canada, have population-wide DNA-banking and -analysis projects similar to Iceland's. Researchers hope one of these populations is a gold mine for DNA-related medical information. For the citizens, however, there is an increased risk of genetic discrimination.

The confidentiality of test results is a problem in the United States. Since many people have employer-provided health insurance, there is a chance that the results of genetic testing will be identified with an individual. Genetic testing is one area in which the technology is outpacing government regulation. In 1996, the Health Insurance Portability and Accountability Act (HIPAA) prohibited health insurers from excluding individuals because of the results of genetic tests. An Executive Order, which then-President Clinton signed in 2000, protects federal employees from genetic discrimination. Individual states have a variety of genetic nondiscrimination laws that differ significantly. Generally, the state laws prohibit employers from requiring genetic testing as a condition of employment, but overall, genetic discrimination has not been tested in the courts.

So, the consumer is left with a dilemma. Is it better to know or not know? Should one take the genetic test to determine whether or not she has a DNA-linked disease and risk having the information made available to her insurance company or employer? Or should one avoid the test and hope for the best? These tests are still a matter of choice in the United States, but whether or not they will be in the future, no one knows.

Human Gene Therapy

Gene therapy is a method to treat, cure, or prevent human disease by changing a person's DNA. This therapy differs from most other therapies, which attempt to fix a problem after the problem has occurred. Gene therapy attempts to prevent a problem from happening by modifying a person's DNA.

This therapy has been heralded as the technology of the future for a long time, but in reality, its development has had a long and twisting path. Scientists have had to overcome many hurdles in maximizing the potential of gene therapy. The first such hurdle was the gene delivery tool. Since our DNA is present in every cell of our bodies, billions of cells have to be modified in order for gene therapy to be effective. A second hurdle relates to the complexity of our DNA and the causes of many diseases. Most diseases involve the interaction of several genes. Therefore, most genetic diseases are related to more than one gene. This fact makes it more difficult to use gene therapy.

There are two different techniques in gene therapy. In an ex vivo approach, cells are taken from the patient, and the new gene is introduced into the cells in a laboratory. The modified cells are then grown in culture. When the cells have multiplied, they are injected into the patient. This technique was used to successfully treat three babies born with the rare immune system disease called *severe combined immune deficiency (SCID).* (You might know this disease as the *bubble boy syndrome.*) Bone marrow was removed from the babies, and the marrow cells were treated in a laboratory with healthy copies of marrow cells. The healthy cells were then injected into the children. The children's immune systems were normal 10 months later.

Most gene therapy treatments, however, take an in vivo approach, in which the corrected gene is injected directly into the patient, using a virus as the delivery mechanism. See **Figure 2-8.** The theory is that, instead of making the person sick, the virus will replace the defective gene with the corrected copy. There is no guarantee, however, that the virus will replace the defective gene. Instead, the virus can insert the new gene into another position in the cell's DNA. The new gene might actually harm the cell and cause it to function incorrectly.

Although gene therapy has the potential to be a powerful tool for medicine, there have been few successes thus far. Since 1990, according to the NIH, more than 1000 gene therapy studies were begun. One promising gene therapy for heart disease generates the growth of new blood vessels to the heart, allowing patients to grow their own heart bypasses. Another gene therapy project showed improvements in patients suffering from Parkinson's disease. Even so, despite the large number of research studies, the FDA has not approved any human gene therapies for sale.

The future of gene therapy is uncertain. While it is true that this method has come a long way, scientists still face many challenges in perfecting it. Gene therapy has successfully changed the lives of some people, but the downsides of using this form of biotechnology are still quite apparent. Considering all the benefits and risks involved, gene therapy is a promising, but terribly unpredictable, technology. Undoubtedly, scientists will continue to research this complex technique and develop even more unimaginable applications for the future.

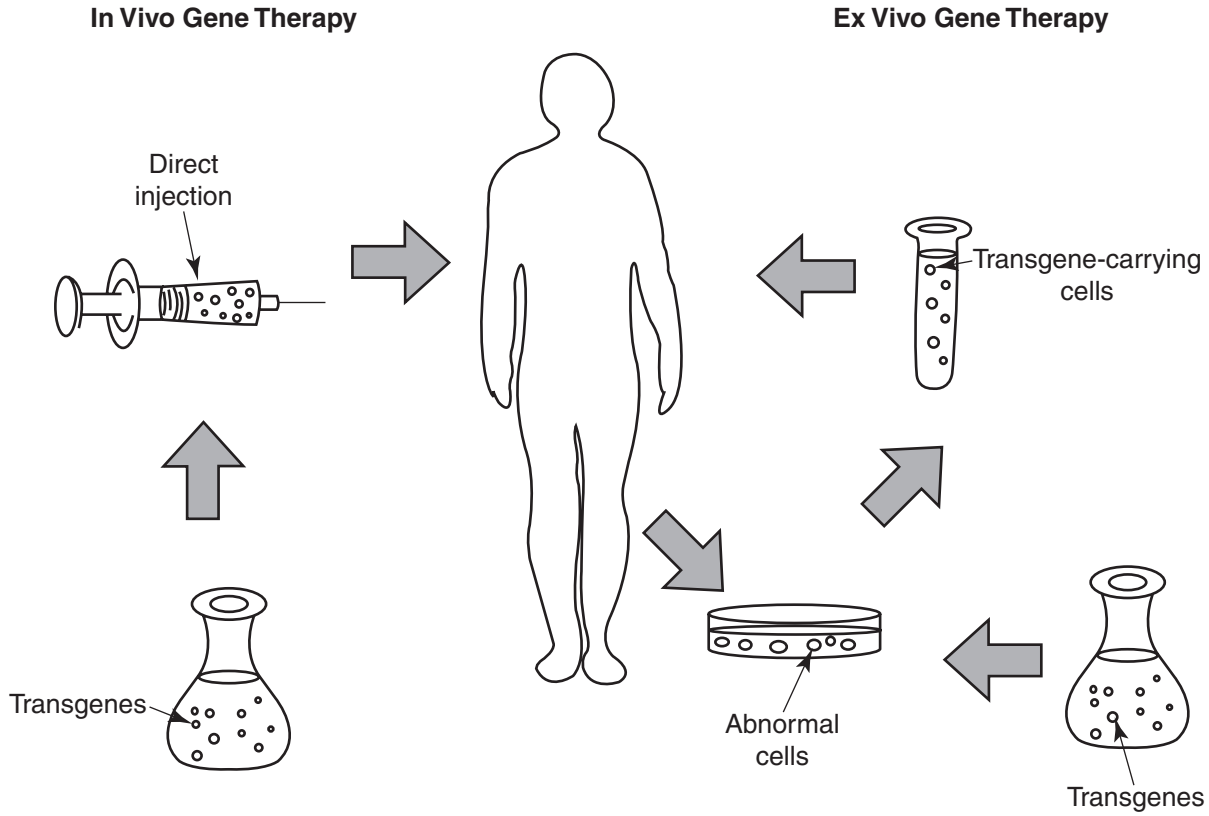


Figure 2-8.
The route of gene delivery is categorized into in vivo and ex vivo gene-transfer methods. For in vivo gene therapy, the transgene incorporated in genetic material is directly delivered into the patient's body. For ex vivo gene therapy, the transgene is transferred in vitro into abnormal cells removed from a patient, and the transgene-carrying cells are relocated into the patient.

Xenotransplantation

Xenotransplantation is the transplantation of animal cells, tissues, or organs into human beings. This transplantation first emerged into the news in the mid-1980s, when cardiac surgeon Leonard Bailey transplanted a baboon heart into a newborn girl known as Baby Fae, who had congenital heart disease. The baby lived for 20 days after the operation.

Since the mid-1980s, doctors have used baboon livers and marrow as transplant material, but a problem exists with organ rejection. Every time an organ is transplanted from one organism to another (even from human to human), there is a great risk of rejection because the host body recognizes the donor organ as foreign and attacks the foreign cells. To allow normal human-to-human transplants to succeed, organ recipients must take drugs that suppress their immune systems. New methods in xenotransplantation might eliminate or reduce these organ rejections.

Xenotransplantation, in the past, has used the animal version of the organ in transplantation. For example, pig heart valves have been used in humans for 30 years without negative effects, but what if the pig organ was genetically identical to the human organ?

The chance of organ rejection would be much less. Recently, scientists have been able to insert human genetic material into pigs so a pig organ would be acceptable to the human body. Pigs are considered to be the best animal for xenotransplantation because pig organs are similar in size to human organs. Since over 62,000 people in the United States wait every year for organs, the potential health benefits for pig-to-human transplants cannot be underestimated.

In the United States, there have been no trials so far with whole animal organs and few medical trials with the transfer of animal cells and tissue. Diacrin, a biotech company in Massachusetts, developed treatments for Parkinson's disease and Huntington's disease using brain cells from pig fetuses. In another medical trial, 10 Swedish patients with diabetes received transplants of pig pancreas cells that manufacture insulin.

From gene therapy to xenotransplantation, biotechnology holds the promise of a healthier tomorrow. What technologies will emerge from this quickly changing field is anyone's guess. Whatever the future holds, one certain thing is the increased use of biotechnology in the health field.

Cloning

Cloning jumped into the headlines in the mid-1990s, when Scottish researchers presented Dolly, the first mammal to be cloned from an adult. See **Figure 2-9.** Dolly was different from other clones because she was an identical copy of another adult sheep, and she had no biological father. Although cloning experiments with frogs and toads date back to the 1970s and experiments involving plants and animal embryos have been performed for years, the news of a cloned sheep led the news worldwide.

How exactly was Dolly created? A team of Scottish scientists, led by Ian Wilmut, scraped skin cells from the udder of an adult sheep (sheep 1). The scientists then removed an unfertilized egg from another sheep (sheep 2) and removed the nucleus of the unfertilized egg. The skin cells from sheep 1 were fused with the unfertilized egg of sheep 2. The composite egg was cultured in a petri dish for a period of time and then placed into the uterus of a surrogate mother (sheep 3). When the lamb, Dolly, was born, she was an exact genetic copy, or clone, of sheep 1, the sheep that provided the transferred cell nucleus. Dolly was not genetically linked to sheep 2, the sheep that provided the egg.

Since the birth of Dolly, researchers have successfully cloned wolves, mouflon, African wildcats, dogs, mules, domestic cats, buffalos, mice, goats, rabbits, horses, gaurs, cows, pigs,



Figure 2-9.
Dolly, the first fully grown mammal to be cloned, is an identical copy of another adult sheep. (Roddy Field, Roslin Institute)

rats, and ferrets. In NZ, scientists were able to clone the last surviving member of a rare breed of cow. The cloning process itself is difficult, however. The success of Dolly followed 276 other attempts to clone a sheep by the Scottish team. Many fetuses were rejected, aborted, or deformed. Now, for every 100 attempts, just two to five live offspring typically are born. Why the success rate is so low is hard to determine. Some scientists believe that cloning—since it is irregular and asexual—might be inherently flawed. Others wonder if the problem lies in the in vitro technology used in the process. In any case, the low success rate of cloning currently limits its widespread use. In addition to the low success rate, it is not clear whether or not a clone is actually older because it is a copy of an adult. The evidence suggests that Dolly's DNA was older than her age. Particularly, her chromosomes were shorter than a normal sheep of the same age. Dolly's chromosomes were the same length as those of the six-year-old donor sheep. Dolly died at the age of six, living about half the normal lifespan of a Finn Dorset sheep. Whether or not her unusual birth caused her premature death is an open question.

Scientists believe cloning will allow the recovery of endangered or extinct species of animals. Chinese scientists have successfully produced a cloned giant panda embryo from an adult animal. The San Diego Zoo has been collecting cells from endangered species since the mid-1970s, and many believe this frozen zoo can be used to create these animals through cloning. Other cloning initiatives have a different motivation. In 2002, Texas scientists announced the first successful clone of a pet cat named Copy Cat (CC). The cat clone is actually not the intended result for these researchers. Their aim is to clone a dog, a more complicated procedure. If this dog cloning is successful, the cloning will cater to a willing public. The company funding this research has had thousands of calls from devoted pet owners willing to pay $20,000 to clone their animal companions. The first pet cloned to order was a kitten in 2004 named Little Nicky. A Texas woman paid $50,000 to clone the kitten from her pet that died the previous year.

Medical Uses of Cloning

Ian Wilmut did not decide to create Dolly for purely scientific purposes. Instead, Dolly was created as part of a plan to make transgenic animals that would produce drugs in their milk. (To review transgenic animals, see the section "Transgenic Animals and Plants.") Transgenic animals contain a foreign gene allowing them to produce proteins. See **Figure 2-10.** For example, a cow can be genetically engineered to produce milk containing human insulin. This way, the cow can produce a large quantity of the drug insulin in its milk. The problem in traditional breeding of transgenic



Figure 2-10.
The world's first cloned transgenic female calf, Victoria, was produced using Advanced Cell Technology's proprietary cloning technology and is carrying a copy of the green fluorescent protein (GFP) marker gene. (Advanced Cell Technology)

animals is that, because of genetics, often the offspring lose the transgenic gene. A company can invest millions of dollars to create the insulin-producing cow, and none of the cow's offspring could have the same insulin-producing gene. In contrast, if the insulin-producing cow is cloned, the clone has the exact genetic makeup and, therefore, is also able to produce insulin in its milk. The use of genetically altered livestock to produce drugs is called ***pharming.***

A combination of cloning and genetic engineering can alter the nutritional content of milk. For example, a significant group of people is lactose intolerant. Presently, these people must either avoid milk or drink milk that has had the lactose removed. Through genetic engineering and cloning, a herd of cows can be bred to produce milk free of lactose. The tinkering with milk does not have to stop there. Many children cannot drink cow's milk when they are young, but if human proteins replace the cow proteins, the milk would be closer to human milk. Milk from transgenic cows, goats, sheep, and rabbits is already being used to produce proteins for several medical conditions.

Besides using cows, sheep, and other animals as factories, cloning can also provide animals that would donate organs to people (xenotransplantation). Transgenic pigs have been genetically engineered to contain an additional human protein to reduce the rejection of their organs once they are transplanted into humans. The cloning of these pigs would allow the transmission of this human protein to their offspring.

Cloning also brings a promise of quickly increasing the quantity and quality of various foods. Current breeding methods require the animal scientist to choose the desired trait and breed two individuals with the most desirable characteristics, but the use of biotechnology and cloning would shorten this process. A cow can be genetically engineered to be leaner, and then that cow can be cloned to produce beef having little fat. Consider the other by-products of animals. We get wool from sheep. What if we could get twice the amount of wool, or even colored wool, from a sheep? Scientists in Taiwan have already changed the color of an animal through transgenic means when they created three green pigs in 2006. The scientists achieved this effect by adding jellyfish DNA to pig embryos. The future possibilities seem endless.

Obviously, the widespread use of cloning is not without risk. Cloning, by its nature, will reduce the genetic diversity of plants and animals. This goes against the processes of evolution and natural selection. Also, improving the quantity and quality of food could lead to population growth that, in turn, would cause more stress on Earth. What about the danger of developing new diseases that could be spread from animal to man? The answers to these questions are not clear yet. The best possible alternative is for scientists to investigate the risks and benefits of cloning at the same time.

Stem Cell Research

One application of biotechnology is in the area of stem cell research. Stem cells are cells from early in the human development cycle. After a sperm fertilizes an egg, a single cell is formed. This single cell then divides into a hollow sphere of cells, called a ***blastocyst.*** The blastocyst has an outer layer of cells and an inner group of cells, called the *inner cell mass.* In normal fertilization inside a woman's body, the outer layer of cells begins to form the placenta. The inner cell mass goes on to form virtually all the other tissues of the body. The cells of the inner cell mass are called *stem cells.*

Stem cells, normally obtained from frozen embryos created during in vitro

fertilization, have the ability to divide without limit and evolve into specialized cells. A second method of obtaining stem cells is to reprogram human-adult cells to behave similar to embryonic cells. In normal development, a blood stem cell specializes and becomes red blood cells, white blood cells, and platelets. Since stem cells have the ability to divide and specialize, they hold the possibility of a renewable source of replacement tissue to treat diseases such as Alzheimer's disease and Parkinson's disease. For example, the production of insulin in the pancreas is disrupted in people who suffer from type I diabetes. Transplanting healthy pancreas stem cells into a person with type I diabetes could reverse this process and cure the diabetes.

Ethical Concerns

The most common ethical and moral arguments against cloning originate from various religious groups. Many religious philosophies believe life is sacred and is created and controlled by a deity. Generally, organized religion takes an anticloning stand, based on a belief that humans should not take over the divine power of creation, but there is a wide range of opinions on cloning and biotechnology.

Many religious groups separate the cloning of animals from the cloning of human beings. The cloning of human beings is much more controversial. Pope John Paul II made a statement, on behalf of the Catholic Church, specifically condemning the cloning of human beings. In contrast, Abdelmo'ti Bayyumi, a theologian from Al-Azhar University, the supreme authority on Sunni Islam, stated that neither animals nor humans should be cloned. Israel's chief rabbi, Meir Law, stated that the cloning of any creature is against Jewish law and recommended a ban on all animal cloning. In contrast to these leaders, however, some American Jewish and Muslim religious leaders testified before the National Bioethics Advisory Commission and stated that they believe cloning has a legitimate purpose in society.

Cloning has also struck a chord in the political world. Human cloning is illegal in France, Great Britain, and Norway, but not in the United States. U.S. federal funds, however, cannot be used for any human-cloning research. The debate over human cloning echoes previous concerns on human-embryo research. Politicians, at least in the United States, are hesitant to allow federal funding for any research involving the manipulation of humans. In addition to ethical concerns, the business viability of cloning is different across the world. In the United States, it is possible to patent both a cloning process and GM organisms. This is not the case in the European community, where one cannot patent a GM organism, but one can patent a cloning process.

Regulatory Considerations

Many industrialists and business leaders grimace at the mention of regulation or regulatory agencies. Regulation often brings to mind endless government bureaucracy and increased costs directed toward legal compliance. This does not seem the case among biotechnology firms, however. To some extent, regulation provides security for companies because the success of biotechnology products depends so strongly on the perceived safety of the products.

Imbedded in the biotechnology regulation processes in the United States is the belief that GM organisms are not inherently risky. This principle underlies the regulation process even today, and this positive perspective toward GM organisms probably accounts

for their acceptance in the United States, at least in the scientific community. At the onset of the twenty-first century, the National Research Council, which provides science, technology, and health-policy advice under a congressional charter, published a report on biotechnology. This report analyzed the potential effects of biotechnology and noted that the modern process did not appear to introduce new risks, compared to older methods.

The United States is not alone in its regulation of biotechnology. International companies must also deal with a wide range of laws and regulations from other countries and governmental entities. Are new biotechnology products worth the trouble? How will regulation affect the developments in this field? The answers to these questions, now, are impossible to know.

Regulation of the Biotechnology Industry in the United States

Regulation of agricultural biotechnology in the United States began in the late 1980s, after more than a decade of mainly laboratory-based R&D. Three federal agencies regulate GM foods in the United States: the FDA, the Environmental Protection Agency (EPA), and the USDA. Broadly, the FDA is responsible for the safety and labeling of all foods and animal feeds derived from plants. This includes foods derived from GM crops. The EPA regulates pesticides. So, if a GM food contains a gene for pesticides, that food product would fall under the EPA's regulation. An example of this type of food is Monsanto's NewLeaf Plus potato, which contains the natural pesticide *Bt*. The third agency, the USDA's Animal and Plant Health Inspection Service (APHIS), has the responsibility to oversee the agricultural and environmental safety of planting and field-testing genetically engineered plants. In addition, the Department of Health and Human Service's NIH has developed guidelines for the laboratory use of GM organisms. These guidelines cover GM food, as well as other biotechnology products. The regulatory process includes many steps and can take up to 10 years to finish. Each agency is responsible for a particular aspect of regulation, but all the agencies work together to assure that all food reaching the public is safe.

Food and Drug Administration (FDA)

The FDA is responsible for the safety of all food and drugs. This includes GM organisms. Since the early 1990s, the FDA declared that biotechnology-derived foods must meet the same safety standards required of all other foods. By this, the FDA established that no special rules were going to be created for GM food. Instead, GM foods are evaluated the same as regular foods. The consultation process requires the developers to notify the FDA of their intent to market a GM food or animal feed at least 120 days before marketing. Companies must send the FDA documents summarizing the data they have gathered to prove that the GM food is as safe as conventional food. The documents must describe the genes the foods use, whether or not the genes are from a commonly allergic plant, how the plant functions biologically, and how many of the genes are found in the new GM food. Also, the company must provide a summary of the GM food safety and nutritional distribution to the FDA and discuss the results of the safety analysis with the FDA's scientists prior to commercial distribution.

After new genetic material is introduced into a crop, studies must be done to determine the safety and whether or not the new genetic material had any unintended effects. FDA scientists review the information, after the company submits the data to the FDA, and generally raise questions. If the GM food is

approved, the new GM food is considered to be as safe as the regular food. The FDA supplies the company with a letter stating that the company has completed the consultation process.

Most GM foods do not have to be labeled in the United States, and they appear at your neighborhood grocery store in the produce section without any notice. The FDA requires special labeling of GM food only if the food's composition is significantly different from its normal counterpart or if its nutritional value has been altered. Also, if the GM food contains a gene that might cause an allergy, it requires special labeling.

Environmental Protection Agency (EPA)

The EPA gets involved in the review of a GM food if the plant has been altered to include pesticides—for example, insect-protected corn or soybeans. Some GM plants are genetically engineered to resist pesticides. Monsanto has a range of GM plants resistant to Roundup chemical herbicide (created by Monsanto). Since these plants (soybeans, cotton, corn, and canola) have the Roundup herbicide–resistant gene, farmers can spray their fields with the pesticide, killing all plants (including weeds), except for the Roundup herbicide–resistant plants. The EPA, in the case of these types of GM plants, determines whether or not these crops pose risks to food or food safety. Also, the EPA determines whether or not the GM food requires special labeling for consumer awareness.

In its review of new GM foods, the EPA examines several parameters. First, it looks at the type of genetic modification and where in the plant this modification shows. For example, if the genetic modification affects only a plant's root, the EPA focuses on the effect of the modification on soil organisms. Next, the EPA is concerned about the toxicity of the added protein. Rodents are fed the protein the introduced gene produces at levels of at least 100,000 times the levels a person would ingest. Also, the EPA requires the company to complete digestibility studies. These studies assess how long it would take for the protein to break down in a person's stomach and digestive system. Last, the EPA concerns itself with the toxicity of the added gene to other organisms, such as birds, beneficial insects, and fish. After a complete analysis of the GM food, the EPA either grants permission or denies the GM food.

U.S. Department of Agriculture (USDA)

Within the USDA, APHIS has the job of protecting American farming against pests and diseases. APHIS reviews all GM plants to make sure these plants do not become plant pests in the environment. A primary role for APHIS is the determination of possible environmental consequences. APHIS analyzes whether or not the modified plant could cross-pollinate with other plants, thereby causing a change in the environment. This was a particular concern with Monsanto's Roundup Ready series of GM plants. Many scientists and environmental activists were afraid the pesticide resistance of the Monsanto plants could spread to the weeds, thereby causing an ecological disaster.

APHIS is involved at two different stages: the field-testing of a GM plant and the commercial distribution. If a company wishes to field-test a GM plant, it must receive APHIS approval before proceeding. An APHIS scientific reviewer evaluates the environmental impact of the field test and assesses the impact of the new GM plant on endangered or threatened species. If the field test is approved, APHIS and state agriculture officials might inspect the site before any planting is done.

Before a GM plant can be sold commercially, the company must petition APHIS for a "determination of nonregulated status" (USDA, 2007, http://www.aphis.usda.gov/biotechnology/extensions.shtml). The company must provide APHIS with extensive

information about the development and field testing of the GM food. After analyzing all the data, APHIS allows commercialization of the plant only if there is no significant risk to other plants in the environment.

The three main agencies involved in the regulation of GM foods work together to assess the human and environmental effects of biotechnology. This coordinated process of regulation has allowed the approval of over 70 new agricultural products since the late 1980s. Despite the increasing use of GM foods in the United States, the U.S. public seems unaware of and uneducated about GM foods. Most Americans believe they have never eaten GM foods. Since GM seed accounts for 40%–60% of all food planted in the United States, this is, however, unlikely.

International Efforts in Biotechnology Regulation

The main international effort in biotechnology regulation is the Cartagena Protocol on Biosafety, which over 140 countries acceded to or ratified. The protocol affects the transport of GM foods across international boundaries. The protocol allows individual countries to decide whether or not they are willing to accept imports of GM foods. A country can decide to ban imports of GM food if that nation believes there is insufficient evidence of the safety of GM food.

More critically, to allay consumer fears, all products containing GM organisms must be clearly labeled. Exporters must obtain the permission of the importing country for the first shipment of a GM organism. This process is called *advanced informed agreement*. When a GM crop is approved in a particular country, the information is published and available via an Internet-based biosafety clearinghouse. If an exporting nation believes a GM food is being blocked for no scientific reason, it can appeal to the WTO.

Summary

Biotechnology has emerged from secluded R&D laboratories to join the ranks of business and industrial enterprises around the world. Startling developments in rDNA procedures, GM food, and cloning are taking place almost daily. As these developments take place, there is a growing unease about the future role of biotechnology in our society.

Despite concerns about GM foods in Europe, the world is quickly increasing its cultivation and use of GM foods. In the future, will GM foods be the norm, rather than the exception? Will "normal" food be unavailable? These questions echo the fear many have about the widespread use of genetically engineered foods in our lives. Perhaps, the anti–GM food world will follow the example of NZ. Until recently, NZ guarded its farms against GM foods. Recently, however, the NZ parliament decided that the benefits of GM food outweigh its risks. The NZ legislators believed they needed to find ways to produce more food and dairy products while using less land, to preserve the NZ environment. They established a new framework for GM foods that both gives New Zealanders more power to participate in the approval process and protects biotech firms against litigation.

Biotechnology is a powerful new technology characterized by a series of promises, as well as an accompanying list of threats. Decisions are being made that might spell either ultimate relief or certain disaster for the human species as we know it. A synopsis of the pros and cons associated with biotechnology research incorporates a wide range of disciplines, including pharmaceuticals, agriculture, energy, defense, animal science, gene therapy, and environmental protection. As with other technological forces, society must manage and control the developments in biotechnology with foresight, based on convergent thinking and systematic decision making.

Discussion Questions

1. Explain some of the reasons biotechnology has become a topic of technological controversy.
2. Why was the *E. coli* bacteria chosen for use in early rDNA research projects?
3. Consider your last trip to the grocery store. Which of the products you bought contained GM ingredients? What is your opinion of GM food?
4. Are you in favor of or opposed to xenotransplantation? If you needed an organ, would your opinion change? Why, or why not?
5. In an attempt to determine the degree to which your academic contemporaries are up-to-date on the developments taking place in biotechnology, you are about to play the role of a reporter. Randomly select five people on campus and record their responses to these basic questions. Be prepared to discuss your findings in class.
   a. Briefly explain what biotechnology means.
   b. Are you in favor of further industrial research in this field?
   c. Provide at least one reason for your stance on this issue.
   d. What is your academic major?

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Science and technology affect every aspect of society. With increasingly high-tech equipment, doctors are better able to understand the human body. Advancements in digital imaging allow health professionals to view more complete images of the body, thus ensuring better health care. (NASA)

Chapter 3

Information Technologies (ITs)

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DATELINE

Washington DC

Hackers expanded their base of operations by breaking into several electric utilities, literally turning off the lights and demanding extortion payment. The Central Intelligence Agency (CIA) shared the information with an industry group of Internet-security experts. Although the break-ins occurred outside of the United States, many U.S. utilities are also at risk. According to CIA senior analyst Tom Donahue, the CIA does not know who planned the attacks. All were done, however, through the Internet.…

Introduction

Without question, information is the most basic resource driving social progress. Information is an essential ingredient for competitive economic growth. Many people in contemporary societies now view increased access to all types of information as the status quo. Some individuals might even experience e-mail withdrawal if they are away from a computer link for more than a few hours. Nevertheless, an abundance of information can be considered useful only to the extent that recipients have the capacity to receive, assimilate, and utilize it in an efficient manner. The modes or methods we use to transfer information among individuals and machines are continually expanding and becoming eminently more powerful.

Information is the primary raw material of communication. Computer-mediated communication (CMC) technologies have transformed the way individuals work together, consult with one another, hire personnel, and make new friends. In every sense, communication has become an incredibly complex industry that makes demands on all of us. For each convenience information technologies (ITs) provide us, however, there is most likely a disconcerting side effect. Electronic messaging technologies (for example, e-mail, computer conferencing, bulletin boards, and Internet chat rooms) are largely displacing traditional modes of communication (such as face-to-face conversations, the telephone, and letters). Despite the variety among these forms of interaction, a salient feature common to each is the participants' lack of physical or real-time presence.

The term *CMC* has been around for many years. The meaning of this term has gradually been expanded, however, as new communication technologies have emerged. In its simplest form, CMC refers to communication between two people through the use of digital or computer means. The ITs make CMC environments a reality all around us. Intercontinental messages bounce off satellites to connect people around the world. Often, first-grade children in the United States feel more at ease with computer terminals and keyboards than they do with writing paper and pencils. Massive quantities of information on just about any topic can be obtained via an assortment of databases and interactive on-line services. Much of the industrialized world is becoming overly dependent on the use of electronic ITs to transmit messages, conduct business, look for employment, select a college to attend, store information, complete financial transactions, and seek companionship.

This phenomenon has created a world of virtual interaction devoid of much regulation or regulatory feedback. This world is replete, however, with social anonymity. A whole new area of study regarding the ethics and etiquette of interpersonal interaction has evolved alongside the emergence of ITs in all aspects of our lives. In today's information-saturated society, individuals are commonly expected to respond to requests as quickly as the computers their coworkers and friends are using initiate them.

Typical key developments enabling us, perhaps even forcing us, to communicate with one another at such a breakneck pace include wireless networks, e-mail, listserv systems, the Internet, the World Wide Web (WWW), subscriber networks such as AOL® and MSN® communication services, Internet-cable providers such as Comcast® service, multimedia technologies, virtual reality (VR), social-networking Web sites, and intelligent software. Each topic represents an entire industrial enterprise of its own. A basic understanding of these areas or developments is therefore a critical starting point for any discussion of ITs.

The long-standing marriage between computers and various communication tools has created and nurtured new conditions of employment. Society is being cajoled to rethink legislation dealing with telecommunication standards and the protection of intellectual property. More people are telecommuting. As we proceed further into the twenty-first century, the number of telecommuters stands at 50 million in the United States. Numerous corporations are weighing the advantages against the potential disadvantages of using videoconferencing or teleconferencing as an alternative to face-to-face meetings among employees who reside in various parts of the country. For the geographically dispersed organization, all the technologies associated with remote-conferencing technologies might address the problems of distance, crisis management, personal time, and travel expenditures.

The linked assortment of technologies making up this ever-changing landscape of communication is both well established and still emerging. Fax numbers, cellular phones, and e-mail addresses are more the rule today than the exception. They were the exception just a decade ago. Agent programs, home pages, Web sites, cyberspace, and VR have become familiar topics of adult social conversations. IT terms also pervade the vocabulary of today's adolescents. These adolescents sometimes pride themselves in being able to break into computer files managed by schools, credit agencies, corporations, and government offices. Factor into this formula concerns about the security of information and the Internet, such as described in the *Dateline* of this chapter. Society has yet another source of concern. The proliferation of computers in our society can cause much alarm with regard to our lack of individual privacy and the security of information systems. The welcome mat to the information age has been at the threshold of our daily routines for quite a few years now. On the other hand, the horizon lying beyond the threshold is continually changing, both in its appearance and location.

The primary objective of this chapter is to briefly describe and discuss a few of the more prominent changes taking place in the information and communication sectors of our society. ITs continue to reshape the way we work, live, and entertain ourselves. We regularly come in contact with computerized goods and services. Refrigerators and automobiles talk. Miniature telephones are carried in shirt pockets. Some people conduct all personal bank transactions from their homes or cars. Countless companies are doing business on the Internet. National governments around the world maintain huge databases on their citizens, in effect, spelling the end to individual *privacy,* in the conventional sense of the word.

Many individuals openly express fear and anxiety regarding their inabilities to keep up with various ITs. Other individuals display an air of indifference and seem willing to ride out the waves of change in order to digest only those technological breakthroughs mattering the most to them. There are also those computer technophiles who cleverly keep abreast of every new development in media-related and communication-based systems. A fourth group of individuals insists it wants nothing at all to do with CMC technologies. Regardless of the segment of the population with which individuals feel most comfortable associating, the success or failure of a distant computerized service or remote database often influences and constricts the infrastructure of life and daily routine. The individual has minimal, if any, control over this service or database. This chapter provides a foundation for a continuing dialogue that can ultimately respond to the following questions:

- What effect has each of the following technological breakthroughs had on the profile of our information-driven culture?
  - Wireless networks.
  - CMC.
  - The Internet.
  - Social networking.
- What are the pros and cons of telecommuting? Would you take a job that included a large percentage of telecommuting? Why, or why not?
- What is the difference between an intranet and an extranet?
- What impacts are leading-edge ITs having on electronic record-keeping activities in our society?
- Is individual privacy an artifact of the not-so-distant past? Do we have any recourse to which we can turn for security?
- How will e-commerce change consumers' buying habits? How will it change organizations that produce goods for the marketplace?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

biometrics
blog
computer blacklist
computer-mediated communication (CMC)
cookies
cybercrime
Defense Advanced Research Projects Agency (DARPA)
e-commerce
e-finance
electronic mail (e-mail)
extranet
fiber optics
firewall
instant messaging (IM)
intelligent software agent
Internet
intranet
local area network (LAN)
social networking
telecommuting
teleconferencing
telematics
Trojan horse
videoconferencing
virtual private network (VPN)
virtual reality (VR)
virus
Web bug
wide area network (WAN)
wireless network
worm

Technologies to Sustain an Information-Driven Culture

Today's information-dependent culture has introduced phrases such as "surfing the Net" and "cruising the information superhighway." The information superhighway and the Internet are constant topics in news programs, technical conferences, and journal articles. Drastic changes in competition and equipment are increasingly apparent. Telephone companies, cable-television providers, and hardware and software vendors in the computer and communications industries form and, just as quickly, dissolve alliances and partnerships. New uses for existing technologies and new technologies to serve future demands continue to characterize a major transition in the industrialized world's communication infrastructure. R&D in ITs is directed toward providing the average person open access to extensive computing power and an incredible amount of information through a networked fusion of communication equipment and distributed computers. Japan, as a society, is in the forefront of developing consumer digital devices. The Japanese population is aging because of low birth rates for the past few decades. Over 20% of Japan's population is over 65. This has led to a burgeoning digital-device market for care technologies. In the next decade, elderly people in Japan can expect to be served food by a feeding robot, ride in a computer-enhanced wheelchair, or be cared for by a nurse in a robotic suit.

The U.S. government has articulated its commitment to providing computation and knowledge resources to its citizenry through various successive initiatives. These initiatives include the National Information Infrastructure (NII), the Next Generation Internet (NGI), and Large Scale Networking (LSN).[1] The vast range of applications being envisioned for these projects requires an integration of computers and networks with, ultimately, wireless access. In the simplest sense, a network is a communication system connecting geographically dispersed computer users by means of circuits, switches, and control software. Networks provide the ability for multiple computers to communicate with one another. There are several important networks in use today. The nation's telephone network, built over the past century on an analog model, is the most mature segment of the communication infrastructure. The digital world, however, is increasing its impact on our everyday lives. In 2009, television broadcasts changed from analog to digital format. For U.S. households that receive their television programming over cable or satellite, the signals were already digitally based. The new Federal Communications Commission (FCC) requirement in 2009 affected households using a regular antenna to receive television broadcasts.

Transmission channels and the signals they carry are typically classified as being either analog or digital. See **Figure 3-1.** An analog signal is a continuous function of time and, at any instant, can possess any value between the limits set by the maximum power that can be transmitted. Analog signals vary continuously and smoothly in amplitude and frequency. Radio relay systems equipped with amplifiers are common examples of analog channels.

Digital technology has had a significant influence on the development of newer communication lines and computer networks. Digital signals have only discrete values. The most common digital signal is a binary signal having only two values (for example, 1 and 0). The numbers *1* and *0* are called *bits,* from the words *binary digits.* An older example of a digital-type channel is a telegraph circuit. The operation of a relay or sounder provides the coded output signal in this circuit.

[1]Computer Science and Telecommunications Board, National Research Council. 1994. *Realizing the information future: The Internet and beyond.* Washington DC: National Academy Press.

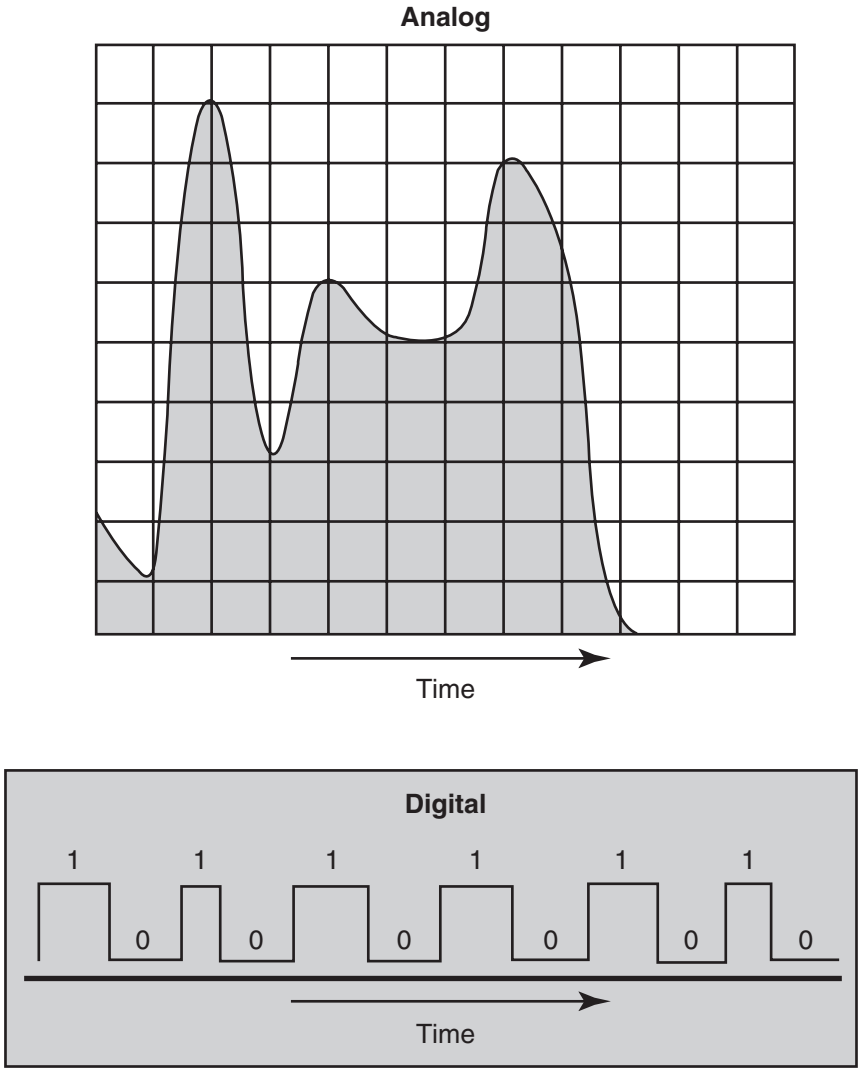


Figure 3-1.
Analog signals are smooth, continuous, and constantly varying, as shown in the top graph. They are often compared to voices. Voices change over a wide range, can be soft or loud, and can vary a great deal in amplitude and frequency. Analog signals can be difficult to receive, since they can vary in strength. Thus, weak signals, high points, or low points can distort them. Digital signals can represent only discrete numbers, as shown in the bottom graph. The most common examples are 0 and 1. Discrete means the signal change is abrupt. Digital signals are used in computers, compact discs, laser discs, and digital audiotape.

Digital communication is a comprehensive, umbrella-like term including such topics as digital transmission, digital radio, and digital recording. Digital transmission is the movement of digital electronic pulses between two points in a communication system. This form of transmitting a signal requires a physical connection or an electromagnetic connection between the transmitter and the receiver, such as a metallic wire pair, a

coaxial cable, a microwave transmitter, or an optical-fiber cable. In digital radio, Earth's atmosphere is the medium for transmitting the signal. Data communication and voice-frequency telegraphy over telephone lines illustrate the process of transmitting digital signals over analog channels. Conversely, analog signals can be altered for transmission over digital channels by means of analog-to-digital converters. Today, most of the telephone network is digital, except for what is called the *local loop.* The local loop is the last mile or so from your home to the telephone company's local office. Most telephone lines in the local loop are still copper wire. Copper wires still carry analog signals best.

When you review the array of available technologies, there is little doubt that the computer has utterly transformed our society. Personal computers (PCs) have been around for a few decades and, more than any other office tool, have had a significant impact on the way American business works. Numerous industrial firms, educational institutions, and residential households have made huge investments in PCs, expecting increased productivity and access to unlimited amounts of information. These expectations can be met only to the extent that a network exists, enabling multiple users to share and exchange information often stored at a remote database. The ability to enhance the computational power of PCs is therefore dependent on linking them together in a ***local area network (LAN).*** See **Figure 3-2.**

A LAN is an array of coaxial or optical-fiber cables or wireless connectors and switching boxes, providing data communication links between computers and other shared devices, such as printers, in the same work area, building, campus, or business park. ***Wide area networks (WANs)*** connect computers

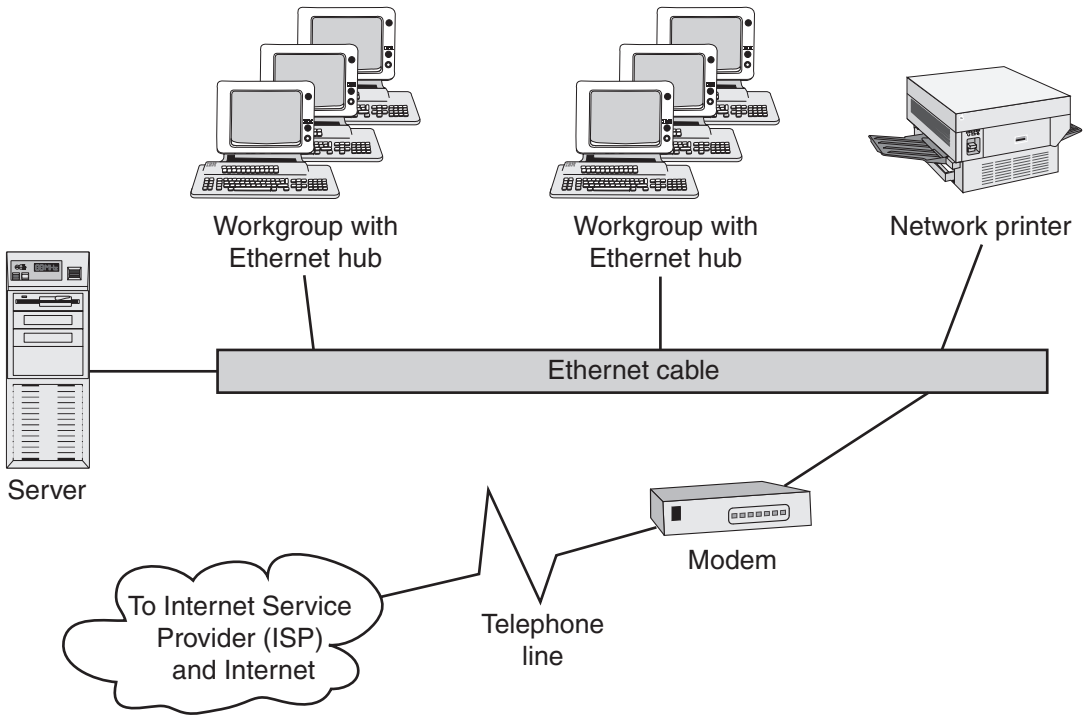


Figure 3-2.
A simple LAN.

or LANs together over a larger geographic area and are commonly referred to as *backbone networks.* LANs allow computers, modems, printers, and other peripherals to communicate with each other directly at very high speeds. Until a LAN is installed, only computers and peripherals hardwired to each other can interface and interact.

The speed at which communications traffic travels or flows through a circuit is referred to as the *bandwidth* of the circuit. The bandwidth is expressed in terms of bits per second (bps). This speed is the difference between the highest and lowest frequencies, measured in hertz, or cycles per second, needed for transmitting a modulated signal. The rate of travel is a crucial determining factor for which kind of information can be transmitted and who can afford to send or receive it.

Managing the flow of data from senders to receivers requires control software that generates a set of signals the network components use to monitor the status of data transfer. As the number of options and types of intelligence in data-communications terminals has increased over the years, the technology of internetworking has evolved. The network architecture outlines the way a data-communications network is organized and generally includes the idea of levels or layers within the layout. Each layer consists of specific protocols or rules for communicating. These protocols carry out a given set of functions. A set of rules governing the orderly exchange of information is commonly referred to as a *data-communications network protocol.* Protocols, formulated by equipment manufacturers and vendors, might regulate lines, types of service, modes of operation and data transfer, circuit compatibility, or entire networks.

Today's ***Internet*** conforms to a protocol suite known as *Transmission Control Protocol/ Internet Protocol (TCP/IP).* Since TCP/IP is an open protocol, or a nonproprietary protocol, it has been incorporated into the UNIX® operating system. One very functional feature of the UNIX operating system is a tool called *UNIX-to-UNIX Copy Program (UUCP).* UUCP enables any computer running the UNIX operating system to dial and connect via modem to any other UNIX computer. The successful union between TCP/IP and the UNIX operating system makes them a dominant communications protocol and a dominating operating system on the Internet. In reality, an open network is one capable of carrying information services of all kinds (not limited to one application, such as TV distribution) to customers of all kinds (libraries, government labs, hospitals, educational institutions, research centers, industrial firms, and private households), across network service providers of all kinds—all in a seamless, accessible fashion.

TCP/IP treats information in a different way than traditional telephone service does. This protocol divides information into packets. Information (for example, an e-mail message) is assembled into a packet. The packet is then sent to an address. The computer sends the packet to the nearest router on the network (analogous to your local post office). The packet is sent from router to router until the last router delivers it to the correct address—your e-mail mailbox.

Perhaps at the heart of research in ITs is a desire to refine the communication infrastructure to enable the realization of an expanded Internet in the near future. This requires continual improvements in the nation's voice-oriented telecommunications system, in order to transmit all forms and large quantities of data between computers. Research being conducted in several areas of enabling technologies must evolve with a focus on flexibility, broad utility, and social benefit. Full computer connectivity and

compatibility mean that the different technologies for providing video, audio, telephone, and data-communications services must be interoperable, linked by recognized and accepted protocols, and capable of sharing a common infrastructure. In simple terms, all homes, places of employment, and public institutions will be inextricably linked together.

New strategies are being brainstormed to reconstruct the "last mile" in the communications industry. This is the connection, or link, between your home and the telecommunications industry (telephone line), cable-TV industry, and electric-power utility industry. In the last decade, telephone and cable-TV companies made substantial upgrades to their equipment. New systems, including interactive television and video on demand, are common across the country. The following sections present a glimpse of several areas of study that continually redefine our images of what it means to communicate and exchange information in today's global society.

Computer-Mediated Communication (CMC)

The presence of computers in our lives offers a provocative array of new possibilities for personal growth and development. Perhaps still less common than the traditional modes of communication, ***computer-mediated communication (CMC)*** is an information-related phenomenon that cannot be ignored. CMC enables people around the world to form new kinds of relationships and master new skills. E-mail correspondence among business and academic professionals has become more the rule than the exception. Parents are finding it easier to keep in touch with their college-aged sons and daughters. E-mail messages can be composed and sent anytime, regardless of time-zone differences and complicated schedules. Radio stations no longer encourage their listeners to simply call. They also announce their Internet and e-mail addresses on the air. The White House went on-line with an Internet-accessible e-mail address (president@whitehouse.gov), reported to have received more than 200,000 messages in a year!

Despite the highly sophisticated nature of the ITs constituting the technical architecture of CMC, many people who participate in these sessions are oblivious to how they all work. The ways in which bits of computer data or portions of video information are transmitted over wires and reassembled as recognizable computer files are invisible and seemingly unimportant to many users. Users recognize how relevant the network architecture really is only when these technologies break down and access to CMC services is restricted. This opaque (sometimes called *user-friendly*) nature of telecommunications and computer equipment has led to a great deal of double clicking among all sectors of our society. The ability to point and click to manipulate images on a screen is nonthreatening. It is a lot less daunting to point and click than to devise, memorize, and type long lines of computer codes just to get a program to load.

Undoubtedly, the most familiar CMC environment is ***electronic mail (e-mail).*** People who use e-mail type their messages into the computer and transmit them to recipients through internal network links or external telephone services. Generally speaking, e-mail software allows the user to save, delete, or respond to the message once it is read. Although e-mail has been featured in computer time-sharing environments since the 1960s, it has been only in the last decade that people have actually begun to include e-mail addresses on their business cards. Issues regarding the privacy of e-mail correspondence are discussed later in this chapter.

A second form of CMC is an instant approach to computer conferencing called ***instant messaging (IM).*** IM allows and promotes real-time, synchronous interaction among users. Most IM messages are text based and allow immediate communication between two people. IM spread quickly as an adjunct to AOL service in the 1990s. Now, IM can include video conferencing, Voice over Internet Protocol (VoIP), and Web-conferencing services. VoIP is the transmission of voice over the Internet, rather than through conventional means, such as the telephone or mobile phone. See **Figure 3-3.** The proliferation of these technologies, however, has run past governmental regulations. Regulators must grapple with the following questions: Should VoIP phone calls be regulated under rules created for traditional telephone companies? What are the effects of Internet phoning on the revenues of states? That is, should Internet phone bills include state fees and taxes?

A third CMC application is a social-networking service that facilitates an on-line social network for people who share the same interests or activities. Early forms of social-networking technologies a decade ago included bulletin boards, multiplayer games, mailing lists, and dating services. Many of the new social-networking services have expanded these options. ***Social networking*** is Web based and gives users many different ways to interact—through pictures, blogs, e-mail, IM, chat rooms, file sharing, and discussion groups. Three popular social-networking Web sites in the United States are the MySpace®, Facebook®, and YouTube® services. The MySpace service, with over 300 million users, appeals to young users—in particular, middle and high school students. These users create interactive networks of friends, personal profiles, ***blogs,*** groups, photos, music, and videos. Surprisingly, a large media corporation,

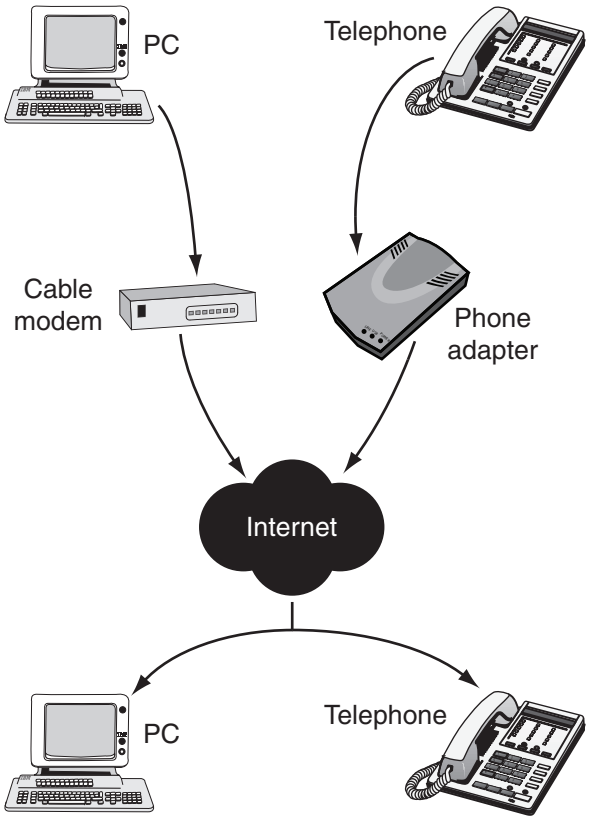


Figure 3-3.
VoIP is a technology that allows two people to communicate by telephone using the Internet, rather than traditional telephone lines.

Rupert Murdoch's News Corporation, owns the MySpace service. The Facebook service, a competing social network, was originally targeted only to students at Harvard College. The membership was quickly expanded to other universities in the Boston, Massachusetts area and then to college and university students across the world. The three largest college networks—Ohio State University, the University of Minnesota, and Texas A&M University—each have more than 70,000 members. The Facebook service, with over 60 million users, is the most popular Web site for uploading photos. This service's revenue, primarily from selling advertisement space on the Web site, is over $100 million. In

contrast to the MySpace and Facebook services, the YouTube service is focused on video sharing. YouTube users can upload, view, and share their videos on-line with other users. The YouTube service, with over 500,000 users, is becoming so popular that YouTube videos were used as the questions in a 2007 Presidential primary debate. Professors, too, are joining the YouTube network. Two professors from the University of Minnesota created a three-dimensional animation explaining a difficult concept in math. This video attracted over 1 million viewers on the YouTube service. A recent listing of videos from iTunes® U, an educational section of Apple's iTunes store, included educational content from hundreds of colleges and universities.

All do not fully embrace these social-networking environments. Government employees in Ontario, Canada are blocked from the Facebook and YouTube services when they use their government computers. Other countries have banned social-networking sites when they believed that the Web sites conflict with their cultural values. The country of Turkey, for example, blocked access to the YouTube service twice because users posted offensive videos criticizing the country's founding father, Mustafa Ataturk. Syria blocked the Facebook service in 2007 as part of a crackdown on political activism on the Internet. Iran and the United Arab Emirates blocked the Web site for being immoral.

Beyond the cultural implications of social-networking sites, there are legal and ethical issues as well. Many young people share music and video files on the Internet. Research shows that over 50% of American Internet users aged 12 to 17 share music files. Among the younger users, there does not appear to be concern for copyright laws or violations. U.S. media companies are very aggressive in protecting their copyrights. This has led to new regulations about downloaded and sharing music, particularly on college campuses.

CMC technological breakthroughs have totally redefined the notion of what it means for us to communicate with each other. Empirical research in the field of CMC is far-reaching and has produced numerous theories regarding the reasons people interact the way they do, as long as they can hide behind the opacity of computer technology. A visionary named Howard Rheingold used the term *virtual community* to describe this evolving social phenomenon in which people form webs of personal relationships in cyberspace. Clinical psychologist Sherry Turkle, in her book *Life on the Screen: Identity in the Age of the Internet*, provides views about the impact of CMC on the way people think about their identities and contributing roles in society. Turkle found that people construct different relationships in their digital world than in their real-life world. Also, the anonymous nature of CMC allows people to change their personas. A man can be a woman. A woman can be a man. Over time, the cyberworld can become more real and more attractive to a person than the actual world. Some people choose to live most of their lives in the digital world. As people increasingly depend on their digital interrelationships, they are less concerned about and involved in the place where they physically live.

The Internet

The number of people connected to the Internet continues to grow at an exponential rate. China, with its over 250 million users, is the world's leading Internet nation. Overall, there are over 6 billion users across the world—most of them in Asia. Similar to the United States' interstate-highway system, the Internet is an immense digital system, linking millions of computer terminals connected to thousands of networks around the world.

The Internet emerged out of the R&D labs the U.S. Defense Department's ***Defense Advanced Research Projects Agency (DARPA)*** operated. The DARPA Network (DARPANET) was created in the 1970s and became the electronic research conduit the government, universities, and corporations dedicated to defense-related projects used. As the advantages of this type of network became apparent and valuable to computer enthusiasts and experts at academic institutions who did not possess defense contracts, the National Science Foundation (NSF) stepped in to fund what has become one of the best-known backbone networks, the NSF Network (NSFNET). The Internet is, therefore, the U.S. government–sponsored successor to the DARPANET. Today, we use domain names to identify companies (such as Microsoft.com). Before the mid-1980s, all computers were identified by their Internet Protocol (IP) addresses (a series of numbers).

More or less, the Internet has exploded into public view. A significant portion of its recently acquired constituency exists in the commercial sector. The fact that the Internet and its predecessors served federally funded research projects rather inconspicuously for nearly two decades is difficult to imagine today. The connectivity and diversity of the resources available through the Internet make it an unprecedented marketing opportunity for American businesses. Most regular Internet users in the United States and abroad think of the Internet first as the WWW or don't think of it at all as they use it to send e-mail to family and friends.

The Internet is not static, however. The United States, as well as other countries, is exploring ways to increase the capacity of the Internet so more and better applications can be delivered. Internet2® software is a nonprofit consortium of U.S. universities, industries, and government agencies that is developing new ways of using the Internet. Universities in this consortium, over 240 by the latest count, are upgrading their computing facilities and linking to the high-speed networks that are the basis of Internet2 software. A new federal initiative, LSN, complements Internet2 software. This time, development in networking is coordinated and funded by 14 interagency groups and coordinated by the National Coordination Office for Networking and IT R&D, instead of by the Department of Defense (DOD). Through this process, the United States is funding $3 billion of new research in networking technologies and services. The focus of this research is in eight program areas[2]:

- ❑ High-end computing infrastructure.
- ❑ High-end computing R&D.
- ❑ Cybersecurity and information assurance.
- ❑ Human computer interaction and information management.
- ❑ Large-scale networking.
- ❑ High-confidence software and systems.
- ❑ Social, economic, and workforce implications of IT and IT-workforce development.
- ❑ Software design and productivity.

As we become more dependent on the Internet, problems with the infrastructure affect us more. In 2008, the Internet collapsed in the Middle East and India because anchors dragged from ships across the sea floor cut two transatlantic cables. Egypt lost 70% of its connection to the Internet outside the country. India lost 50%–60%. The companies based in India were quicker to recover because they had redundant connections to the Internet. Previously, they saw the fragility of the Internet connections when an earthquake

[2]Subcommittee on Networking and Information Technology and Committee on Technology, National Science and Technology Council. 2007. Research and Development Networking and Information Technology Research and Development. http://www.nitrd.gov/pubs/2008supplement/08Supp_FINAL-August.pdf.

off the coast of Taiwan in 2006 severed seven undersea cables. Not just Indian and Egyptian companies, however, were affected. Many U.S. businesses, including Microsoft, Dell, and Apple, have service call centers in India.

There are also negative aspects to the Internet. The Internet has dramatically increased digital piracy, since it is so easy to share music, videos, and photos. Also, today, digital hackers—viruses, worms, and Trojan horses—affect many computer users. The term *virus* is the most widely used because, in many cases, it has become the way people refer to any program glitch in their computer. A true computer ***virus*** is a small program designed to alter the way a computer operates and function without the knowledge of the user. Viruses can affect either a user's computer or an entire network. When you get a virus on your computer, it starts itself and starts reproducing and infecting clean files.

Trojan horses are files masquerading as something else. These files do not reproduce once they get to your computer. Generally, Trojan horses are spread by e-mail. They can be started only if you open them. When you open them, however, they can cause tremendous damage. A Trojan horse called *Eurosol* targeted consumers who used a certain electronic payment system, the Russian-based WebMoney® system. The users were told they could earn money for viewing advertisements while they were on the Internet. After the user clicked on the option to begin, the Trojan horse began showing advertisements and, at the same time, looked into the user's computer to find bank data. Eurosol then transferred the stolen financial data to another computer.

Worms are programs that move from one computer to another automatically. The worm program places a new document containing the worm on a user's computer. Often, a worm uses an e-mail program to send itself to another computer. The Nimda worm used a security hole in Microsoft's Outlook® messaging and collaboration client to have users' computers automatically send infected e-mail messages to anyone on their mailing lists. This worm infected over 1.3 million computers in its first release in the early part of the twenty-first century.

Whether a virus, worm, or Trojan horse, these intruders decrease the security involved in going on-line. These programs, at the same time, lead to increased use of antivirus software, certainly a booming industry in the digital world. No matter how good the antivirus, however, some programmer will find a way to circumvent it. Eventually, one or more of these unwelcome visitors might infect home users. So far, the spread of viruses and worms has not stopped the digital revolution. For most people, it is a small price to pay for the benefits of IT.

The World Wide Web (WWW)

One of the more novel information services available on the Internet is the WWW. The WWW consists of pages of information sent over the Internet using a protocol called *hypertext transfer protocol (http).* Timothy Berners-Lee, a physicist who worked at the *Conseil Européen pour la Recherche Nucléaire (CERN),* or the European Organization for Nuclear Research, a particle-physics lab in Geneva, developed the codes used to make Web pages, hypertext markup language (html), and http. Berners-Lee wanted to develop an easier way for physicists to share information and research. His new method was eventually adopted and expanded and has become the WWW we know today.

The WWW became available on the Internet in the early 1990s. This web is the fastest growing Internet tool for users and businesses desiring to establish their cyberspace presences on the Internet. The WWW is based on a hypertext paradigm. In this paradigm, a document is organized as a graphical collection of multimedia objects, each of which has pointers to other relevant objects. This web provides the necessary tools to let anyone attach a Web site. The WWW exemplifies an open marketplace exchange of ideas. A Web site is accessed using its Web address, or Uniform Resource Locator (URL). For example, http://www.oswego.edu is the Web address for Oswego SUNY, and http://www.apple.com is the Web address for Apple Inc. URLs can be broken into the following components:

- ❏ http—hypertext transfer protocol.
- ❏ www—World Wide Web.
- ❏ oswego or apple—registered name in a domain.
- ❏ edu or com—name of the domain and type of service or organization supporting the account.

The top-level domains on the Internet include .com for commercial; .edu for education; .gov for nonmilitary government agencies; .mil for military agencies; .org for other types of organizations, such as nonprofit and research associations; and .net for network. In addition, there are two other types of top-level domains: sponsored top-level domains (sTLDs) and nonsponsored domains. An independent agency proposes and monitors sTLDs. For example, .aero is restricted to members of the air-transport industry and is monitored by the *Société Internationale de Télécommunications Aéronautiques (SITA),* or the International Society of Aeronautical Telecommunication. Some nonsponsored domains include .biz (businesses engaging in commerce on the Internet), .info (intended for informative Web sites), and .name (for the use of individuals' real names). The Internet Corporation for Assigned Names and Numbers (ICANN) manages the assignment of domain names and IP addresses. The most successful of the new domains is .info. Over four million Web sites carry the .info name.

Web addresses such as those above generally indicate that the Web site is located in the United States. The highest level internationally is a two-letter identifier indicating a country or dependent territory. The Web address for the University of Oxford in the United Kingdom (UK) is http://www.ox.ac.uk/. The .uk in the URL indicates this site is in the UK.

The number of WWW pages has exponentially expanded since the early 1990s. Currently, there are more than 11.5 billion Web pages. These Web pages are becoming more interactive and complex. It is common to watch videos, download music, view photos, and play games on the WWW. In addition, more business is being conducted via the Internet. Both consumers and businesses are finding it easier to compare prices on-line to get the best deals. This new use of the Internet, e-commerce, has the potential to change the way people interact with their world.

E-Commerce

E-commerce is the sale or purchase of goods and services using the Internet. This commerce is a fairly recent phenomenon. E-commerce is, however, an exploding phenomenon. There are many different types of e-commerce activities today. The future possibilities are endless. Today, there are several categories of e-commerce:

- ❏ Business-to-business e-commerce includes companies obtaining supplies and contacting suppliers through the Internet.

- Business-to-consumer e-commerce includes on-line versions of traditional stores, as well as digital catalogs, such as catalogcity.com.
- Consumer-to-consumer e-commerce allows individuals to become their own companies by utilizing on-line auction sites, such as eBay® trading services.
- Information retrieval and services from banks, government agencies, libraries, or other sites allow individuals to run errands on-line.

Although, at first, we might think of e-commerce as a consumer purchase of a product through the Internet, much e-commerce is actually done through business-to-business interactions. With the increasing globalization of manufacturing, many large corporations manage their supply chains through the WWW (for a detailed discussion, see Chapter 6). International business-to-business e-commerce is expected to double over the next decade.

Although e-commerce is increasing dramatically each year, it still constitutes only a small percentage of total sales in the United States (less than 5%). The largest growth has been in the on-line sales of traditional "brick-and-mortar stores." The five largest Internet retailers are Amazon, Staples, Office Depot, Dell, and Hewlett-Packard. Amazon's 2007 Christmas holiday season was its best ever. On its best day (December 10, 2007), Amazon's customers ordered more than 5.4 billion items.

In the middle of the first decade of the twenty-first century, consumers averaged almost $3 billion in e-commerce each week. Over the last few years, the amount of business-to-consumer e-commerce has increased significantly each year. Also, more people are using on-line auction sites. One of the largest auction sites, the eBay service, experiences an annual growth rate of 10%–20%. Even more interesting is that over one million eBay sellers use the eBay service as their primary or secondary source of income. The U.S. Department of Commerce estimates that all types of e-commerce will continue to grow at an ever-increasing rate over the next few years.

In many ways, e-commerce allows a company to market its products more effectively. Most sites use imbedded Web-browser features to collect information about where a customer goes and what he clicks on when Web pages are visited. ***Cookies*** are files placed on the user's computer when that user visits a specific Web site. These files generally store personal information about the user, such as passwords and screen names. Cookies are stored in a folder named Cookies in the Windows® operating system directory of your PC. If you look into this folder, you will generally see a list of places you have been on the Web. Another type of Web tool is a Web bug. ***Web bugs*** are little software programs on a Web site that can record the actions users take when they are on a Web site. Amazon.com keeps all information about what individual customers purchase on its site. When you return to Amazon.com, you are greeted with a customized Web page recommending books or products based on those you have already bought. The most interesting thing about cookies and Web bugs are that most users have no idea this information is being collected. Since most people cruise the Web alone, they assume they alone know where they go on the WWW. Instead, today, the WWW is more similar to a market-research laboratory. Whenever you go on the WWW, someone is keeping track of you. This unseen surveillance does not bother some people. To what extent it will be used in the future, however, is an open question. An Internet provider's privacy policy protects users. How many people, however, read their privacy policies?

The growth in e-commerce has affected states in their tax-collection efforts. Since the late 1990s, there has been a ban prohibiting taxes on Internet access, as well as new taxes on Internet transactions. This is not the main issue, however, for states. Currently, individual states cannot force out-of-state businesses, including e-commerce sites, to collect state sales tax. For example, if a consumer lives in California and buys a book from an e-commerce site in Georgia, the consumer might not pay the California sales tax. So, for example, if you live in California and buy a book from Amazon.com, you will not be charged any tax because Amazon.com does not have a physical presence in California. If, however, a California resident buys a baby gift from Amazon.com, sales tax is charged because the baby-gift supplier is Babies 'R' Us. Babies 'R' Us has stores in California. Confusing? Just imagine yourself running an Internet business.

Another aspect of e-commerce falls under the umbrella of ***e-finance.*** Many banks, brokerage companies, and other institutions allow customers to manage their money and investments on-line. Another aspect of e-finance is on-line lending. Today, consumers can use on-line lending companies such as E-LOAN or mortgage.com to get a mortgage, car loan, or credit card. Since the launch of E-LOAN in the late 1990s, this on-line lending company has originated over $32 billion in consumer loans. See **Figure 3-4.** On-line lending companies increase the options for consumers. At the same time, however, they increase the competitive pressure on local banks.

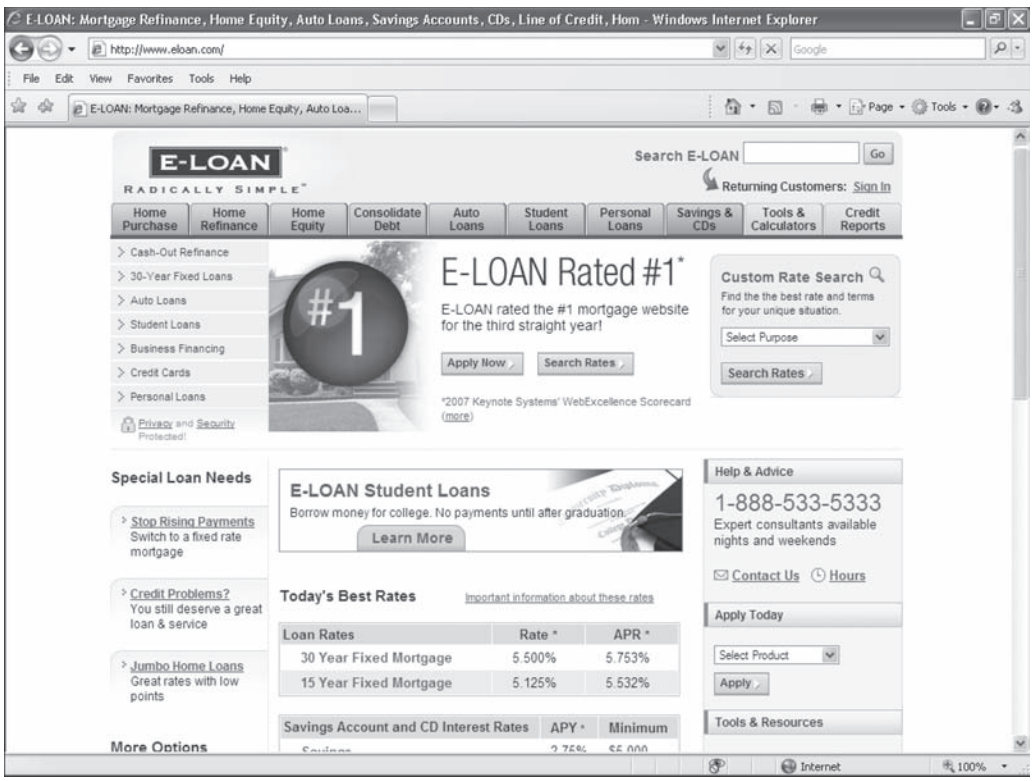


Figure 3-4.
E-LOAN's Web page allows users to access and maintain multiple loan accounts on-line.

One prevalent concern with e-commerce lies with the security of the data being transmitted. Many consumers are fearful that their personal and financial data can be stolen as they buy a book or gift on the Internet. These concerns are justified. In the past few years, various unscrupulous individuals have used numerous techniques to intercept personal and financial data. These techniques include electronic eavesdropping, spoofing (creating phony sites that appear to sell legitimate goods), and altering data to change the dollar amounts. Most e-commerce companies have responded to these threats by increasing security and creating a secured network for all financial interactions. These secured networks begin with a URL of Hypertext Transfer Protocol over Secure Socket Layer (https), instead of the familiar http. Most of the financial transactions are encrypted so only your computer can see the financial information. The negative side of e-commerce has brought an entirely new set of words into common usage, including *pharming*, *phishing*, *spyware*, and *spam* or *spamming*. Pharming is the technique by which a hacker redirects the traffic from a legitimate Web site to a counterfeit Web site. Hackers use pharming to steal personal information such as user names, passwords, and account information. Phishing uses e-mail or IM to acquire personal information from people, usually by posing as a trustworthy person or business. Phished e-mail messages often include official logos from real organizations. When the user clicks on the link, however, she is sent to a counterfeit Web site, instead of the organization's Web site. Spyware refers to a variety of software programs that load themselves surreptitiously on your PC and collect personal information, distribute ads, or change the configuration of your computer without obtaining your consent. Often, a computer user is not aware of the existence of spyware until his computer slows down or behaves erratically. Internet-security experts estimate that almost 50% of PCs are infected with some type of spyware. Spamming is the sending of unsolicited bulk messages, usually through e-mail. The unwanted messages themselves are called *spam.* Today, spam is everywhere. Some experts estimate that over 80% of all e-mail in the world is spam. Other than being a nuisance, spam increases the costs of doing business on-line. Spam costs the United States alone more that $13 billion a year in lost productivity and increased software and hardware costs.

E-commerce has transformed the U.S. economy, as more businesses create on-line versions of themselves. In addition, the government is taking more advantage of e-commerce to assist its customers. The U.S. Customs and Border Protection unit of the Department of Homeland Security uses a customized Web page to undertake all customs activities for companies importing goods into the United States. Since the start of the page in 2004, U.S. Customs has collected more than $14 billion in duties and fees on-line. Two million manifests have been filed on-line with the bureau. The Internal Revenue Service (IRS) is in the middle of a strong push to get all Americans to file electronically. Today, most taxpayers file electronically with the IRS. The number of electronic filers grows each year.

Whether we want to or not, we are going to be required to use the Internet and e-commerce to complete our everyday work in the future. Smart cards and mobile phones are now being used to pay for goods and services using electronic cash. The MasterCard® service is promoting its system, the PayPass® card, to allow customers to speed up electronic cash transactions. New York City subway travelers on the Lexington subway line can use a PayPass card to pay their tolls. Instead of using a token or swiping a credit card, a traveler taps her electronic PayPass card on the

reader. The electronic-cash device uses radio frequency identification (RFID) technology to transmit the payment information on a ***wireless network.*** (See Chapter 6 for a detailed discussion of RFID). Electronic cash is not, however, solely a U.S. innovation. In the Philippines, for example, more than four million cell-phone users use their phones as virtual wallets to buy goods or transfer cash.

In the future, will U.S. citizens have to pay extra if they use old-fashioned dollar bills instead of electronic cash? Will department stores build any more stores, if it is cheaper and easier to sell everything electronically? Will banks close down their local branches to save money and require customers to communicate with them electronically? No one knows the answers to these questions. Both e-commerce and e-finance, however, will transform the way we interact with businesses and each other.

On-Line Education

The Internet and the IT revolution began in the educational world. Despite this, universities have lagged behind businesses in exploiting the WWW. In the past few years, universities have begun to adopt Internet-business models, as a means of increasing their revenue. As a medium, the Internet holds several attractions for education. Universities have extensive physical plants. With reduced funding from state governments and research, it is more difficult to expand by building new buildings. Here, the use of the Internet seems ideal.

As compared to the rest of the world, the United States has a highly diversified higher education system. This system includes research universities, private liberal arts colleges, public community colleges, and public universities. Today, a new entity is joining the education world—the for-profit provider. These for-profit ventures are bringing new pressure to bear on educational institutions.

One of these new on-line universities is University of Phoenix On-Line. The University of Phoenix On-Line is an offshoot of the University of Phoenix program. The University of Phoenix began in the mid-1970s and offered accelerated undergraduate and graduate programs to working professionals. Currently, it has over 300,000 students at 250 campuses and learning centers established in 38 states, the District of Columbia, Canada, and Puerto Rico. The University of Phoenix On-Line, begun in the late 1980s, offers 100% of its coursework via the Internet. This makes this program particularly appealing to students who are working or having problems commuting to a traditional campus. Currently, this university has over 100,000 students taking courses toward a bachelor's, master's, or doctoral distance-learning degree.

The growth of the University of Phoenix and other on-line universities has caused a tremor in the halls of the traditional university. The result has been that many traditional universities have jumped on the on-line bandwagon. A growing number of schools—including Duke University, Stanford University, and New York University—hope to profit from on-line learning, similar to the way the University of Phoenix did. MIT is taking another approach. This school recently started an on-line Web site that will post lecture notes, course outlines, and teaching materials for all its classes—free. Today, you can view more than 1800 MIT courses on-line on the institute's Web site.

Will universities join the e-commerce trend and begin selling courses on the WWW? Or will they follow MIT's lead and provide information for free and for the betterment of society? There is no simple answer to these questions. As universities feel increasing financial pressure, they will undoubtedly use the WWW and other networking technologies to alleviate this stress. The effect of on-line learning on the quality of education will be an ongoing concern.

Telecommunications Networks

The delivery of personalized communication services to all people, regardless of where they work or reside, is one of the underlying ambitions of the NII. The United States maintains a competitive edge in the development of networking technologies. Today, many of us are so accustomed to surfing the Internet that we ignore the technology underlying it. The Internet has become as ubiquitous as the telephone system. We think about it only when it does not work.

Many smaller networks and links make up the Internet. The Internet is a vast computer network. Networking, however, is no longer the sole province of large businesses and universities. Small businesses, even homes, can now utilize emerging technologies to create networks. As many small businesses and home users learn, the problem with connecting to the Internet via a modem is the slow speed. A network using a wireless connection, digital subscriber line (DSL), or cable modem can decrease the time it takes to access the Internet.

How does a network work? A network begins with the individual computers. Each of the computers has to be able to connect to the network, either through a modem or a network interface card (NIC). The most common type of NIC allows the computer to use an Ethernet type of network. See **Figure 3-5** for a graphic example. This network can use wires. On the other hand, it can be wireless. If there are enough computers, one might add a hub to connect

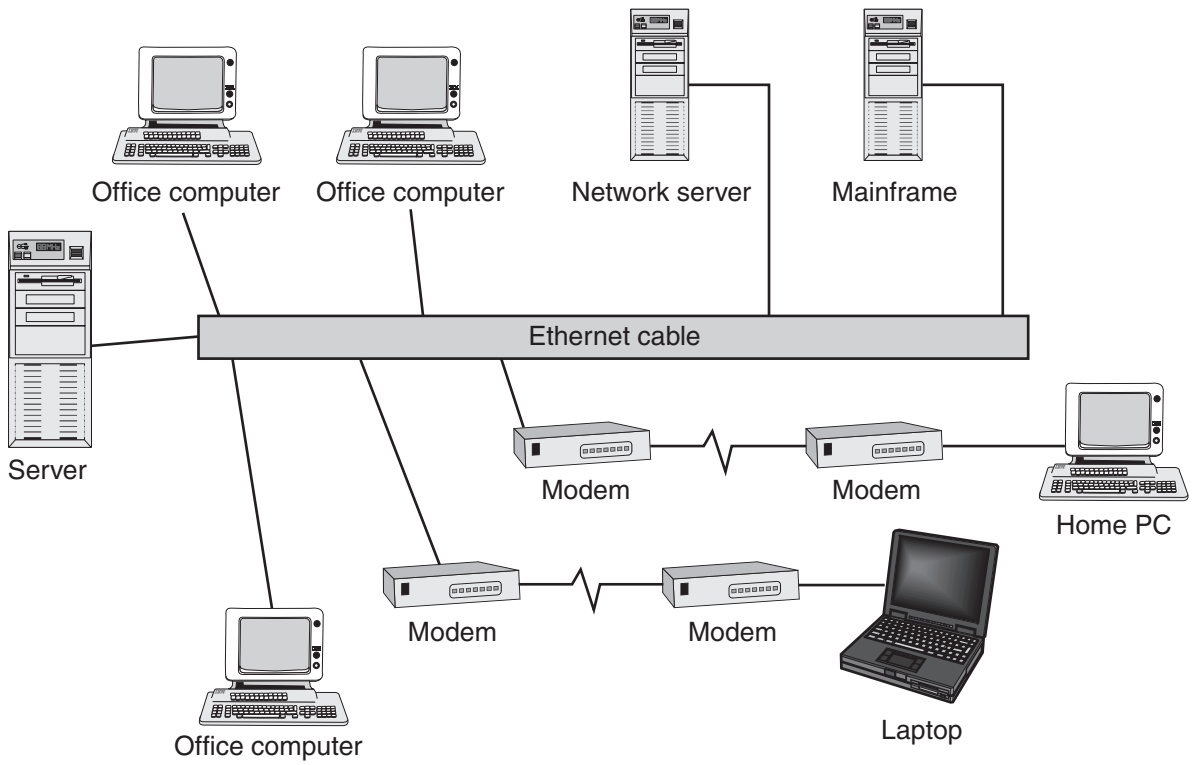


Figure 3-5.
This network for a growing business includes computers connected to a LAN, as well as the ability to access the network through a modem.

these users. Since a hub requires users to share the network, if there are too many users, either a switch or a router replaces a hub. A switch sends information only to the recipient, not to the entire network, as a hub does. A telephone analogy is the difference between a private line and a party line. In a party line (hub), when one person is using the line, no one else can use it. In a private line (switch), each party uses a dedicated line to talk to another party.

Routers are even more complex. They use the complete address to decide where the information should go. Routers are used to connect one network to another in the same building and as an interface to connect a network to a WAN. As shown in **Figure 3-5,** servers are added to the network when there is more demand for shared files. It is faster to place shared files on a central server than to e-mail them back and forth.

In general, LANs are used for people who are in the same building or location. WANs connect users and LANs from different locations. The connection speed of LANs tends to be much higher than that of WANs. A basic Ethernet LAN has a capacity of 10 million bps. A fast modem, in contrast, can transmit information at only 56,000 bps. This is about 1% the speed of an Ethernet LAN. A home user or a small business can get faster connections. Integrated Services Digital Network (ISDN) is a network technology that allows traditional voice or telephone service to share the network with data or digital traffic. ISDN uses regular telephone lines. An ISDN connection is about twice as fast as a standard modem. A cable-modem connection can be almost as fast as an Ethernet LAN.

Faster ways of accessing the Internet, coupled with new networking hardware, have opened a new market—home networking. The number of home networks will continue to increase in the next few years, as dual-computer users realize the value of sharing fast Internet links among different computers in the home. Several computer companies are jumping on this new market and are selling home-networking products that will allow easy networking using phone lines, cable networks, Ethernet, or wireless communication. These companies promise that, eventually, home networking will be as easy as plugging a new telephone into an existing telephone jack.

Fiber optics

Contemporary fiber-optic networks emerged on the scene in the 1970s. In the 1970s, Corning Glass researchers fabricated a useful light-wave conduit. These glass fibers in use today transmit voice, video, and data at speeds 10 to 200 times faster than the standard copper wire used for more than 100 years in telecommunications networks. There are two types of optical fibers. Single-mode fibers, used in telephones and cable TV, are used to send one signal in each fiber. The more common type used in telecommunication is multimode fibers. This type can transmit thousands of signals in each fiber. Almost every year, the capacity of fiber-optic cables increases. See **Figure 3-6.**

For most fiber-optic systems to transmit a conversation, voice signals (electrical impulses copying a caller's voice) are converted into digital form. When computers are the senders and receivers in the link, the conversation is already in digital form. The digitized information is carried on light pulses produced by laser diodes through a glass fiber at a very fast rate (faster than 40 megabytes per second). When this information reaches its final destination, it is translated into its original analog form. ***Fiber optics*** are being installed to replace old wiring systems at an increasingly rapid rate. Unlike using electrons, using light waves makes transmission less susceptible



Figure 3-6.
Fiber optics have a multitude of uses. They are so prevalent that LumiGram® incorporates them into its clothing designs. (LumiGram®)

to electromagnetic interference caused by electrical storms or faulty hair dryers. Since these conduits do not create electromagnetic fields, inductive pickup devices cannot tap fiber-optic cables. As a result, the messages are ultimately transmitted without distortion and with almost no loss of information. Satellites have lost some of their telecommunications business to optic fibers because fiber-optic networks are more secure. It is significantly more difficult to steal signals from enclosed glass filaments than to pirate signals sent through the atmosphere.

In contemporary fiber-optic networks, each time a light pulse is amplified, switched, sent into the network, or removed from the network, it must be reconfigured into a stream of electrons for processing. Light-wave signals are diminished when the fiber-optic cabling is interrupted to connect new hardware. It becomes more difficult for the network to process the smaller pulses of light required to transmit gigabits of digital information each second. In today's ultrahigh-speed networks, once the transmission rate exceeds 50 gigabits per second, it is very hard for electronic equipment to maintain the constant back-and-forth conversions between light waves and electrons.

Wireless networks

In another camp of internetworking technologies, communication technologists are confronting the challenge of providing computer users access to ubiquitous wireless networks. Wireless communication is indeed a significant growth segment of the global telecommunications industry. Mobile workers and residents of remote areas anywhere might soon be the beneficiaries of personal communication services that were heretofore unimagined.

People whose employment requires them to connect to their offices from remote locations are finding it easier to do so with each passing year. Mobile workers have become accustomed to the liberation cellular telephones afford and now expect the same range of freedom for their digital links. The use of cellular phones exploded in the late 1990s and is considered by many to be a necessity, not a luxury. Personal digital assistants (PDAs) and smartphones have gained widespread popularity, especially with the release of the Apple iPhone™ mobile digital device in June 2007. There are several brands of PDAs. These brands include the Palm® handheld and the HP iPAQ® Pocket PC. There exists a fine line, however, between PDAs and smartphones. PDAs are electronic organizers for appointments, addresses, writing, and Internet access. Smartphones are PDAs with cellular-phone capabilities. They have all the features of a PDA, with the additional

advantage of making and receiving phone calls. Although tens of millions of PDAs are in use, smartphones, such as Apple's iPhone mobile digital device and the Blackberry® smartphone, are replacing them. More than 60 million smartphones are sold each year. Many devices today use the wireless fidelity (WiFi) standards for wireless connectivity. See **Figure 3-7.**

A typical demand for a wireless link between the traveling worker and the central office is to exchange e-mail. More rigorous expectations of wireless networks entail connecting remote employees with real-time corporate data, applications running on network servers, and mainframe computers in the home office. Wireless networks might also be used to provide service technicians who come to your home or office access to technical documentation and up-to-date warranty information. Anyone who has called the United Parcel Service or Federal Express (FedEx) requesting information about a shipment knows both companies currently use unique wireless software and thousands of mobile computers to track all their packages in transit.

As with any new area of development relying on concurrent advancements in several science and technology suites, many obstacles stand in the way of wireless networks. One key difference between wire service and wireless service is the transmission medium for radio communications. This medium is regulated and requires frequency administration. Unlike examining the potential for success in an optical fiber or wire environment, a test of a new concept using radio technology calls for a ruling by the FCC.

Employees who connect to the office from a field site want high speed. Customers are purchasing portable telephones, PDAs, smartphones, and other wireless devices at an increasing rate across the nation. About 80%–90% of all households in the United

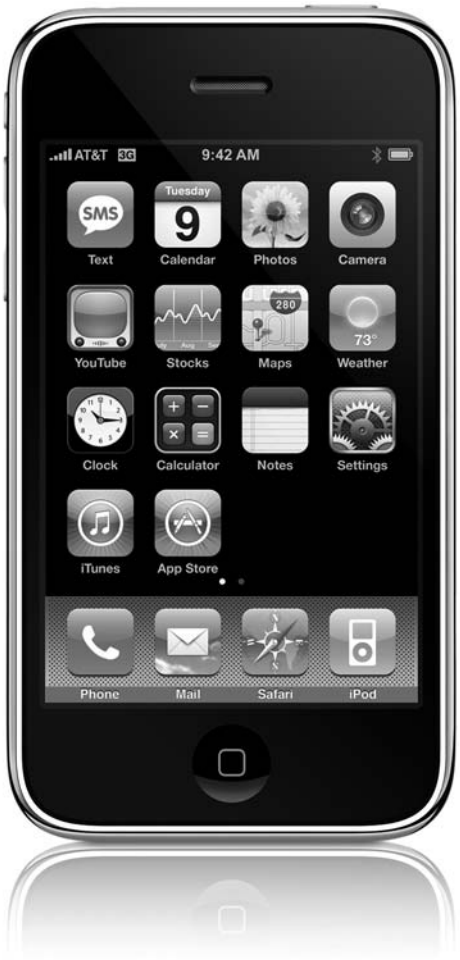


Figure 3-7.
The Apple iPhone™ mobile digital device allows users to make and receive phone calls, access WiFi Internet, and install applications for a myriad of purposes. (Courtesy of Apple)

States have at least one cell phone. Among the young, cell phones are replacing conventional telephones. In the United States, almost a third of all adults aged 25 to 29 live in a household with only cell phones and no conventional telephones. Also, cell-phone users under 30 years old use their mobile devices three times more than older users do, in addition to using the cell phones to

access social-networking Web sites. Today, there are more wireless phones sold in the United States each year than PCs.

Cell phones are only the first level of wireless technology. As the options of cell phones expand and the phones become minicomputers, the demand for additional wireless technology will grow. See **Figure 3-8.** Today, all cell phones sold in the United States are expected to contain another wireless feature, a Global Positioning System (GPS) chip. (The GPS is discussed in more detail in Chapter 4.) In the mid-1990s, the FCC passed a new rule for cell phones requiring all cellular phones to include a way to pinpoint the caller's location for 911 calls to within 50–300 meters. All U.S. cell phones will eventually contain a GPS

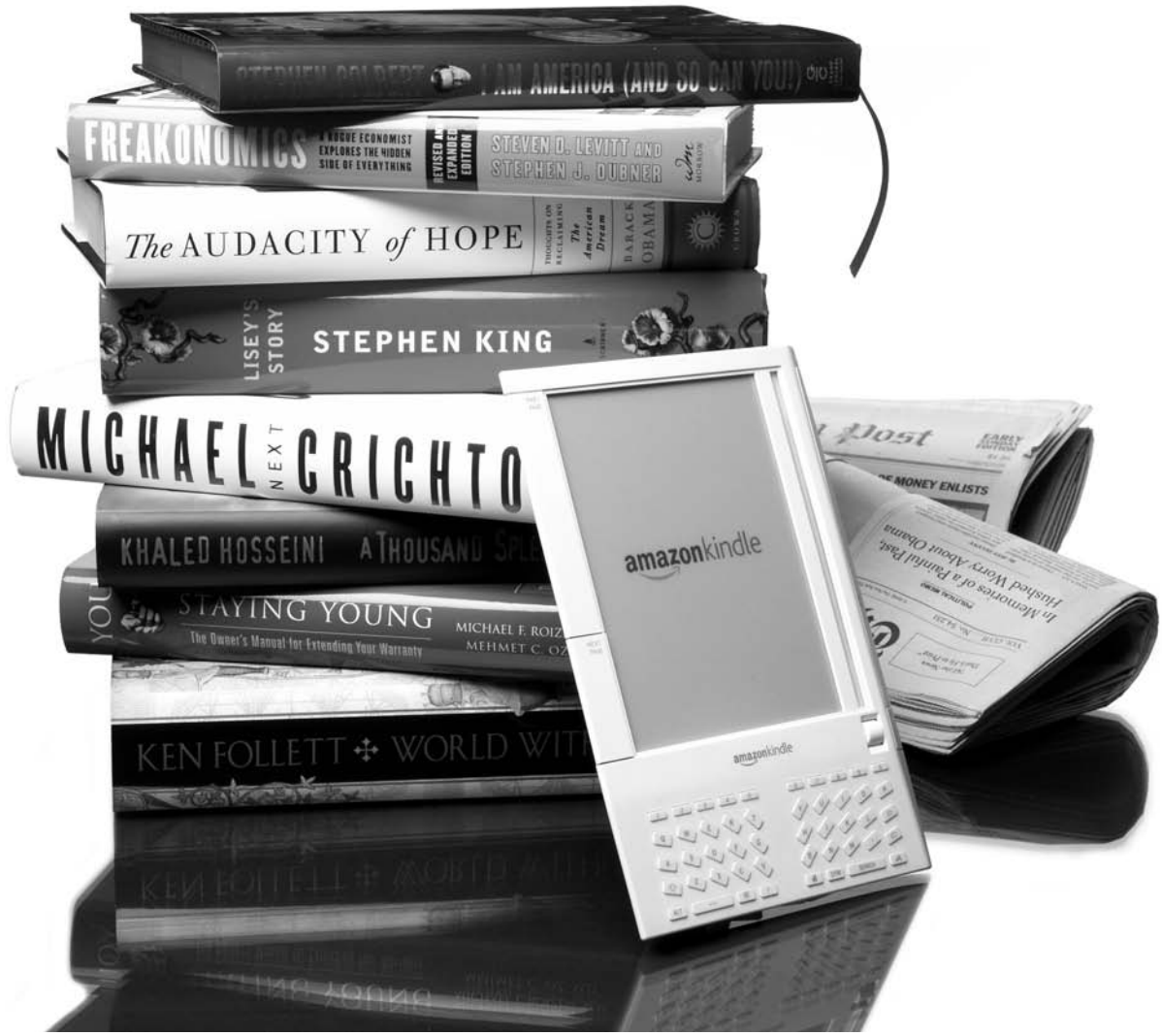


Figure 3-8.
The Amazon Kindle® device is designed to hold more than 200 electronic books. This device's sleek design makes the Kindle device ideal for travel. The Kindle device comes with wireless Internet access to thousands of books that can be downloaded instantly. (Amazon.com)

chip because of this enhanced 911 rule. One wonders, however, what other uses this chip will have. Now, most cell phones include the option to turn off the GPS tracking feature except for 911 emergencies. It is unclear, however, how this technology will be used in the future and how information about the consumer will be available through the GPS.

In the future, the applications in handheld computers will also expand. Today, it is possible to browse the Internet, get directions from a GPS, and link to a home computer with a PDA, all using wireless technology. This is only the beginning, however, of the expansion of wireless technology. Wireless services have begun to appear in noncomputer devices. You can buy a new car equipped with an imbedded wireless system. Drivers can get e-mail, driving directions, news, and stock quotes. The sky is the limit. This type of application is called ***telematics.*** Telematics is the use of wireless voice and data technologies between a car and somewhere else. See **Figure 3-9.**

Telematics first was used on Ford Lincoln cars in the mid-1990s. This use, however, was mainly for roadside assistance. General Motors expanded the telematics to include driving directions and now offers its OnStar® system as standard equipment in all its U.S. brands. As more buyers lined up to buy these systems in cars, more systems have been developed. All major automobile companies include a GPS either as a standard feature or an option for new cars.



Figure 3-9.
There is no need for maps or asking for directions. GPSs for cars are widely available.

Wireless technology is not, however, limited to GPS devices. Cities all over the United States are planning or building municipal wireless networks. The city of Philadelphia launched its Wireless Philadelphia network in 2005. This network now includes wireless coverage of most of the downtown area. Each year, the project is expanded to new neighborhoods, using routers installed on light poles and other structures about 1000' apart. As part of its plan, Wireless Philadelphia focuses on distributing wireless laptops to the city's poor households so they can have Internet access. Anaheim, California, the home of Disneyland and Mickey Mouse, has also installed a citywide WiFi network. The city of Tempe, Arizona installed more than 400 wireless access points, providing WiFi to subscribers in most of the city. The wireless network is also available on the campus of Arizona State University and in outdoor areas in downtown Tempe. Plans are underway in at least 200 additional U.S. towns and cities to develop or install municipal wireless networks.

Universities have also adopted wireless technologies and are expanding their wireless networks at a breakneck pace. Almost two-thirds of U.S. universities have wireless networks on part or all of their campuses. Universities are discovering it is more efficient and affordable to use wireless technology than to provide computer laboratories for their students. Carnegie Mellon University has begun replacing its existing wire network with a wireless network, Wireless Andrew. This network will cover the entire 103-acre campus. Wireless Andrew will include a scattered array of antennas that will each supply coverage to a small geographic area of the campus.

The future of wireless technology seems limited only by the imagination and resourcefulness of industry. Imagine earrings lighting up when you get an e-mail message, a belt attachment acting as a voice-input device for your handheld computer, or a bracelet containing an electronic organizer. In addition, in the aviation industry, wireless communication is being expanded through digital cockpits that include computer displays allowing the pilot to merge information gathered from the GPS and other sources. This information includes the route and terrain on the same display.

Experts believe that wireless technology will foster an increasing demand for tracking and security. A cellular company in Japan, NTT DoCoMo, projects that, by 2010, 20 million wireless devices will be implanted in pets and 60 million devices will be in bicycles. There will be no more worrying about your dog getting lost, because you can track it through an imbedded GPS chip. Whether or not these projections hold true, there is no doubt that more uses will be found for wireless technology.

Intranets and extranets

A business can utilize networking and Web technologies to create a private corporate network called an ***intranet.*** Today, the computers in most businesses are connected to the Internet through one means or another. Intranets can be kept private and protected through a firewall. A ***firewall*** consists of hardware and software placed between the private intranet and the outside network (the Internet). The firewall examines all information entering and leaving the intranet to make sure there are no unauthorized messages. In this way, the firewall stops hackers from breaking into a company's computer system. The actual intranet uses Web pages to run the corporate network. The difference between the intranet and the Internet is that the intranet Web pages are accessible only to people inside the company.

An intranet becomes an ***extranet*** when a company allows customers and other users to have limited access to the organization's intranet. General Motors, for example, uses a corporate extranet, along with wireless technology, to distribute service manuals to its dealers. A few years ago, General Motors converted from a paper manual system to a PC-based system. In this PC-based system, technicians access information from CD-ROMs. The company discovered this was ineffective, however, because most repair shops have only one computer. The manual information was loaded onto a corporate extranet. Now, technicians can access this information through a secured Internet site open only to authorized users. Technicians can even access these manuals at their individual workstations using special handheld computers Fujitsu designed.

Another new type of network is a ***virtual private network (VPN).*** A VPN is a low-cost alternative to a private WAN. Before the Internet explosion, the only way a company could create a network linking remote offices was by creating its own WAN. A WAN generally requires a business to either lease lines among its various offices or provide dial-up access. In any case, this network requires the business to spend a lot more time and money monitoring and administrating their own private network. With the growth of the Internet, many companies are accomplishing the goals of a WAN without having to lease telephone lines themselves, by using a VPN. A VPN is a secure connection between two points on the Internet. In contrast to a WAN, VPNs are available through Internet providers. Remote users just use their modems or Internet connections to access the Internet provider. This leads them to the secure VPN. Companies have quickly realized the cost benefits of VPNs. About 80% of large-sized companies already use some type of VPN in their business. Global spending on VPNs already exceeds $6 billion each year!

All these types of networks are exploding. Companies are realizing the cost savings involved in networking. When a FedEx client uses the company's extranet to track the status of his package instead of calling the service center, FedEx saves $8. Cisco Systems has a large intranet it uses to link the corporate headquarters in San Jose, California with offices in 75 countries. Tupelo Grill, a restaurant located across the street from New York's Madison Square Garden, has an interesting twist on this type of network. This restaurant uses the AT&T network and software from CEverything transmission. The owners can watch their restaurant, using streaming video and the Internet, from anywhere in the world. This allows them to monitor the service their customers receive without actually being there. The growth of ***telecommuting*** (see section below) will only increase the creation and use of VPNs by companies throughout the world. Instead of costly travel to a company seminar, a company can utilize its VPN to deliver training to employees located throughout the world.

TELECOMMUTING

The concept of using telecommunications technology to transport work to employees who, therefore, avoid the daily commute to a distant job site.

When we think of a traditional business, we imagine a quaint storefront located in either a mall or a downtown business area. Now, these storefronts are digital. The goods displayed are located somewhere else in the country. As more companies take advantage of networking over the next decade, there will be profound changes as to how we use and view the Internet. What these changes will be, only time will tell.

Intelligent Software

In the not-too-distant future, our already information-saturated, sensory-overloaded society will make use of ***intelligent software agents*** that know users' interests and needs and act autonomously on their behalf. In the true sense of technology designed to expand or enhance a person's physical and intellectual potential, these software agents might assume the role of personal secretary to the user. Agent programs differ from conventional software in their capacities to learn from experiences and respond to unexpected situations. An ideal software agent program strives to achieve a known goal and can sense the current state of its environment in order to make continual progress toward the goal. For example, a college professor might employ an intelligent agent program to update her lecture notes at the end of each semester. Specifically, the agent's knowledge that the goal is to locate projected international energy-resource consumption rates for the next 20 years will direct the agent to patrol the Internet and beyond, to seek information for its owner.

One glitch to using intelligent software agents is they look similar to invasive viruses to the security systems on other users' computers. This mistaken identity can prompt the network to delete agents or refuse them entry to various sites. Software engineers perceive a clear and present need to devise standards to ease the travels of these agents across the Internet. Currently, there is no clear agreement about what an agent is or what it should be. A development called the *Unified Agent Architecture (UAA)* proposes a uniform look for mobile agents. In essence, the UAA attaches special codes to software agents that both identify their owners and allow them to be destroyed if they run awry or if a virus contaminates them. The technologies to monitor as this field is further commercialized include expert systems and neural network simulators.

Virtual Reality (VR)

A few short years ago, ***virtual reality (VR)*** was regarded more as science fiction than as a functional tool. Television reports presenting virtual worlds as computer-generated alternatives to reality have convinced us that VR has the overarching potential to transform computers into extensions of our whole bodies. While we are still a long way from the world of having a VR chamber in every household, virtual environments figure prominently in several industrial application areas. These areas include marketing, prototyping, and training.

Contemporary applications for VR range from fire fighting to medicine to the design of automobiles. VR is a promising training medium for people who aspire to be firefighters and others who must learn to resolve dangerous tasks without risking their own lives. This medium takes simulation another generation forward. VR transforms (and even distorts) a person's perceptions, by appealing to several senses at once (vision, hearing, and touch) and presenting graphic images that respond immediately to his movements. This medium permits people to behave as if they are somewhere they really are not. PIXELearning developed a simulator for an international accounting firm to train interns. The interns use role-playing inside the virtual world to practice their skills in dealing with clients. This allows them to make mistakes and learn from those mistakes, without trying out their new skills on actual clients. VR equipment has been used to help people overcome their fear of heights. Pilots and astronauts train in VR cockpits that combine three-dimensional graphics with the view out the window. Sound systems provide environmental cues. Automotive companies are looking at VR technologies as these technologies apply to car design, construction, assembly, and repair.

With the advent of Apple QuickTime® digital video, a new type of VR has sprung up using QuickTime VR. Students can visit the Louvre and take a virtual tour of its galleries by accessing its Web site. Instead of spending thousands of dollars on equipment and travel, one can climb Mount Everest or explore the pyramids through a virtual expedition. Another current use is in real estate. QuickTime VR allows realtors to provide virtual Web tours of their properties. Instead of wasting time driving to a house, a potential buyer can view the house on the WWW.

There has been a growth in distributed VR worlds. These worlds include those that serve as social-networking sites. These sites feature multiplayer on-line role-playing games and are usually targeted at a particular audience. Club Penguin, part of the Walt Disney Company, is targeted to children aged 6–14. In this virtual world, children can play games and interact with each other, using penguins. Each child uses her penguin to interact with other players. Other VR Web sites are targeted at adults. One popular adult site is Second Life, launched in 2003. This site has more than 10 million users, with around 50,000 users on-line at a single time. Second Life users interact with each other through an avatar. An avatar is a computer user's representative of himself. In Second Life, the users design most of the content of the virtual world. Second Life has its own currency (Linden dollars). Users create new goods and services and buy and sell them in the virtual world. Several companies and countries have a virtual presence in Second Life. Dell Computer has a sales office inside Second Life. Reebok has a store. The Maldives were the first country to open a virtual embassy on Second Life's Diplomacy Island. Other countries, including Sweden and Estonia, have since joined them in this virtual world. Universities have also been creating virtual selves on Second Life. In fact, there is so much activity among universities that there is now a virtual international conference of best practices in simulated education. One thousand educators from over 100 institutions around the world attended the 2007 virtual conference. Beyond its entertainment profile, VR is an aspect of information manipulation you can expect to be around for a long time.

Telecommuting to Work—Virtual Transportation

Just as VR technology allows people to behave as if they are somewhere they are not, a convergence of powerful technologies enables telecommuters to work as though they are in their corporate offices, even though they are at their home computer terminals. Alvin Toffler first coined the term *electronic cottage* in his best-selling book, titled *The Third Wave*, in the early 1980s. Telecommuting has given way to yet another new concept labeled *virtual transportation.* In virtual transportation, work is transported to the employees, instead of the employees physically transporting themselves to the job site.

History of Telecommuting

Jack Nilles at the University of Southern California's Center for Futures Research initially coined the word *telecommuting* for futures research in the early 1970s. Oddly enough, the emergence of this word coincided with a major international oil embargo that prompted researchers to seriously evaluate the use of telecommunications networks, to allow workers to avoid gasoline-dependent automobile trips to and from work. Another term frequently used, particularly in Europe, to describe remote working is *teleworking.*

The past three decades have introduced more computers, LANs, e-mail messages, fax machines, videoconferences, and other services into the workplace. These converging technologies have greatly expanded the number and types of jobs that can be performed wholly or in part without travel. Recent estimates of the number of people who already telecommute at least one day a week range from 25 to 32 million. About 10% of the U.S. workforce teleworks, at home, on the road, or in a satellite office. Very few people telework full-time, however. Most still spend about two to three days per week at their central offices. For most teleworkers, work tends to be allocated differently during office days and telework days. Office hours are used for interpersonal work activities, such as face-to-face meetings and team meetings. Telework hours are generally reserved for projects, writing reports, and research. VPNs have made it easier for workers to telecommute. They allow the home worker to access the office computer easily and more securely. While it is difficult to forecast future telecommuting scenarios, experts estimate that some 25 million people could be efficiently telecommuting the majority of the workweek by the decade's end. Writers, consultants, stockbrokers, realtors, software engineers, music teachers, accountants, architects, and government employees who work for countless companies and state and federal offices are already avoiding the hassles of the daily driving commute.

Public interest in telecommuting in the coming years will more than likely rest on the social goal to alleviate problems of traffic congestion and the related energy and air-quality issues. A survey the U.S. Department of Transportation conducted in the early 2000s revealed that the average American commuter drives 6000 miles back and forth to work each year, burning approximately 300 gallons of gasoline. The EPA found that employee commutes to work make up 20% of all vehicle miles yearly on American roads. Emissions of greenhouse gases range in the millions of tons each year. These gases cause severe environmental problems. If just 10% of the nation's workforce telecommutes one day a week, there would be thousands of tons less air pollution. The country would conserve more than 1 million gallons of fuel each year.

Based on productivity surveys, there is a positive benefit to employees telecommuting. If one employee telecommutes, others in the firm must be more organized. This organization might partially explain gains in productivity. Also, telecommuting employees tend to use less sick time and work a longer workday. If telecommuting programs are critically conceived and implemented, reported productivity gains of 5%–19% are typical.

Benefits of Telecommuting

There are some proponents of telecommuting who suggest consumers will be the ultimate beneficiaries as the trend toward telework continues to emerge. Companies' direct expenses might be lower. Established firms will face greater competition, as entrepreneurs take advantage of technical developments and hire workers who had not previously been part of the traditional workforce. This might ultimately lead to lower consumer costs for established goods and services.

One of the most significant economic benefits for companies considering launching a telecommuting program is the potential for saving on current or additional office space, building maintenance, and computer time. Unlike costs associated with the computers and networking, construction prices continue to climb. When a company doubles its workforce in a short period of time, the cost of building expansion can be prohibitive.

Telecommuting programs are a mechanism through which organizations can recruit and retain valuable employees. These programs can also cut relocation costs for both new and veteran employees. Companies can eliminate the fees associated with moving their personnel to housing within commuting distance by allowing these individuals to work from their own homes. Telecommuting workers might then be asked to commute only occasionally to either the main office or a nearby satellite office.

Telecommuters who sincerely enjoy working at home tend to work harder and longer than their office-restricted counterparts. One of the most prevalent productivity nightmares is the winter blizzard. If the office does not have to close down completely, it is probable that the few employees who do manage to show up to work will spend most of the day worrying about the trip home, instead of getting any useful work done. The employees who never left home are easily going to be more productive under these circumstances.

In short, telecommuting promises benefits for all concerned. Telecommuting can yield lower costs for businesses, more freedom for workers, and a fuller family life for parents. This program also increases the range of services and products available to consumers and lowers prices along the way.

Potential Drawbacks of Telecommuting

Before you close this book to start dreaming about the luxurious life of the telecommuter, it is necessary to review some of the not-so-wonderful aspects of telecommuting. From the corporate perspective, one of the most frequent excuses used in opposition to telecommuting programs references the loss of managerial control. Some executives believe it is impossible to manage people they never see. Overcoming this out-of-sight prejudice might take more time for some than others. Telecommuters must be measured strictly by their output and have fewer opportunities to "snow the boss," so to speak.

From the employees' viewpoint, the out-of-sight, out-of-mind syndrome can be more serious. Employees might be forced to deal with the possibility that they will be overlooked when it comes to such things as promotions, new projects, and raises. Prime decision makers within organizations who give promotions tend to work during conventional daytime hours. Those workers who work outside of the nine-to-five routine have always been at a disadvantage. Since it is frequently the casual interactions taking place on the job site that open doors for career advancement, the invisible employee might remain looking in from the outside.

Many people look to their workplaces as respites from domestic chores and responsibilities. If the home becomes the workplace, these people might experience a sense of imprisonment and isolation. Adult workers often need a chance to interact with colleagues for sociopsychological reasons. Face-to-face meetings also encourage workers to remain involved with the organization and keep abreast of pending technological changes.

More importantly, working at home requires a considerable amount of self-discipline, coupled with tremendous concentration. Although the office environment has its share of interruptions, a person's home is full of distractions. Unsuccessful telecommuters report they have gained weight, learned how to procrastinate in the garden, and become hooked on a daytime soap opera. On the opposing side of these stories is the tale of the man who insisted on dressing in a three-piece business suit each morning before walking down the hall to his den to begin the workday with a tape of the

sounds of his former office. Family members might not be able to adapt to the ever-changing roles the telecommuter is forced to play when the home is where the job is. This might be viewed as the "Mommy or Daddy doesn't work anymore–syndrome."

Finally, the issue of security eventually comes to the mind of corporate executive officers who are responsible for managing large amounts of data. Is it wise to allow sensitive corporate data out of the office? Information becomes vulnerable as it is conveyed electronically via a modem, diskettes, or e-mail. Papers shipped to and from home workers can easily be lost or stolen. Who is liable for the security of the information once it leaves the corporate office—the chief executive officer (CEO) or the telecommuter?

Employee Selection Criteria

Some telecommuting advocates say the question is not who should be allowed to work at home, but who should be forced to work in the office. This statement might be somewhat premature, in light of the above concerns. Other proponents indicate the key to initiating a successful telecommuting program is the selection process itself. The company, rather than the employee, should set the selection criteria. Once these criteria have been established and potential candidates have been identified, the process should then become one of voluntary self-selection. In other words, approved employees should have the option of either accepting or rejecting the offer.

Some of the numerous personnel selection guidelines that corporations satisfied with their telecommuting programs use are summarized as follows. If you ever find yourself in the position to make this type of high-level corporate decision, perhaps these criteria will be insightful:

- Employees whose work is dependent on direct interaction with customers who visit corporate offices cannot work effectively at home.
- Those employees who are regularly involved in team projects and those whose work is regularly dependent on interaction with their colleagues are usually eliminated from consideration. Some companies, however, allow team employees to meet at specified times at the office or virtually through computer or virtual networking.
- Some corporations have had success in hiring employees specifically to work at home. Most recommend that telecommuters be selected from personnel who have been with the company for some time and understand how it operates.
- The psychological makeup of the employee is also crucial. Not everyone is suited for telework. Telecommuters must be intrinsically motivated individuals who can work well without immediate supervision. It is also prudent to eliminate those people who obviously place a high priority on the social relationships fostered in the office.
- Successful companies do not offer the telecommuting option as an employee benefit. This option is not a reward. The telecommuting option is simply another way of getting the job done.
- Lastly, successful telecommuting usually requires telecommuters to return to the office periodically. As a rule, most effective programs tend to require their telecommuters to return to the main or area office occasionally to "plug back into" the daily office routine.

Remote Conferencing

Remote conferencing refers to the use of IT to facilitate collaboration and communication between people in at least two geographic locations. There are many different technologies used today to allow remote conferencing for individuals and organizations. Some organizations use videoconferencing facilities. For example, the FedEx Office® workstation offers private conference rooms with remote-conferencing capabilities at more than 120 locations in the United States. In addition, teleconferencing offers another option for communication at a distance. Each year, more options are available for teleconferencing, as new and improved communications software is developed.

Videoconferencing

Videoconferencing was first introduced in the mid-1960s at the New York World's Fair. In the mid-1960s, AT&T unveiled its videophone that delivered voice and video over standard telephone lines. It took at least 20 years for corporations to make serious investments in videoconferencing technologies. The basic philosophy of videoconferencing has focused on moving electrons, rather than people. These information and communication technologies provide an alternative to face-to-face meetings and the frustrations of playing telephone tag. Advocates of this type of electronic meeting credit videoconferencing for reduced business-travel costs and much improved communications. It is estimated that a significant percentage of all business meetings requiring travel are intercompany conferences among people who already know each other. Electronic meetings can be scheduled and might eliminate the necessity of being physically together. Businesses that want to establish offshore subsidiaries might be able to enter foreign markets sooner by using videoconferencing to reduce the number of required trips to destinations around the globe. For instance, traveling to Argentina once a year, and then maintaining contact via bimonthly videoconferences, is considerably more manageable and less expensive than making multiple intercontinental trips.

VIDEOCONFERENCING

The ability to communicate visually using computer technology, television monitors, cameras, microphones, and special modems.

Concurrent engineering (CE) is another area that can benefit greatly from videoconferencing applications. CE (discussed in Chapter 6) calls for a refinement of the product design cycle. Basic stages, such as conceptualization, preliminary design, final design, manufacturing engineering, and assembly, are no longer completed independently of each other. They are executed concurrently among various work teams. Videoconferencing allows these often geographically dispersed groups to be virtually colocated. They are able to refine engineering drawings and argue interactively about key design aspects of a prototype without leaving their work sites. Technical issues can be worked out a lot quicker using videoconferencing than if a series of face-to-face meetings had to be arranged.

The potential applications of video-conferencing, using today's technology alone, are limitless. Universities and public schools are using videoconferencing technology to teach courses to students at distant locations. See **Figure 3-10.** Videoconferencing technologies that are becoming more affordable will undoubtedly influence the capacity for even more people to telecommute to work.



Figure 3-10.
The Education Service Center, Region VI in Huntsville, Texas hosts a virtual field trip with the Johnson Space Center of the National Aeronautics and Space Administration (NASA) as part of a staff-development training initiative for teachers. Elementary, intermediate, and middle school science teachers participated in an hour-long, two-way, interactive videoconference with NASA Learning Outpost staff and research assistants. This videoconference featured a customized tour of the *International Space Station* mockup. The left monitor shows Sherri Jurls, the tour guide, at the NASA remote site. The right monitor shows an audience of Region VI science teachers at the local site of Huntsville. (Sandy Goss, Science Education Specialist; Lynda Degeyter, Distance Learning Specialist of Education Service Center, Region VI in Huntsville, Texas)

Teleconferencing

Teleconferencing is the newest videoconferencing option found in LAN and desktop systems. Instead of telephone lines, these systems use PCs connected through a LAN or the Internet. Web teleconferencing uses the features of the WWW to allow two or more users to communicate instantaneously. The simple Web conferencing methods use IM and chat features to have text-based communication. Some companies supplement this with Web cams and streaming video. Companies can either host their meetings themselves by buying conferencing software or use a hosting service.

TELECONFERENCING
A videoconferencing option found in desktop systems connected to a network utilizing digital-video transmission.

This option has expanded the vision of educational institutions as well. Most large universities have offered traditional distance-education programs using videoconferencing, or similar technologies, for many years. Teleconferencing, however, has increased the possibilities for education at a distance. Both videoconferencing and teleconferencing are expanding at an ever-increasing rate. As they do, the line between these two technologies

seems to fade. If one uses a dedicated videoconferencing facility, but she also uses the Windows Meeting Space program, is this videoconferencing or teleconferencing? Whatever one calls it, it has the potential to dramatically change both education and the workplace.

Potential Effects of Remote Conferencing

Both videoconferencing and teleconferencing can be considered as forms of remote conferencing. The primary reason for utilizing these in the business environment is reduced cost through travel substitution. This claim generally attracts higher-level executives. The cost of moving people from place to place is escalating, as is the discomfort of the people being moved. Although some employees genuinely enjoy traveling, most find it very draining. Interestingly enough, remote conferencing has not yet proven to be a direct substitute for travel.

If remote conferencing is to be effective, it must be reviewed critically for what it is. This conferencing is a branch in the family of office-systems technologies. Remote conferencing should be viewed as a business-communications support system, rather than as a rigid replacement for face-to-face meetings. Not all organizations have the same potential for success using remote conferencing. This is not necessarily due to a lack of technical competency or even insufficient investment capital. Remote conferencing does not address a specific task or area of need within every corporate setting.

In order for the decision to implement remote conferencing into one's operational strategies to be made intelligently, several aspects of the technology should be evaluated. In other words, do the potential cost advantages outweigh the possible negative side effects that might develop over time? Take a moment to place yourself in the position of the CEO who is attempting to make this type of commitment to a new form of business communication. Consider the following potential cost advantages of remote conferencing:

- ❏ Reduced travel expenses.
- ❏ Reduction of unproductive time for people doing the traveling, as well as their inevitable travel fatigue.
- ❏ Reduced mistakes made, due to the fact that the critical person was not at the meeting as scheduled.
- ❏ Increased interaction between project teams working in different locations.
- ❏ Shortening of the normal business cycle and facilitation of more efficient decision making.
- ❏ Reduced equipment downtime when the most skillful repair person is at another site.
- ❏ Reduction in the effects of unforeseen interruptions due to weather, fuel shortages, or political upheavals.

On the other hand, consider the following potential negative effects of remote conferencing:

- ❏ Increase in the amount of unproductive time spent in easily arranged, but unnecessary, meetings.
- ❏ Decreased freedom of operation for the remote field sites due to an excessive amount of managerial control.
- ❏ Lower employee morale because of decreased personal contact.
- ❏ People encouraged to become overspecialized and narrow-minded.
- ❏ Fostering of an overdependence on technology that could easily fail as a result of equipment limitations or sabotage.
- ❏ Difficulty of using teleconferencing for complicated meetings, such as negotiations.

No decision regarding technology comes with a menu of guaranteed outcomes. Remote conferencing is a set of technologies that can bring many benefits to the economy as a whole and can potentially serve the political sector as well.

Electronic Privacy

The concept of privacy is quickly changing with the increasing prevalence of electronic communication in today's society. Personal interactions once were between only the individuals directly involved. Technology has made it much easier for information to travel to outsiders. Personal rights to privacy have been questioned. Privacy in the workplace has almost become extinct. Considering the ease of gathering "private" information on the Internet, it is not surprising that many legal and ethical issues have come along with the rise of telecommunications.

Personal Privacy on the Internet

Years ago, in small towns across the nation, community residents made it their business to be in tune with what everyone else was up to. Although this meddling came to be expected as a way of life, it existed long before we entered the so-called *information age.* People did not concern themselves too much with their individual rights to privacy. More often than not, they simply accepted the fact that, sooner or later, their neighbors would be wise to their daily activities, as well as their deepest family secrets. With our current electronic record-keeping systems and numerous communications networks in operation, people today have a lot more to worry about than busybodies in their neighborhoods.

Many of the technological developments reviewed in this chapter have a direct effect on the extent to which personal information is considered public or private. Just consider that an innocent trip to the grocery store allows bar code scanners to create a permanent record of your product preferences. Advancements in e-mail, digital telephony, remote conferencing, biometric ID databases, and other forms of computer-to-computer communications have raised serious questions about the protection of privacy. The exponential growth in the collection, storage, and communication of personal data seems to have been accompanied by an increased potential for abuse and misuse. Satellite technology has introduced an international dimension into the dilemma. See **Figure 3-11.** Personal information can be indiscriminately exchanged back and forth around the globe.

In the mid-1970s, the U.S. Congress passed the Privacy Act, to address the tension between individuals' interest in their personal information and the federal government's collection and use of that information. Privacy is a value that has always been regarded as fundamental in America. This value's meaning, however, has remained obscure. The definition serving as the basis for this legislation read something similar to this: Privacy is the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about themselves is communicated to others.

Numerous case studies and popular editorials have been published on the topic of personal privacy. Others address the issue of legislation, or the lack of it, designed to protect our individual rights to privacy. For the most part, these writings are generously sprinkled with horror stories of people who have been refused credit, insurance, employment, or welfare assistance. What

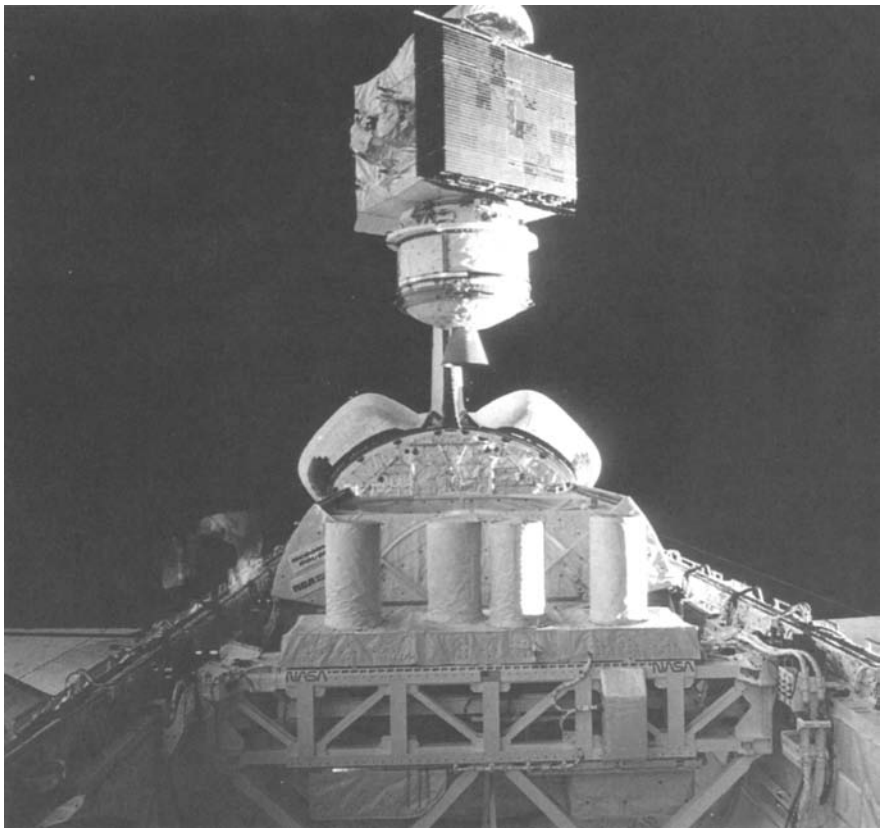


Figure 3-11.
A communication satellite being placed into orbit from a space shuttle. The use of orbiting satellites allows electronic communication to circle the globe with potentially negative impacts on personal privacy. (NASA)

makes these personal accounts horrifying is the fact that the actions taken were usually predicated on incorrect, outdated, or deliberately manipulated data. In addition to inaccurate data, there is more risk about data being stolen. Hackers have become increasingly bold and destructive. Recently, a hacker was able to breach the security of a company that processes credit card transactions. Over 2 million Visa® and MasterCard cards were compromised. Overall, ***cybercrime*** is on the increase in the United States. The Federal Bureau of Investigation (FBI) estimates that cybercrime costs U.S. businesses over $10 billion each year.

Privacy continues to be a significant and enduring value held by the American public. It is apparent through a review of several opinion polls and numerous casual interviews that many people believe computer electronics and communications technologies exemplify pervasive threats to their individual privacy. General concern regarding the lack of adequate safeguards to protect personal records has grown over the past several years. A large percentage of citizens perceive the need for new and revised laws to govern how organizations that possess the computer files can use personal information records. The legal system is presently lagging too far behind the technological capabilities related to this issue. Simply stated, there is increasing public support for additional government action to protect privacy in this country.

Personal information in the private sector can be collected, stored, and transmitted with very few governmental restrictions. Key areas of information acquired include consumer credit, banking, insurance, employment, medical care, and education. Now, because most grocery stores and gasoline stations allow their customers to use their bank cards to make purchases, this list will undoubtedly expand to include our eating habits and automobile usage as well.

Business e-commerce sites are collecting more data from visitors. Researchers have estimated that more than 80% of dot-com sites collect at least one piece of identifying information (for example, name or e-mail address) and at least 50% collect demographic information (such as gender, preferences, or zip code). All this data being collected can be used to identify and target WWW users.

Computer blacklists have also become a burgeoning growth industry in the field of IT. They represent another electronic assault on individual privacy. For example, Experian Inc., TransUnion Inc., and Equifax Inc. have long relied on huge banks of mainframe computers to conduct their businesses. These credit bureaus provide consumer credit records for banks, department stores, finance companies, and employers. On an average working day, credit-bureau machines process hundreds of thousands of requests for information, culling through a massive database containing detailed records of the payment habits of hundreds of millions of people.

Contemporary ethical and legal controversies on the Internet are causing users around the world to ponder many things. Some of these things are the definition of appropriate content, freedom of electronic information, software piracy, thefts of trade secrets, and policing or censorship of communications. The social norms and etiquette of CMC are still being defined and refined.

Biometrics

Biometrics is the use of body characteristics, such as fingerprints or eye scans, to verify a person's identity. Many consumer electronic products now include biometrics, usually fingerprint readers, as security controls on their products. Despite being available for a decade, the use of biometrics has increased because of increasing security concerns. Biometric scanning is being used at over 15 airports in the United States, mostly by business travelers who want to pass the security check quicker. Customers pay around $100 each year to Clear, a company that manages the biometric system. Potential users submit an application with biographic information. They then visit an enrollment location. At this location, they are photographed. Two biometric measures (fingerprints and an iris scan) are taken. After the U.S. Department of Homeland Security reviews these users' applications, the users can access the Clear® lane at the airport.

A more extensive biometrics system is being used in Australian airports. SmartGate is a biometrics-based border-control system being used in selected airports. This system works with a digital passport. When an Australian or NZ traveler approaches the SmartGate, the SmartGate kiosk compares the traveler with the digital photo of the traveler imbedded in the ePassport. If the two pictures match, SmartGate confirms the person is authentic. If the two pictures do not match, the traveler is sent to a Customs Officer. After a three-year trial, Australia Customs started using the SmartGate kiosk at the Brisbane Airport in 2007. See **Figure 3-12.**

Research by the National Institute of Standards shows that automatic recognition of faces has improved tenfold since 2002. The FBI is already compiling a biometrics database of palm prints, fingerprints, and face scans to help it solve crimes. As face-recognition



Figure 3-12.
SmartGate uses face-recognition software to perform customs and immigration checks. This technology has been implemented in Australia and NZ airports. (SmartGate Communications)

software continues to evolve, it will be possible to search for faces in crowds. There are privacy concerns with the widespread use of biometrics in public areas. People using the Clear system in the United States and SmartGate in Australia choose to have their biometric data collected. What about the people who do not choose? How is an individual's privacy protected when face scanning is used in a public place? As future technologies are developed, there is no doubt other issues will emerge.

Electronic Monitoring of the Workplace

Along a similar vein, organizations whose members or employees have access to e-mail accounts are in the throes of establishing rules and norms to guide the use of this technology. Today's massive population of e-mail advocates who expect privacy might risk embarrassment, loss of employment, lawsuits, or worse. For many, the physical act of typing in a personal password seems to reinforce the notion that e-mail missives are private. Further, the interface design of the e-mail systems often gives the illusion no one is watching. Three forms of policy seem to prevail in contemporary organizations regarding the use of e-mail:

- **Right-to-monitor policies.** The organization publishes a statement saying all e-mail messages are monitored since e-mail is a company resource and provided as a business-communications link.
- **Hands-off policies.** The organization publishes a statement saying e-mail messages are not accessed. Although these policies support privacy, they cannot legally guarantee it.
- **No policy.** The organization does not publish a statement. This is the situation in some organizations today. If there are no formal or explicit policies regarding management's access to e-mail, employees generally behave as if e-mail is a private communications medium. In the future, having no e-mail policy is likely to create more legal and ethical problems than even having a bad one might. Whatever employees believe, without a set policy, companies have the right to monitor and open e-mail.

Beyond e-mail, there is the issue of the WWW. As more employees are linked via the Internet, they can use the Internet for non-job-related activities. This is a growing concern among businesses. Surveys from various monitoring agencies have revealed that approximately 25% of WWW use at work is not job related. For companies, this represents a dramatic reduction in the working hours of their employees. Nonwork sites most commonly visited are general news, sex, investments, entertainment, and sports. Companies have responded to this trend by increasing the monitoring of their employees. According to a major survey by the American Management Association, over 75% of large and midsized companies admitted they monitor their employees electronically. In addition, 65% use software to block access to inappropriate Web sites.

Electronic monitoring is not only the province of companies. Any user can add software to his computer to monitor WWW use. This type of software is generally referred to as *snoopware.* There are many different types of snoopware available, some designed for businesses and some for home users. There is snoopware that takes screen shots of a user's activities, logs every keystroke, and can intercept "private" passwords. One such program is Spector Pro® software. This program collects detailed records of all activity on an employee's computer or a PC—the programs used, the e-mail sent, chats, what the user does on

social-networking sites such as the MySpace and Facebook services, and the Web sites visited. The software then puts the data into a database. The manager or parent can assess this data to see what the users were doing on their computers.

One technique to limit electronic surveillance is encryption. A user can electronically alter her e-mail so only the designated user can read it. Encryption works by dividing the e-mail message into sections and using a private key to convert the e-mail into gibberish. After delivery, the message must be decrypted with the same key. The most widely used encryption standard today is the Pretty Good Privacy® (PGP) computer program. Phil Zimmermann originally wrote the PGP computer program in the early 1990s. PGP computer programs are the standard for e-mail encryption today and have millions of users across the world.

Despite the millions of e-mail users, most people who e-mail do not use encryption. Many do not even know about it. Until there is more awareness of snoopware among users, encryption will remain a small part of the e-mail process.

Summary

It was unusual to own a home computer 25 years ago. Today, most households in the United States have their own home computers, as well as an array of other digital devices. As ITs invade more everyday appliances, one can see a future in which all home appliances are linked in a vast network. The purely digital home is still in the future. Portions are here, however, today.

ITs are changing the faces of business and government and even our personal outward appearances. In many places, we are known by our electronic personas, rather than by our own faces. As governments increasingly depend on electronic communication to govern, will our electronic personas begin to dominate us and define us to the world?

Technology has changed the face of communications in our society. Telecommunications breakthroughs have transformed our views of each other and the international community as a whole. Direct-broadcast satellites enable us to be on the scenes of entertainment activities, as well as terrorist uprisings, instantly. All-optical and wireless networks hold many promises yet to be realized, with reference to the quantity and types of information we can transmit anywhere through the telephone system, computer networks, and airwaves. At the same time, the electronic devices that are becoming more prevalent are putting us more in touch with our jobs—perhaps, too much in touch. In many ways, technologies such as cell phones and PDAs act as digital leashes that make it easier for our work life to spill over into our home life.

If we truly live in an age of information saturation, perhaps the technologies associated with information transfer have converged to help us. As the amount of information available to the general public has expanded, advancements in electronic record storage and retrieval have followed. Rather than be fearful of our inability to keep up with the rampant pace of change in the telecommunications industry, we should systematically accept these developments for what they are. These developments are a series of mechanisms and devices allowing us to interact with one another within a vast array of CMC environments.

There are several social issues related to the technological hardware associated with communications networks. Videoconferencing is quickly rising as a corporate-business communications strategy. Thousands more workers might soon be given a telecommuting option to complete their job-related assignments. Finally, individual citizens have begun to

express their concerns regarding the extent to which new legislation might be essential to mediate the impact of technology on the privacy of personal information. The degree to which these issues will be resolved or widely adopted in the near future remains tentative.

Discussion Questions

1. Identify and describe at least two forms of CMC. Explain how each of these might enhance your capacity to perform your academic or employment duties more efficiently.
2. Briefly explain the concept of VR. Conjecture as to how this technology might one day figure prominently in your daily routine.
3. Besides the examples listed in this chapter, can you think of any other advantages or drawbacks to the practice of telecommuting in our society?
4. What are some of the immediate applications and advantages of remote conferencing in the corporate world? Is there a downside to this IT?
5. Describe some of the problems you might expect to encounter if you suddenly found out that your employer read your "private" e-mail correspondence to a friend in Australia.

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Chapter 4

Space Exploration

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DATELINE

Baikonur, Kazakhstan

A Russian government commission approved the inclusion of the first extraterrestrial tourist today. American millionaire Dennis Tito became the first tourist to visit the *International Space Station,* arriving as a guest of the Russian space agency on a *Soyuz* spacecraft. Mr. Tito paid $20 million to the cash-strapped Russian space program. Also, he signed an agreement to pay for anything he breaks, and if he is hurt, neither he nor his heirs can sue for compensation.

The other partners of the *International Space Station,* particularly NASA, were very unhappy about this turn of events, but they realized there was little they could do to stop their Russian partners from bringing along a guest. NASA decided to make the most of it and have the resident astronauts at the space station spend their time baby-sitting the visiting California millionaire. Tito's first words as he arrived at the *International Space Station* were "I love space!" The Russian space agency is planning more tourist flights in the future.…

Introduction

When it comes to discussions about space exploration, many historians and political scientists seem to share a common sentiment. They tend to concur that no scientific venture has captured the fancy and emotional support of the American people as the space program has. In the mid-1980s, it quickly became apparent that the 25th mission of this nation's reusable spacecraft, the shuttle (technically called *America's Space Transportation System),* had attracted international attention. While its previous missions were devoted to sophisticated scientific research projects, this spacecraft was supposed to carry the first private citizen, a schoolteacher, into orbit. When the shuttle *Challenger* burst into flames less than two minutes after its liftoff, people around the world were forced to grasp the intensity of an unexpected tragedy. Stunned into silence, it is likely that many lost all faith in technology—even if just momentarily.

Following the crash, NASA was called on to rethink its long-range goals, with regard to national space policy. In the wake of a disaster of this magnitude, there are never any easy choices or decisions to make. Some observers initially felt the shuttle accident would bring an end to manned spaceflights for many years to come. In comparison with previous setbacks in the U.S. space race, such as *Apollo 13,* the shuttle in which one of the oxygen tanks caught on fire during flight, the *Challenger* accident caused a shift in the public's perception of spaceflight, particularly in the safety of these flights. The loss of a second shuttle, *Columbia,* in 2003, amplified the concerns about the technologies and safety in the space program. NASA itself was faced with a more critical analysis of its missions and procedures, from both the U.S. Congress and the general public. Until this loss, this country's space community had been obsessed with expensive programs that had not been dedicated to meeting any clearly defined long-term goals. As you will see in

this chapter, the public and Congress forced NASA to revise its procedures and approach its work in a different way, including finding international partners to meet the challenges of new demands.

Five decades ago, it appeared that humankind had finally begun its conquest of outer space. The events of the early years brought to life scenarios that had previously been the material of science fiction writers. The 1950s and '60s introduced many feats in space travel: the first artificial satellite, the first human in space, the first planetary probe, the first space walk, and the first human on the Moon. It seemed almost certain that the remaining decades of the twentieth century would unveil the development of space stations and space colonies, trips to the planets, and perhaps even vacations in space. At least one forward-thinking individual envisioned building the first Hilton® hotel in space. Unfortunately, as we proceed further into the twenty-first century, few, if any, of these dreams appear to be forthcoming.

Added to the space challenges for the United States is the increased internationalization of space, with over 40 countries already having satellites orbiting Earth. The biggest international project, the *International Space Station,* includes the scientific expertise and participation of 16 nations: the United States, Canada, Japan, Russia, Brazil, and the 11 nations that are members of the European Space Agency (ESA). Space exploration has grown beyond the cold war scenario of the United States versus the Soviet Union. How different countries will balance their own interests against international concerns has not yet been determined. In this chapter, we will examine a variety of technical, socioeconomic, and political concepts that presently characterize space ventures being envisioned around the world.

The National Aeronautics and Space Act of the late 1950s did not establish an aerospace trucking company. Primarily, it did set up an R&D agency. If NASA continues to place numerous scientific projects on hold, it might be forced to redefine its primary responsibility to the American public. Is it plausible for NASA to continue promoting its politically favored flagship programs, such as the shuttle and the *International Space Station,* while it also conducts a vigorous unmanned program in applied technologies, exploration, and science? Before anyone can honestly attempt to respond to this inquiry, it is essential to determine first what we wish to accomplish in space and then identify the means through which these goals can be best attained. This chapter provides a foundation for a continuing dialogue that can ultimately respond to the following questions:

- In light of the history of the space shuttle, what should contemporary space transportation systems realistically be designed to accomplish?
- The persistent challenges to colonize and industrialize space have become international in scope. What interest, if any, do national defense departments have in space-development projects?
- What are the primary technological objectives of the American satellite industry? What contributions has this industry made toward the social and scientific advancements of society?
- What concerns have been expressed about prolonged periods of time spent living and working in space?
- Are there any specific long-range goals that should define international space policies? Would these goals ensure future support?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

aerobraking
artificial satellite
bioastronautics
Deep Space Network (DSN)
faster, better, cheaper (FBC)
geostationary orbit
geosynchronous orbit
glass cockpit
Global Positioning System (GPS)
gyroscope
International Space Station
Skylab
space adaptation syndrome
space junk
spectrograph
spectrometer

The Conquest of Outer Space

Outer space, for decades, has been emotionally regarded and applauded as the final frontier. Space's romance is almost blinding at times. Although the risks were always there and the failures of man-made spacecraft were statistically inevitable, we continued to press on with an ever-increasing ration of the pioneer spirit. The ability of mankind to conquer and industrialize outer space within our lifetime seemed inevitable. Why? One of the more prominent features of the earliest days of the space age during the late 1950s was the intense competition between the Soviet Union and the United States. In the mid-1950s, the Soviets, who successfully launched the first ***artificial satellite,*** *Sputnik 1,* into orbit, stunned people around the world. American scholars hung their heads and questioned the credibility of our educational system, the scientific community, and our technological leadership. The United States subsequently embarked on an accelerated scientific journey, containing a series of technological obstacles, in order to overtake the Soviets. Along the way, public support of the emergent space program was born out of patriotism, coupled with blind faith in new and exciting forms of technology.

In the early 1960s, the Soviets were once again victorious, after they sent the first human, Yuri Gagarin, into space. The United States followed a few months later, when Alan Shepard became the first American to be launched into outer space in the Mercury Project. Project Mercury arose directly as a U.S. response to the launching of *Sputnik* by the Soviet Union. This project made 6 unmanned flights around Earth in the early 1960s and provided NASA with valuable experience in how to recover both man and spacecraft safely. The Mercury Project led to the Gemini Project, which was seen as a necessary intermediate step before the *Apollo* flights to the Moon. The goals of the Gemini Project, which included 12 flights, were to support two men in space for long-duration flights up to two weeks and to practice rendezvous and docking with other vehicles in space.

Despite the successes of the Mercury and Gemini Projects, the Soviets were still ahead of the United States in most areas of space technology. Feeling frustrated and perhaps embarrassed, the Kennedy administration challenged NASA to land a man on the Moon before the close of the decade. The Apollo Moon Program was inaugurated and ultimately captured the hearts and minds of American men, women, and children throughout the 1960s. This program clearly represented a bid for national prestige and a demonstration of technological savvy.

The race between the United States and the Soviet Union wore on in the early 1960s, as NASA forged through its Mercury, Gemini, and Apollo Programs. Throughout this series of missions, astronauts were commonly viewed as our heroes. The pressure of the space race forced us to underwrite the tremendous expense of each spacecraft launch. Congress approved each request NASA submitted, culminating with a tremendous victory just five months before the close of the decade. Millions of viewers around the world were glued to their televisions screens, as the *Apollo 11* mission created another significant entry for our historical journals. Astronauts Neil Armstrong and Buzz Aldrin became the first men to take a walk on the Moon—the United States had won the race.

The thrill of victory, however, was short-lived. Congress grew tired of financing adventures that had, at least on the surface, the same plot each time. Government officials called for more scientific fieldwork and fewer flashy stunts performed by our nation's finest men. The problems of *Apollo 13* added to the public's uncertainty with the program, although before the mission was aborted because of an explosion onboard, the public barely noticed *Apollo 13.* Also, NASA tended to downplay the problems it had with *Apollo 13,* so the public was never really fully informed about the dangers that existed for the crew. One example of the type of behavior that, unfortunately, did receive national media coverage, much to NASA's chagrin, involved the 1971 lunar mission of *Apollo 14.* The major "scientific experiments" included Alan Shepard driving a golf ball and Edgar Mitchell attempting to send telepathic messages to fellow parapsychologists on Earth. Although Shepard did make the longest drive in the history of golf (thanks to the Moon's gravity), congressional expectations were far from satisfied.

The United States finished its abbreviated series of *Apollo* lunar landings one year later with a geologist onboard *Apollo 17.* By this time, the American public had become somewhat disinterested and was trying to envision what America's next space triumph would be. On the flip side, the nation's leaders were not in any sort of agreement on what the next step should be for the space program. The magnificent success of the Apollo Program was partially related to the fact that its goal was precise and short-term: send a man to the Moon and return him safely to Earth. We developed and refined the technology to accomplish that goal, and then we stopped. Less than 15 years after NASA had been formally inaugurated in the United States, its very existence was in a state of jeopardy. The follow-up Apollo Applications Program was cancelled due to insufficient funding, and NASA did not have a long-range goal that could sustain the country's space program. NASA was in a bind—it needed to find new projects that would allow it to survive into the next millennium.

Space Technology of the Present

Although most public and press attention centers on the shuttle, the shuttle is not the only space technology today. The scientific value of space exploration is expanding more through other lesser-known missions, including the *Hubble* telescope and the *Chandra* observatory, an orbiting X-ray telescope. Also, ESA has funded major space missions during the last 20 years, including *Ulysses,* a spacecraft studying the solar wind blowing from the Sun, and the *X-ray Multi-Mirror Mission–Newton (XMM-Newton)* space observatory, a space telescope using a

series of nested, curved mirrors to collect X-ray information about the galaxy, although the American public barely notices these non-American missions. It is clear from the work of ESA, as well as of other entities, including the Russian and Japanese space agencies, that the pursuit of space in the future will have a more international flavor.

A unique exploration ESA is sponsoring is the Cluster Program. Today, there are four *Cluster* spacecraft, carrying the same 11 instruments, zipping around Earth, collecting data. The goal of the Cluster Program is to study space weather inside and outside of Earth's magnetic field. The four *Cluster* spacecraft, named *Rumba, Tango, Salsa,* and *Samba,* are taking simultaneous measurements of the space around Earth. The orbits of these four are designed so each one is located at a vertex, or an endpoint, of a tetrahedron. Using the data from these four spacecraft, scientists will create the first detailed three-dimensional model of Earth's magnetic shield. Two additional satellites, called *Double Star,* designed and operated by the Chinese space agency, have supplemented the *Cluster* spacecraft. The six satellites take coordinated observations.

Despite the Cluster Program and the many other space missions, the shuttle is the one space technology capturing the imagination of the American public today. Perhaps it is the image of traveling to space as a passenger on a spaceship. Also, since the shuttle has a mixed crew (civilian and military), the public can feel invested in the astronautical missions. As NASA has changed the gender and racial makeup of its crews, these new astronauts are more appealing to the American public. In the early 1980s, the first American woman in space, Sally Ride, even had her own slogan, "Ride, Sally Ride."

The Saga of the Space Shuttle

The idea of the shuttle evolved at the end of the Apollo Program era, when NASA was looking for another project to continue the exploration of space. Under a certain amount of political and economic pressure, NASA officials decided to replay the Apollo Program technique. They contemplated the need for a costly, long-term project that would appeal to the hearts of the American people and, therefore, their congressional decision makers. NASA had previously initiated the idea of developing a reusable spacecraft, after its first lunar landing, when the nation was extremely concerned about numerous environmental issues. The central premise was it could save millions of wasted dollars by reusing the launcher's components (the boosters, the fuel tanks, and the orbiter itself). NASA believed a vehicle of this configuration would assure its survival, since it would take many years and a large sum of money to develop, construct, and deploy. Out of this proposal emerged the Space Shuttle Program.

From its inception, the Space Shuttle Program was forced to operate under a fair amount of pressure. NASA's initial proposal to develop a reusable space shuttle for routine transportation into space was predicated on two main opinions:

- ❏ Humanity belongs in space.
- ❏ A permanent space station was the next logical step to putting the species out there on a long-term basis.

NASA further promoted the concept by saying the shuttle would service and restaff the ***International Space Station.*** Payload costs onboard the shuttle had to be kept low enough to make this type of activity affordable.

INTERNATIONAL SPACE STATION
An orbiting space station that serves as an international laboratory for research.

NASA placed itself squarely behind the Space Shuttle Program and proceeded to gain the support of numerous federal agencies. Specifically, it fought hard to attain the support of the DOD, in order to assure White House approval. In doing so, NASA agreed to incorporate a number of military specifications into the shuttle design. For instance, the Air Force requested a huge payload bay measuring 15′ × 60′; 60,000 pounds of lift capacity; and the ability to land on either the East or the West coast of the United States. Early in the project, military officials were mainly interested in launching large reconnaissance satellites. Even still, they also stipulated that the spacecraft should be able to return quickly from orbit and maneuver easily under threatening conditions. As you can well imagine, NASA immediately said farewell to any hopes it might have had for low developmental costs. NASA placed all its space eggs in one basket and promised Congress that a fleet of five orbiters would be operational by the end of the 1970s. NASA's original cost estimate ranged between $5 billion and $6 billion.

Following its approval by the Nixon administration, the Space Shuttle Program got off the ground when Rockwell International won the design contract in the early 1970s. Construction began two years later. Delays were encountered repeatedly along the way, due to inadequate funding and continual problems with the main engines and heat shield tiles. Realizing the Space Shuttle Program had severely overrun its budget, NASA made several decisions to scrap a variety of valuable research programs already in operation. One of the most memorable of these abandoned projects was *Skylab*. See **Figure 4-1.**

Skylab was a preliminary version of a U.S. space station that had evolved during the era of the Apollo Program. NASA launched this huge orbiting space laboratory in the early 1970s. In less than one year, three crews of astronauts visited *Skylab* and respectively spent one month, two months, and 84 days living and working inside the space station. During these visits, Western scientists were finally given an opportunity to make an exhaustive study of the physiological effects of prolonged spaceflight. NASA's decision to abort the Skylab Project resulted in the project's eventual demise. One of the first proposed tasks of the new shuttle vehicle was to visit *Skylab* and keep it functioning, but the shuttle was not ready in time, so *Skylab* burned in the atmosphere in the late 1970s. Noting the irony of the fact that we no longer had a space station of some sort in orbit, some observers began to question the validity of the Space Shuttle Program.

Plagued by a series of engine fires, the shuttle schedule was modified and set back on a regular basis during the late 1970s. No one had built throttled liquid rockets of this size before. The problems of pressurizing, heating, and containing the explosive fuel were (and still are) quite formidable. Leaks, fires, and turbo-pump failures occurred over and over again. From the original target launch date in the late 1970s, the shuttle slipped almost three years behind schedule, and *Columbia* was finally launched for the first time in the early 1980s. Many of the technological bugs had not been worked out, and the heat shield tiles had not been flight-tested to ensure the safe return of the astronauts. The cost of the project had approached the $11 billion mark by that point—double NASA's initial projections.

The space shuttle has three main parts: the orbiter, which holds the crew and supplies; a large external fuel tank, which holds the fuel for the main engines; and two solid rocket boosters, which provide the fuel for the shuttle's liftoff and first two minutes of flight. See **Figure 4-2.** The external fuel

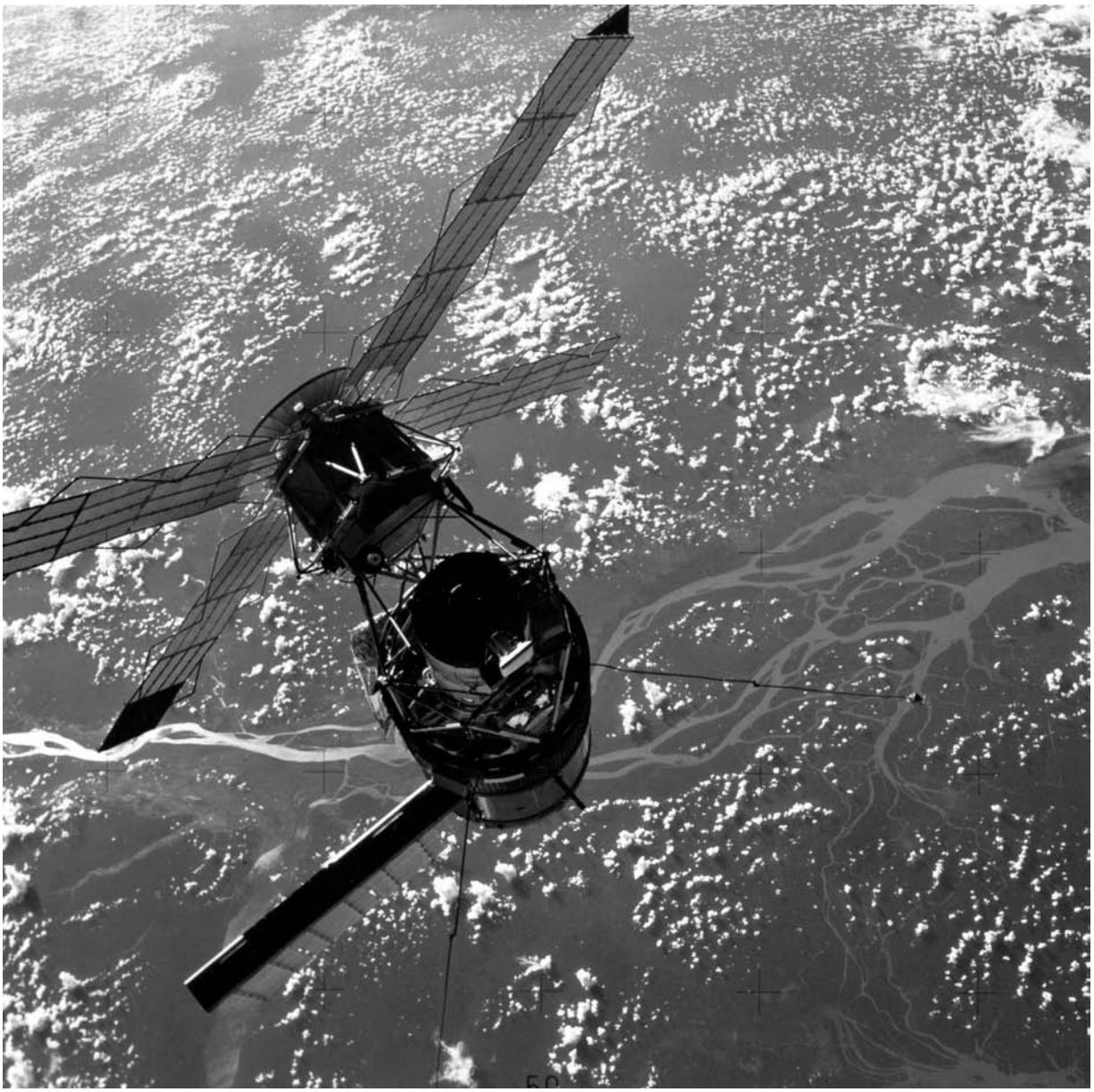


Figure 4-1.
Skylab flew over the Amazon River delta during the *Skylab 3* mission. (NASA)

tank is burned in the atmosphere after launch, but the other parts are reused. The solid rocket boosters detach after the first two minutes of flight and fall to Earth, while the orbiter (or as it is usually called, the *shuttle*) returns to the ground and lands similarly to an airplane. Currently, there are three U.S. space shuttles in operation: *Discovery, Atlantis,* and *Endeavor.* Each of them is designed to fly at least 100 missions.

Prior to the *Challenger* disaster in the mid-1980s, NASA successfully executed



Figure 4-2.
The liftoff of space shuttle *Atlantis* began an 11-day mission to the *International Space Station* in 2000. While onboard, the seven-member crew performed support tasks, transferred supplies, and prepared the living quarters in the newly arrived Russian *Zvezda* service module. (NASA)

24 shuttle flights over a four-and-a-half year period. By far, 1985 was the best year for the program, with three shuttle orbiters in operation and 9 successful flights. As impressive as this might sound, NASA's original projections during congressional hearings in the early 1970s indicated that each orbiter would be launched once each month after the program had gotten underway. In other words, NASA optimistically envisioned some 60 flights per year! An accurate history of the Space Shuttle Program is given in **Figure 4-3,** which shows the number of shuttle flights per year since the early 1980s. It is interesting to compare this history with NASA's original projection. Using NASA's original plan, the number of 101 total shuttle missions should have been reached in only two years.

Even before the 25th mission of the Space Shuttle Program ended in a fatal explosion, experts had begun to question the economic viability of the star player in this country's space program. The questions began anew with the explosion and loss of the shuttle *Columbia* during reentry into Earth's atmosphere in 2003. A piece of foam insulating the wing broke off. This allowed

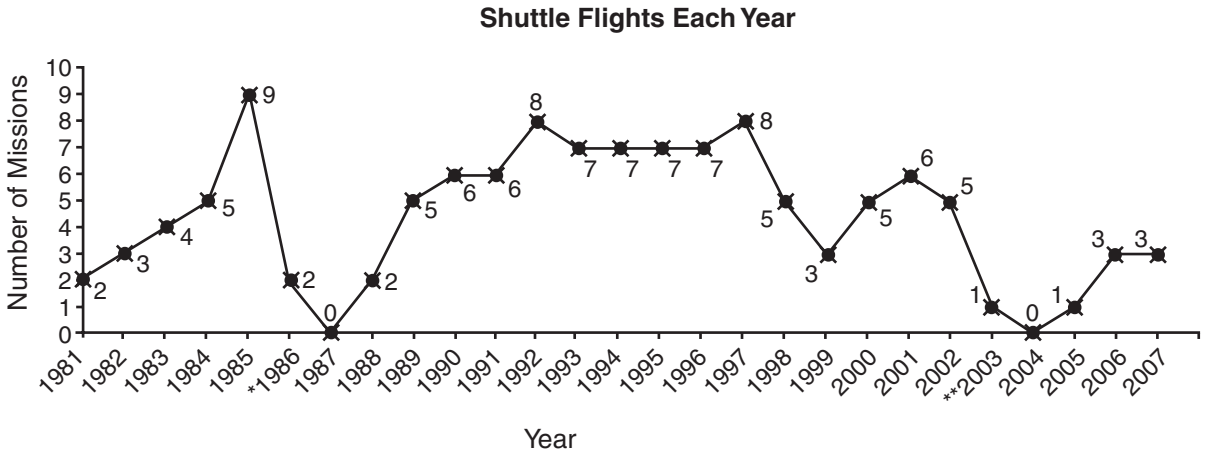


Figure 4-3.
The number of shuttle flights each year from 1981 to 2007.
*1986 was the year of the *Challenger* disaster. There were no shuttle flights in 1987.
**2003 was the year of the *Columbia* disaster. There were no shuttle flights in 2004.

superhot air to breach the protective covering of the spacecraft and cause the aluminum in the left wing to melt. The accident was not, however, caused by only technical flaws in the spacecraft. The accident review board found that NASA's organizational structure was also to blame—in order to maintain the shuttle's schedule, NASA engineers, scientists, and administrators tended to overlook potential problems.

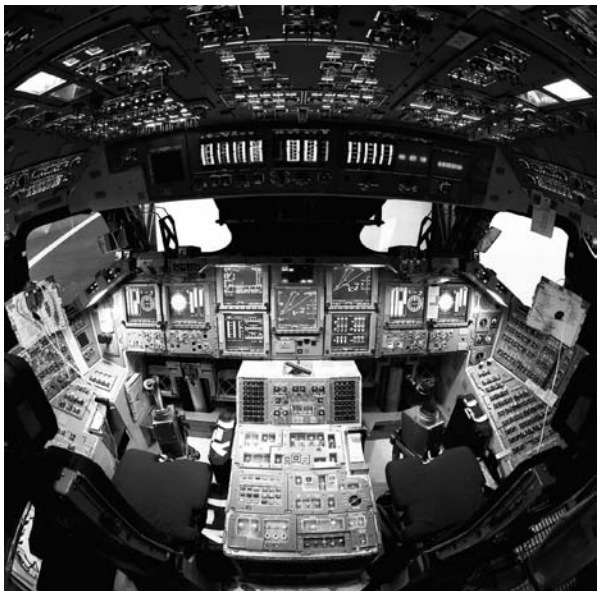
After the loss of the second shuttle, there were many who wondered if the space shuttle would ever fly again. NASA spent over $1.5 billion retrofitting the remaining shuttles before being cleared to fly again in 2005. When the shuttle *Discovery* launched in 2005, NASA was optimistic. Photos the *International Space Station* took, however, showed damage to the shuttle's protective tiles. Luckily, *Discovery* made it back to Earth safely. The Space Shuttle Program was again stopped, however, for safety reasons.

Costs per pound of payload for the shuttle's operation were 20 to 50 times greater than NASA's initial projections. NASA's budget for the Space Shuttle Program alone in 2007 was over $4 billion. This budget, since there were only three missions, results in an average cost of over $1 billion for each mission. One of the main reasons for these very high operational costs for the shuttle stems from the shuttle's most significant design feature—the shuttle must be operated with human beings onboard. The life-support systems and safety features necessary to make a spacecraft safe for human passengers weigh a lot. Also, there are other costs, including safety and performance upgrades; ground operations before, during, and after the flight; and flight hardware (such as engines and external fuel tanks). These costs could be justified if scientific experiments or manufacturing procedures requiring human input were the primary purpose of the shuttle. Over the last 20 years, however, the shuttle has been used mostly to deploy unmanned satellites and provide supplies and parts to the *International Space Station* (discussed further later in this chapter).

The shuttle is the most complex machine ever built, having more than 2.5 million parts and weighing 4.5 million pounds at



The Old Cockpit



The Glass Cockpit

Figure 4-4.
These photos compare the old cockpit and the new glass cockpit. The crew of the first space shuttle, Commander John Young and pilot Bob Crippen, are shown aboard *Columbia* before the first shuttle launch. The old cockpit featured green screens and gauges. The fish-eye view on the right illustrates NASA's glass cockpit. This is the fixed-base space-shuttle mission simulator in the Johnson Space Center's Mission Simulation and Training Facility. (NASA)

launch. This complexity keeps the shuttle expensive, despite the shuttle's reuse. To add to this complexity, the design of the shuttle has constantly changed over the last 30 years to increase both its efficiency and safety. Since the early 1980s, the shuttle's engines have been overhauled four times. Imagine redesigning and replacing the engine of your car four times during your ownership! The cockpit has dramatically changed. Now the pilots have a ***glass cockpit.*** The new improved glass cockpit was first used in the shuttle *Atlantis* in 2000. The design of the glass cockpit replaced 32 gauges and electromechanical displays and four cathode-ray tube (CRT) displays with 11 new full-color, flat-panel display screens. See **Figure 4-4.** These changes allowed the space shuttle to use cockpit displays that have become common in many new commercial aircraft, and this new cockpit has an added benefit. This cockpit is 75 pounds lighter and less power hungry than before.

The shuttle has found a new purpose and justification with the building of the *International Space Station.* Construction and installation of the various components occupy most of the shuttle's time. Four of the five missions scheduled for 2008 related to construction projects for the *International Space Station.* Right now, the shuttle is scheduled to be decommissioned in 2010. What new vehicle will NASA develop after the end of the Space Shuttle Program? Will the United States continue to dominant space, or will other countries take a more active role? At this point, no one can accurately foresee what will happen when the three remaining shuttles are retired in 2010.

The *Mir* Space Station

Mir is the last in a long history of Russian (formerly, the Soviet Union) space stations. While the U.S. space program focused its energies on the Space Shuttle Program and held its sights firmly on the construction of a permanently manned space station, Russia made steady strides toward extending its civilization into space. The first space station launched in the early 1970s. *Salyut 1*—about the size of a mobile home—had a checkered history as a space station. The first crew, sent on *Soyuz 10* to occupy *Salyut 1,* was unable to enter the station because of a problem with the docking mechanism. The second crew, sent on *Soyuz 11,* lived on the station for three weeks, but the crew members died during their return to Earth because of a malfunction in their spacecraft. Over a 10-year period, the Russians launched a total of nine space stations and supported five crews successfully.

One of the most important achievements of the Salyut Program was that it proved astronauts could successfully live in space longer than expected, and it was long-term space exploration, which was the goal of the second generation of Russian space stations. Through the mid-1980s, 75% of all manned experience in space belonged to the Soviet Union. The Soviet Union's cosmonauts worked onboard their space stations for more than eight months at a time, with the longest stay being 237 days. Compare this to the longest American space mission onboard the *Skylab* of less than three months. *Salyut 6* and *Salyut 7* were active from the mid-1970s to the mid-1980s and together were visited by 26 different crews, including 12 long-duration crews. These cosmonauts routinely performed in-orbit repairs and tested several furnaces for producing specialized materials. Smaller docking craft called *progress service modules* resupplied the station on a regular basis.

The Soviet Union boosted its successor to these space stations, known as *Mir* (peace), into a low earth orbit (LEO) in the mid-1980s. *Mir* was actually many spacecrafts in one, and it was expanded over the years into a complex of many parts. This spacecraft was more than 108' long, when both the *Soyuz* spacecraft and progress service module were attached, and about 90' wide at its largest point. The central *Mir* module was designed as the living quarters and included six docking ports. Over time, six more modules were added to the *Mir* space station, giving it a total weight of 143 tons. *Mir* served as host to 28 crews representing 63 other countries, including seven American astronauts. One crew member on *Mir,* Dr. Valeri Polyakov, holds the record for the most consecutive time in space—439 days. Anatoly Solovyov, another Russian cosmonaut, spent 651 days on *Mir* over the course of five missions.

After the fall of the Soviet Union, the United States and Russia started a four-year series of joint missions using the *Mir* space station. Since *Mir* had, at that time, been used for 10 years, NASA believed it could use *Mir* as a learning experience before beginning the construction of the *International Space Station.* At the same time, the Russian space agency was under increasing financial pressure because of the changes in that country after the end of the cold war. Cooperation with NASA allowed the launch of the last two modules: *Spektr,* which contained more than 1600 pounds of U.S. scientific equipment, and *Priroda,* a science module that added Earth–remote sensing capability to *Mir. Mir,* however, was showing its age and had a series of problems—including fires, leaks, and the collision of a progress service module with the *Spektr* module—that overshadowed the scientific efforts of the crew members and resulted in its closure. Much of the efforts

of the *Mir* crews had to be diverted into repairing the space station, and it became clear that *Mir* would not survive to become part of the *International Space Station.*

In 2001, after 15 years circling Earth, *Mir* finished its voyage. Russian space controllers turned on its engines for the last time and sent it into the atmosphere, breaking it apart. *Mir* crashed in the Pacific Ocean between NZ and Chile, but the importance of *Mir* has outlived the space station itself. *Mir's* contributions as the first permanent space station will never be forgotten. In its 15 years, it orbited Earth 86,331 times and hosted a total of 104 astronauts. The lessons learned from *Mir* about living in space will aid all space exploration in the future.

The *International Space Station*

The *International Space Station* had its roots in the later years of the cold war. At that time, Russia had a permanent space station, *Mir,* and the United States did not. Then-President Ronald Reagan, in the mid-1980s, approved the development of a U.S. space station called *Freedom*, a name chosen to show the contrast to its Russian counterpart. Over the next few years, the design underwent several changes. The space station has a unique phased approach. The station is built in modular segments. The segments are then connected in space similarly to a giant LEGO® toy. International cooperation was a necessity from the start because of the tremendous costs involved. The prime international partner in the original space station was ESA. Tired of being treated by NASA as an afterthought, ESA demanded concessions from NASA. ESA wanted to guarantee free access to the space station because of the continued conflict between the United States and Russia. Also, it wanted technology transfer from the United States in return for its financial contributions to the space station. The United States, Europe, Japan, and Canada agreed to limit space station use to peaceful purposes because of these pressures, and the final agreement for the *Freedom* space station was signed in the late 1980s.

The *Freedom* space station, however, was to undergo another transformation in the 1990s. As the cold war period drew to a close in the late 1980s and early 1990s, the station was redesigned once again to reduce costs and increase the level of international cooperation. The station also received a new name, the *International Space Station,* when the Russian government agreed to supply major hardware for the space station that had originally been planned for *Mir II*. The new design uses 75% of the original *Freedom* design.

The *International Space Station* is a very complex feat of engineering. The completed station will have a mass of about 1 million pounds, and it will be about 260′ wide and 290′ long. At the same time, it is being built with the scientific expertise and participation of 16 nations: the United States, Canada, Japan, Russia, 11 members of the EU, and Brazil. It is no wonder the station is so complex.

The station is being built in stages. See **Figure 4-5.** The historic competitors in space, the United States and Russia, contributed the first two modules, *Zarya* and *Unity,* but these two countries are not alone in the construction program. Canada provided a 57′-long robotic arm for assembly and maintenance on the space station, and Italy is providing a series of Multi-Purpose Logistics Modules (MPLMs) that serve as moving vans for the space station. These MPLMs, named *Leonardo, Raffaello,* and *Donatello,* carry equipment, experiments, and supplies to and from the space station using the shuttle's cargo bay. After the MPLM is unloaded in space, used equipment and trash are loaded into the module to return them to Earth.

Module	Country of Manufacture	Date
Zarya control module. *Zarya* means "sunrise" in English	Russia	November 1998
Unity connecting module	United States	December 1998
SPACEHAB double-cargo module	United States	May 1999
Zvezda service module	Russia	July 2000
Destiny laboratory module	United States	February 2001
Raffaello Multi-Purpose Logistics Module (MPLM)	Italy	April 2001
Ultra High Frequency antenna	United States	April 2001
Canadarm2	Canada	April 2001
Pirs docking compartment	Russia	August 2001
Integrated truss structure *Starboard Zero (S0)*	United States	April 2002
Mobile base system	Canada	June 2002
Starboard truss segment, *Starboard 1 (S1)* truss	United States	October 2002
Port truss segment, *Port 1 (P1)* truss	United States	November 2002
Port truss segments, *Port 3 (P3)* and *Port 4 (P4)* trusses	United States	September 2006
Port truss segment, *Port 5 (P5)* truss	United States	December 2006
Starboard truss segments, *Starboard 3 (S3)* and *Starboard 4 (S4)* trusses	United States	June 2007
Starboard truss segment, *Starboard 5 (S5)* truss	United States	August 2007
Harmony node 2	United States	August 2007
Columbus, a 23'-long cylinder equipped to host experiments inside and outside the station	*ESA	February 2008
Kibo Japanese Experiment Logistics Module-Pressurized Section (ELM-PS). *Kibo,* in English, means "hope."	Japan	March 2008
Special Purpose Dexterous Manipulator	Canada	March 2008
Kibo Japanese Experiment Module-Pressurized Module (JEM-PM)	Japan	May 2008
Starboard truss segment, *Starboard 6 (S6)* truss	United States	March 2009
Russian Multipurpose Laboratory Module	Russia	Future
Universal Docking Module	United States	Future
Cupola observation deck and control tower for robotics in space	ESA	Future
Node 3	United States	Future
European Robotic Arm	ESA	Future
Japanese Remote Manipulator System (JEM-RMS)	Japan	Future
Science and Power Platform	Russia	Future
* ESA is a collaborative alliance among Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and the UK.		

Figure 4-5.
The current construction sequence of major modules in the *International Space Station.*

The cornerstone of the first stage is the *Unity* connecting module because this module has six ports, and the space station will be built by connecting onto these six ports. Connection of the *Zvezda* service module to *Unity* allowed the space station to become operational because the *Zvezda* module provided the first living quarters, life support, electrical power, data processing, and propulsion system. The addition of the *Destiny* laboratory module in 2001 allowed the *International Space Station* to begin its scientific mission. Although wide-scale experimentation on the space station is still in the future, about 120 researchers have already been chosen to conduct experiments using this laboratory. See **Figure 4-6.**

The *International Space Station* welcomed its first crew in 2000. The international crew of two Russian cosmonauts and one American astronaut reached the space station using a *Soyuz* spacecraft. The Russians supplied a *Soyuz* spacecraft to the space station as a lifeboat. Over the life of the station, the *Soyuz* craft will be replaced so it is always ready to be used. Since 2000, the space station has welcomed more than 100 astronauts and visitors representing 10 countries. The flight of the first space

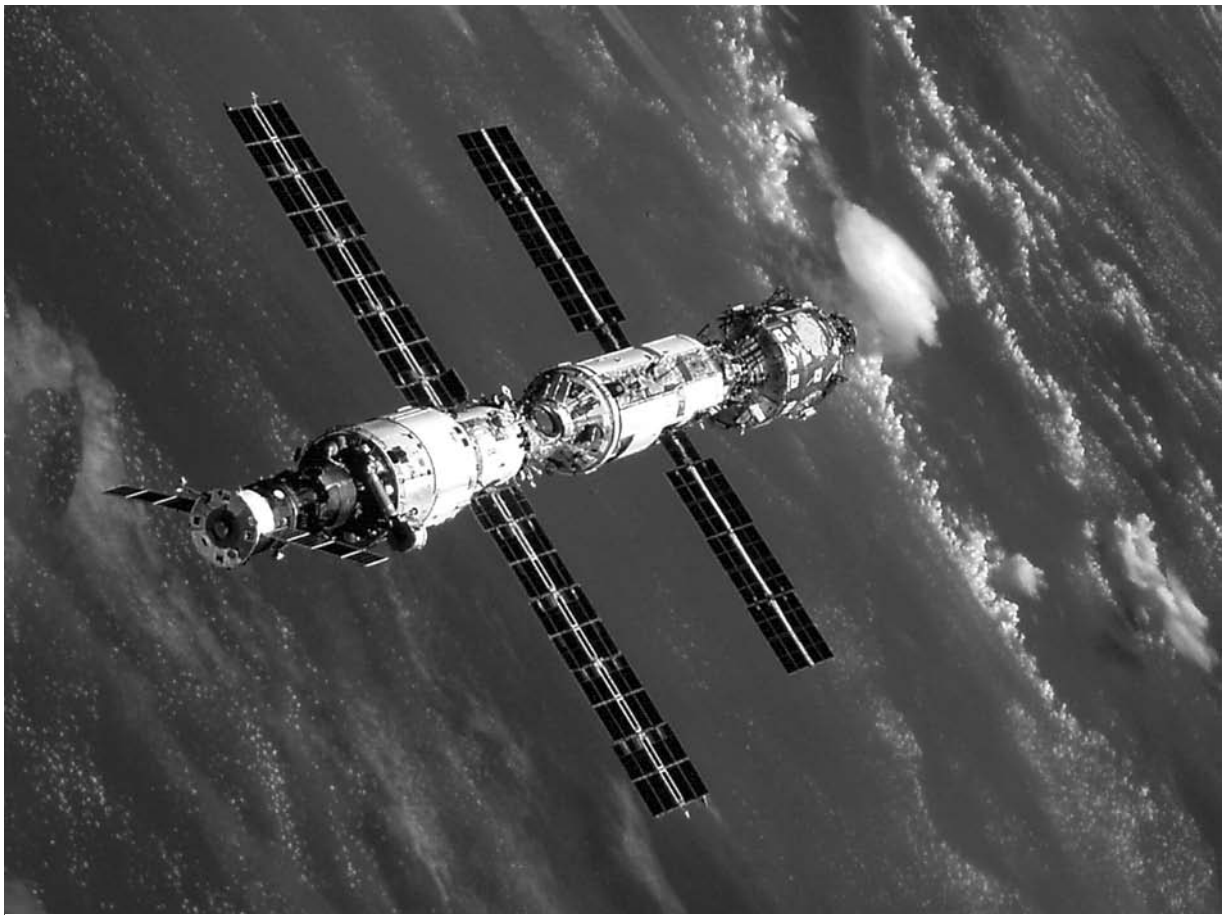


Figure 4-6.
The space shuttle *Atlantis* photographed the *International Space Station* against clouds over a landmass on Earth during a fly around. (NASA)

tourist (see the *Dateline* article earlier in this chapter) was a *Soyuz*-replacement flight. The California millionaire took probably the most expensive vacation ever, with his $20 million trip to the space station, but he assisted the crew members and was their guest, as they replaced the *Soyuz* escape craft. Since his visit, four other space tourists have visited the *International Space Station,* all on Russian supply vehicles. The Russians have also delivered progress supply vessels to the space station. As discussed in the section on *Mir,* the unmanned progress resupply ships were successfully used to deliver food, fuel, oxygen, and supplies to the station. The *Soyuz* spacecraft also have been used to transport astronauts to and from the *International Space Station* because of problems with the space shuttle.

Most of the construction of the station is done in space, so it is critical that all parts mesh and work well. After all, there is no local Radio Shack in space, in case the astronauts need a spare component! Computer problems on the U.S.-built sections of the station have hampered the early construction of the space station. In one day, all three command-and-control computers failed on the space station, and the station was forced to rely on a pair of computers in the *Unity* module. Although NASA engineers eventually fixed this computer glitch, the precarious nature of construction in space is still very evident.

In addition to the technical problems inherent in a construction project of this complexity, there are financial and political pressures as well. The Russian space agency is feeling financial pressure because its budget has been cut resulting from the changes in Russia since the end of the cold war. Added to these financial woes is the price hike in the cost for the space station that became public in 2001. ESA estimates that the total cost of the space station will be over $130 billion by the time it is finished. NASA has scaled back its plans for the space station, and it appears that the space station will never host its full crew of seven. Only three crew members will be supported at the space station at one time because the only emergency-exit vehicle is a Russian *Soyuz* spacecraft. Despite these problems, there is no doubt construction will continue on the *International Space Station.*

Telescopes in Space

Over the last 20 years, NASA and ESA have pursued a scientific study of the universe using a series of orbiting telescopes, or observatories. NASA's Great Observatories Program is a family of four orbiting observatories: *Hubble, Compton, Chandra,* and *Spitzer.* ESA operates the *XMM-Newton*. Each observatory was designed with a particular technology to measure specific subjects or events. *Hubble* is an optical and ultraviolet telescope. *Compton* observed the emission of gamma rays. *Chandra* and *XMM-Newton* use X rays. *Spitzer* obtains images and spectra by detecting the infrared energy. All together, they have provided a new view of the universe for scientists.

Telescopes and observatories in space are superior to their counterparts on Earth because these space-based instruments are free of the distorting effects of Earth's atmosphere. They can see farther and clearer than any telescope ever could on Earth because they are in space. All these space observatories make significant scientific contributions, but unfortunately, the general public rarely knows or understands them. As unmanned vehicles, they are inherently cheaper to both build and operate than NASA's flagship programs, the shuttle and the *International Space Station.*

The *Hubble* space telescope

The *Hubble* space telescope is the first large orbital optical observatory. The space telescope is named after American astronomer Edwin P. Hubble. This telescope consists of an optical-telescope assembly, a support systems module, and a series of sophisticated scientific instruments. *Hubble* is very big, about the size of a large school bus, and very heavy. On Earth, it would weigh over 25,000 pounds.

The $2.2-billion telescope was launched in 1990 from the space shuttle *Atlantis.* Soon after its launch, however, NASA discovered that the primary mirror was defective. The mirror had a flaw called *spherical aberration,* caused by a manufacturing mistake in the grinding of the outer edge of the mirror. Images, when seen through *Hubble,* appeared fuzzy. Astronauts from the space shuttle *Endeavor,* who added corrective mirrors to *Hubble,* had to repair *Hubble* in the early 1990s.

NASA sent additional servicing missions to *Hubble* in the 1990s and 2000s. See **Figure 4-7.** The second servicing mission added two new scientific instruments to *Hubble.* The Space Telescope Imaging Spectrograph (STIS) expands the spectrographic ability of *Hubble* by 30 times for spectral data and 500 times for spatial data. A ***spectrograph*** separates the light from the telescope into different components so, for example, the composition and temperature of a planet or star can be analyzed. The second instrument, the Near Infrared Camera and Multi-Object Spectrometer (NICMOS), allows *Hubble* to see objects farther away than before.

The third servicing mission, originally scheduled for preventative maintenance of *Hubble,* was made more urgent when the fourth of six gyroscopes failed in 1999, causing *Hubble* to go dark. A ***gyroscope*** is used to keep a spacecraft in balance. Usually, there are gyroscopes to monitor motion on a spacecraft in one or more of the three spatial movements: vertical (called *yaw*), longitudinal (called *roll*), and lateral (called *pitch*). When the spacecraft shifts its position in space, the gyroscopes are measured electronically. The information is applied to the spacecraft's navigation computer, which then can adjust the ship to keep it in balance. For most of 1999, *Hubble* had been operating with only three of its six gyroscopes working. When the fourth failed, *Hubble* went to sleep. The third successful mission added to or replaced old equipment on *Hubble,* including all six gyroscopes, a faster computer, and a new data recorder, among other improvements.

The last two serving missions to *Hubble* replaced old or obsolete equipment. In these missions, NASA replaced the survey camera with an enhanced digital camera; removed the existing solar panels and replaced them with smaller ones that produce 30% more



Figure 4-7.
The *Hubble* space telescope has been serviced several times since its placement in space. During each service mission, astronauts perform repairs, replace parts, and update the telescope's technology with new instruments. (NASA)

power; and added two new instruments, a wide-field camera and a spectrograph, which will allow *Hubble* to scan the universe in the ultraviolet range. The enhancements to *Hubble* should allow the telescope to be used for an extended period of time, probably until after 2020.

Since its first repair by the shuttle in the early 1990s, not counting the one-month downtime in the late 1990s, *Hubble* has fulfilled its goal and provided scientists with extensive data and photos of space. *Hubble* has a 7.9′ mirror that can make observations 24 hours a day. Also, since it orbits about 380 miles above Earth, it has a clear view of space. *Hubble* can detect objects as faint as the 31st magnitude. In contrast, the human eye can see celestial objects as faint as the 6th magnitude. Each magnitude is approximately 2.5 times dimmer than the one before. Therefore, *Hubble* can see objects 8 billion times dimmer in space than we can see with the human eye. This would be similar to you looking out your window in Washington DC and seeing two fireflies 6′ apart in Tokyo.

NASA scientists declare that the difference between the *Hubble* telescope and contemporary optical telescopes viewing the sky from ground observatories is analogous to the difference between Galileo's first telescope and the human eye. More specifically, consider these assertions:

- ❏ Man's unaided eye limit—600,000 light-years distant.
- ❏ Ground observatory limit—2 billion light-years distant.
- ❏ The *Hubble* space telescope's expected limit—14 billion light-years distant.

A distance of 14 billion light-years equates to a volume of space 350 times greater than can presently be seen from Earth.

Each year, astronomers compete for observation time on *Hubble.* They must submit a proposal to NASA. These proposals are then submitted to peer-review committees. The Hubble Institute director makes the final decision as to which proposals are funded. *Hubble* has been used to observe a wide range of celestial phenomena because of the large number of astronomers and their divergent interests. In its first 10-year period of operation, *Hubble* has probed over 14,000 celestial objects and made over 330,000 exposures. Each day, it generates three to five gigabits of data—enough to fill six CD-ROMs.

In its lifetime, *Hubble* has provided astronomers with thousands of dazzling images and has affected almost every area of astronomy. *Hubble* has helped astronomers in their understanding of the life of stars, the properties of galaxies, the atmospheres of the planets, and the properties and existence of black holes. See **Figure 4-8.**

The *Compton* Gamma Ray Observatory (GRO)

The *Compton* Gamma Ray Observatory (GRO) was launched from the space shuttle *Atlantis* in the early 1990s. *Compton* orbited Earth, collecting data about the gamma ray emissions of the solar system, until it was forced to reenter Earth's orbit in 2000. Named for Nobel prize winner Dr. Arthur Holly Compton, *Compton* carried four different instruments that could detect a broad range of high-energy gamma rays. *Compton* was unique because of the large size and increased sensitivity of its instruments. Although the number of gamma rays is small in the universe, these rays are the most powerful form of radiation. Also, because the number of gamma rays is small compared to the number of light rays, instruments need to be large in order to detect them.

Area	Pre-*Hubble* Knowledge (1990)	*Hubble* Contribution (2006)
Distant galaxies and galaxy evolution	Very little is known about galaxies beyond a few billion light-years.	Deep imaging traces the evolution of galaxies and rate of star formation. Galaxies seen over 3 billion light-years from the Earth.
Remote supernovas as distance indicators	Not possible to discriminate supernova light from light of host galaxy.	*Hubble* detects supernovas all the way back to 5 to 8 billion light-years away from Earth. The results show the universe is accelerating.
The universe's rate of expansion	Two research groups disagree by a factor of two. This yields estimates for the age of the universe of 10 to 20 billion years.	The value converges toward 10% accuracy, suggesting an age of the universe of 12 to 14 billion years.
Supermassive black holes	Data collected from Earth suggests the existence of black holes.	*Hubble* precisely measures gas velocity around a black hole, providing definitive proof. The *Hubble* surveys reveal black holes are common to the cores of galaxies.
Quasars	Quasars originated early in the universe. Some are surrounded by a "fuzz," which is interpreted as the host galaxy. Black holes likely power quasars.	*Hubble* clearly resolves questions about a variety of galaxies hosting quasars. Some galaxies are involved in mergers with other galaxies. These collisions fuel the central black hole.
Gravitational lenses	A few examples are known.	Scientists have confirmed more than 40 new gravitational lenses. Astronomers are studying these lenses to understand how galaxies are created.
Pluto	Transits and eclipses of Pluto's moon Charon yield a brightness map of the surface.	*Hubble* confirms the earlier map by showing a variegated surface. Images clearly separate the planet from its moon Charon. *Hubble* finds two new moons orbiting Pluto.
Supernova 1987A	The nearest supernova in 400 years, an armada of telescopes watches its changes, following the February 1987 explosion.	Only *Hubble* has the resolution to trace the yearly change happening at the sub-light-year scale, including changes in the fireball debris and circumstellar ring of enriched gas.
Galactic bulge structure	Only the Milky Way's central bulge and the bulges of nearby galaxies can be viewed in detail.	Large bulges formed early in the universe, along with elliptical galaxies. Ongoing star birth, fueled by disk instabilities or galaxy mergers, can inflate small galaxies.

Figure 4-8.
Some of the scientific achievements in the first 16 years of *Hubble.* (Adapted from NASA and the Space Telescope Science Institute)

The $670 million spacecraft had a broad mission, including the study of different bodies in space: solar flares, gamma ray bursts, pulsars, novas, and supernovas. During its brief nine-year life span, it collected volumes of gamma ray data and discovered new and unique types of objects in our galaxy. *Compton's* mission was cut short when one of its gyroscopes used to maintain its orbits failed. NASA decided to force *Compton* into the atmosphere rather than wait for it to enter on its own. Similar to *Mir,* but with a much shorter active life, *Compton* ended its life scattered across the Pacific Ocean.

The *Spitzer* space telescope

A Delta rocket launched the *Spitzer* space telescope in the early 2000s. *Spitzer* contains a telescope assembly containing a 33" telescope and three science instruments. In order to function properly, the telescope needs to be supercooled to a few degrees above absolute zero—about –460°F (–273°C). The spacecraft cannot operate properly at very cold temperatures, however, so the telescope is divided into warm and cold sections. *Spitzer's* job is to detect the infrared energy of objects in space. Earth-based telescopes have a difficult time observing infrared radiation from space. *Spitzer* can look at objects too dim, distant, or cool to study with other astronomical techniques because it is in space. This telescope can observe space objects over 11 billion light-years away. Instead of orbiting around the Earth, *Spitzer* follows the Earth in the Earth's orbit around the Sun. Over time, *Spitzer* will drift away from the Earth.

In its short existence, *Spitzer* has been able to look through the dust in the galaxy to uncover missing black holes known as *quasars.* Using *Spitzer's* telescope, astronomers were also able to study several planetary systems in the Milky Way. Based on their data, worlds with a potential for life might be more common than previously thought. Since *Spitzer* was a bargain by NASA's standards, only $720 million, its impact is even greater.

X-ray telescopes

At the start of the twenty-first century, there are two X-ray telescopes circling Earth. NASA funds the *Chandra* X-ray observatory. ESA funds the *XMM-Newton* space observatory.

The Chandra *X-ray observatory*

NASA's newest telescope, the *Chandra* X-ray observatory, had the longest development cycle of any recent mission. *Chandra* was first proposed in the mid-1970s, and funding for this project began in 1977. As time went on and NASA's budget (and priorities) shifted, the project was downsized. Overall, it took over 20 years to design, build, and launch this spacecraft, and it was not until the late 1990s that *Chandra* was launched from the cargo bay of the space shuttle *Columbia.*

Chandra has three major parts: the X-ray telescope, the scientific instruments recording the X rays, and the spacecraft itself. The X-ray telescope system of *Chandra* is unique. Since X rays would penetrate a normal mirror, *Chandra* was designed with cylindrical mirrors resembling tubes within tubes. See **Figure 4-9.** The mirrors of *Chandra* are the smoothest ever created, and the largest of the mirrors is almost 4' in diameter and 3' long. Overall, the entire spacecraft is over 45' long and 64' wide when the solar panels are deployed. At 12,930 pounds, *Chandra* was the largest and heaviest payload the space shuttle ever launched.

This observatory has an unusual elliptical orbit taking this spacecraft from 6200 miles above Earth to a third of the way to the Moon. It takes *Chandra* 64 hours and 18 minutes

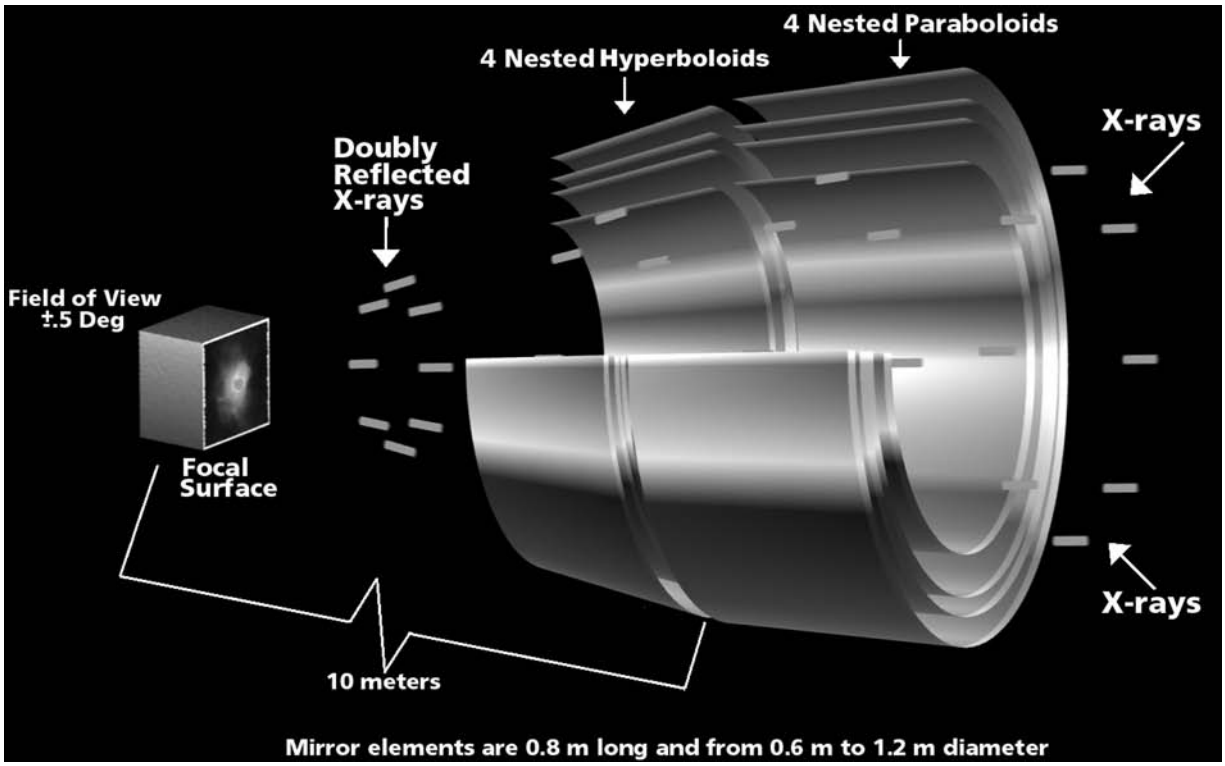


Figure 4-9.
This cutaway illustrates the design and functioning of the High Resolution Mirror Assembly (HRMA) system on *Chandra.* (NASA/CXC/SAO)

to complete one orbit. Named after the late Indian-American Nobel prizewinner, Subrahmanyan Chandrasekhar, *Chandra* studies X rays, rather than conventional photos, to give scientists information about the structure and evolution of the universe. Since *Chandra* orbits in a higher orbit than *Hubble,* it is able to get clearer readings while away from the belts of radiation surrounding Earth. In fact, *Chandra's* orbit takes the spacecraft 200 times higher than the *Hubble* telescope.

This telescope is designed to observe X rays from high-energy regions of the universe, including the remnants of exploded stars. *Chandra's* high resolution allows scientists to see more features of these cosmic events than ever before. *Chandra* can produce images with 50 times better resolution than was obtained before. Astronomers use *Chandra* to study black holes and use the data from *Chandra* to confirm the existence of the event horizon, the outer edge of the black hole, which Einstein's theory of relativity predicted.

The X-ray Multi-Mirror Mission–Newton (XMM-Newton) *space observatory*

XMM-Newton, launched in the late 1990s by ESA, complements *Chandra.* Similar to *Chandra, XMM-Newton* uses a series of nested, curved mirrors to collect X-ray information about the galaxy. The mirrors on *XMM-Newton* are the most powerful ever developed in the world. This allows the *XMM-Newton* space observatory to see

even further back in time than *Chandra* can. An interesting fact about space is that the farther the distance a telescope sees in space, the further it sees back in time. This is because what a telescope is actually seeing is light. Since light travels at a set rate, the farther away one can see light, the older it is. Even though *XMM-Newton* can see farther back in time than the *Chandra* can, *Chandra's* telescope has a crisper focus than *XMM-Newton's* does.

The *XMM-Newton* space observatory has detected hundreds of new high-energy sources in the universe. One of its tasks is to explore X-ray background emissions. These emissions occur widely throughout the universe, but the cause of them is not known. *XMM-Newton* was able to begin to solve this celestial mystery with its 10-hour-long observation of Andromeda. The information this probe gathered showed the presence of various chemical elements in this diffusion. This discovery gave astronomers more clues about the behavior of the galaxy.

Exploring Earth's Neighbors

In addition to the manned missions the various space agencies undertake, there are many unmanned spacecraft that have scientific exploration as their primary missions. These smaller missions receive less press acclaim, but their long-range contributions to science are more significant than the more popular programs. Each of these missions has a more narrow focus. Therefore, they tend to be significantly cheaper than the manned missions.

A landmark unmanned mission is that of *Pioneer 10*, first designed to study the planet Jupiter. After 30 years, *Pioneer 10* is still making its way across our galaxy and is the first Earth spacecraft to leave our solar system. *Pioneer 10* carries a plaque, designed by Carl Sagan, that includes an illustration of a man and a woman and a diagram showing Earth's location in the galaxy. See **Figure 4-10.** *Pioneer 10* is now over 10 billion miles away from Earth. A signal from the spacecraft was last received in the early 2000s, and scientists believe they will receive no more signals from *Pioneer 10* because its power source is almost gone. When *Pioneer 10*'s last signal was received, it took over 11 hours for the radio signal to reach Earth.

The *Voyager* mission is another long-lasting mission. The two *Voyager* probes have been collecting data about the outer planets of our solar system since the mid-1970s. In the late 1990s, *Voyager 1* became the most distant Earth spacecraft, as it passed *Pioneer 10* (although these spacecraft are traveling in different paths out of the solar system).The *Voyager* spacecraft have surveyed farther than ever expected because of their sturdiness. NASA estimates that these two spacecraft will continue to operate well into the first two decades of the twenty-first century—over 40 years in space.

Not every mission the United States or another country launches can expect the longevity or output of the *Voyager* or *Pioneer* missions. During the 1990s, NASA and ESA launched many different missions that had as their goal the exploration of our neighbors in space. In this section, we will highlight several successful missions to explore our solar system.

Exploring the Sun

Two spacecraft are currently studying the nature and behavior of the Sun. Interestingly, both of these projects are joint missions of ESA and NASA, although ESA is the senior partner. *Ulysses,* launched in 1990, is studying the solar wind blowing from the Sun, while the main goal of the *Solar and Heliospheric Observatory (SOHO)* spacecraft

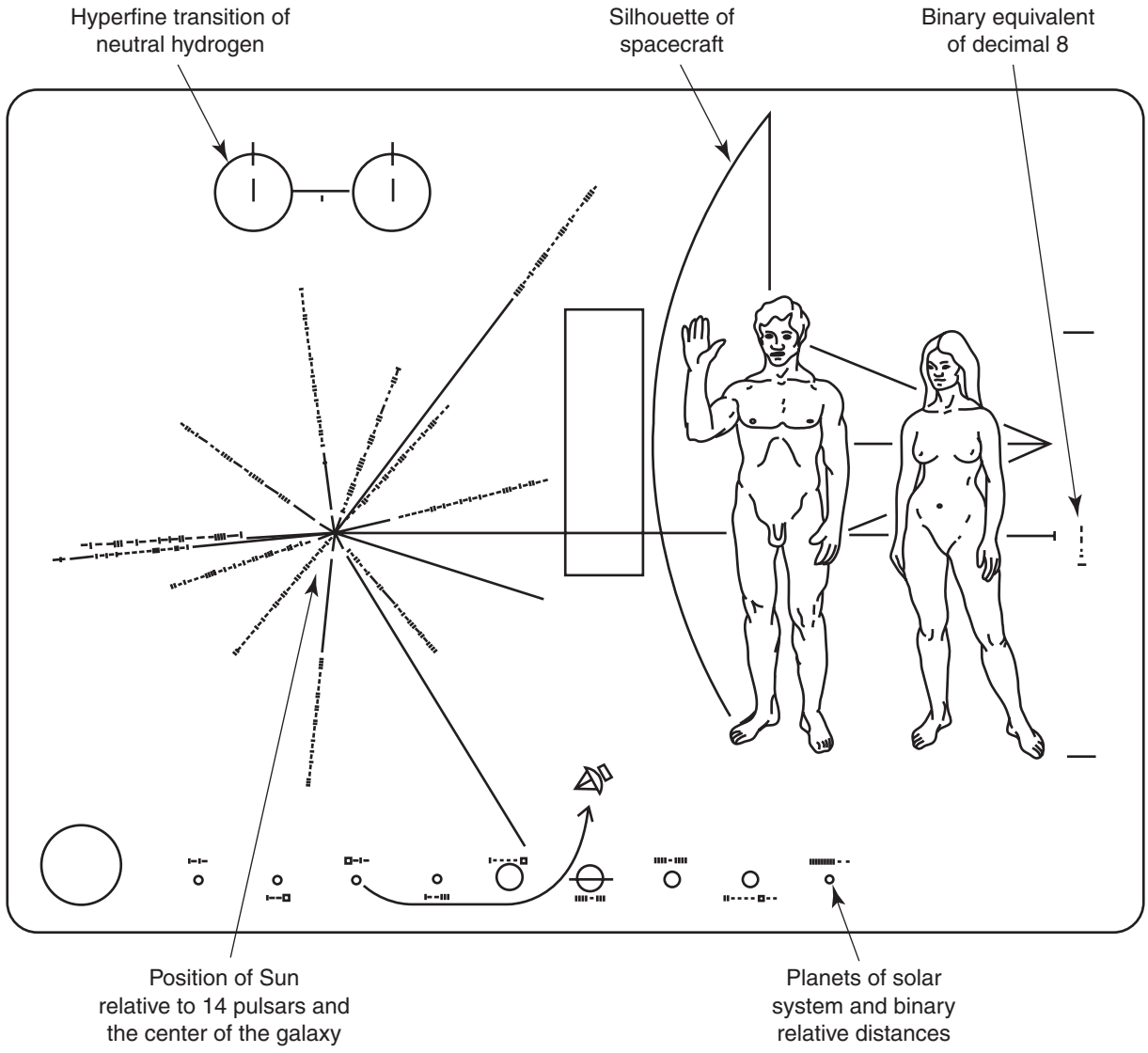


Figure 4-10.
Pioneer 10 carries a graphic message in the form of a 6" × 9" gold anodized plaque bolted to the spacecraft's main structure. (NASA)

is to observe the Sun from the Sun's interior to its surface and atmosphere. These two spacecraft complement each other. Together, they give scientists a deeper understanding of how the Sun works to sustain our galaxy.

Ulysses follows a polar route around the Sun, and it took over six years for this satellite to complete one rotation. During its journey around the Sun, *Ulysses* was able to detect and measure magnetic fields, cosmic rays and dust, solar X rays, electrons, and wind ions. Before *Ulysses* began its observation of the Sun, physicists knew that the solar wind left the Sun at two speeds, fast

and slow. The data *Ulysses* collected shows there is a boundary between these two solar wind areas, and the fast wind pushes the slow wind toward the Sun's equator. *Ulysses* was also used to acquire data from the tails of comets on three separate occasions. NASA expects to decommission *Ulysses* in the later years of the first decade of the twenty-first century.

SOHO was built by companies in 14 European countries and had a total weight of about 3500 pounds at its launch in the mid-1990s. The spacecraft has 12 sets of instruments, and more than 500 scientists in 15 countries are involved in conducting research using data *SOHO* collects. NASA monitors *SOHO* at the Goddard Space Flight Center in Maryland and uses its ***Deep Space Network (DSN)*** antennas to collect data from this Sun probe. Many international missions such as *SOHO* use DSN and its antennas. DSN has three different sites on Earth: Goldstone, California; Madrid, Spain; and Canberra, Australia. See **Figure 4-11.**



Figure 4-11.
DSN's largest antenna is 230' (70 m) in diameter, nearly the size of a football field. (NASA/JPL/Caltech)

The *SOHO* spacecraft holds a position between the Sun and Earth, about 900,000 miles from the Sun's surface. The original plan was to shut *SOHO* down after three years, but *SOHO* has been so successful in its mission that NASA and ESA extended its life. *SOHO* has operated continuously since its launch, with the exception of two time periods, about four months each, in the late 1990s. During the first period, NASA lost contact with *SOHO,* although scientists were able to reconnect with the spacecraft after a few months. The second operational lapse was due to gyroscope failure in the spacecraft.

SOHO has proven to have unexpected benefits for scientists on Earth. This spacecraft has discovered more comets than any other machine (or person) in the history of astronomy. Within the first 10 years of its deployment, it had found more than 600 comets. Also, *SOHO* can detect sunspots on the far side of the Sun. Since sunspots and flares can have harmful effects on satellites and power lines, this early detection is invaluable for minimizing the harmful effects of solar flares on Earth. Also, since space agencies continue to send astronauts into space, reducing astronaut exposure to dangerous particles from solar flares is very useful.

Exploring the Moon

Since the end of the Apollo Program, the Moon has been relatively neglected. Now, there is a renewed interest in exploring the Moon. Just as NASA used the Moon to demonstrate its superiority in space, other countries are using the Moon to test new spacecraft technologies. ESA pioneered the new Moon exploration with its *Small Missions for Advanced Research in Technology–1 (SMART-1)* spacecraft, which studied the Moon for over one year and gathered data about the composition of the Moon's surface in

visible, infrared, and X-ray light. Two new space powers, Japan and China, now have spacecraft in orbit around the Moon. Japan's spacecraft, *Kaguya,* contains 13 scientific instruments, including a high-definition television camera. *Kaguya*'s mission is to make detailed maps of the Moon's surface, to search for frozen water, and to study the Moon's gravity.

The Chinese spacecraft, *Chang'e-1,* joins *Kaguya* in its exploration of the Moon. Costing $264 million, *Chang'e-1* is the first of a series of three Chinese spacecraft that will visit the Moon. *Chang'e-1* is in orbit around the Moon and is taking three-dimensional pictures of the lunar surface. The Chinese spacecraft includes several instruments: a microwave radiometer to measure the depth of lunar soil, spectrometers to determine the composition of the soil, and a stereo camera for mapping the Moon's surface. In the next few years, China plans to send two additional spacecraft to the Moon: *Chang'e-2* will land on the Moon and will contain a rover, and *Chang'e-3* will return Moon samples to Earth.

The Asian spacecraft will soon have company in exploring the Moon. Three more countries, the United States, Russia, and India, plan to send new spacecraft to the Moon in the next decade. Why is the Moon so popular again? Most of the space agencies are still intent on manned flights to other planets. The Moon is a good place to teach people about living on other worlds. NASA planners call this type of training *in-situ resource utilization.* People on Earth most likely would call it *living on the land.* NASA and other space agencies want to use the Moon to test new technologies for survival in difficult environments and better recycling systems so future astronauts can find water and oxygen locally. NASA plans to send astronauts to the Moon for extended periods by the 2020s.

Exploring Jupiter

After a six-year journey through space, the *Galileo* spacecraft arrived at Jupiter in the mid-1990s. This spacecraft was an unqualified success for NASA, as it more than doubled its expected life span of two years. *Galileo* had two parts: the spacecraft and the probe, which together weighed almost 6000 pounds at launch. When it reached Jupiter, *Galileo* released the 700-pound probe, which entered Jupiter's atmosphere and descended 95 miles through the planet's atmosphere. The probe relayed data to the *Galileo* spacecraft, which then transmitted this data to Earth. After 58 minutes, the intense heat of Jupiter's atmosphere vaporized the probe.

Galileo had an unusual design. One section, rotating at three rotations per minutes, contained six instruments that gathered Jupiter data while the section was rotating. The other section of *Galileo* had a fixed position and held four instruments.

When the original mission ended in 1997, *Galileo*'s goals were expanded, and the spacecraft began a two-year study of the Jupiter moons Io and Europa. *Galileo* sent back data showing an ocean under the surface of Europa, and it has studied the behavior and effect of the many volcanoes on Io. In fact, images from Io show so many volcanoes that the entire surface seems to be lava in various stages of cooling. Also, data from *Galileo* shows that some of the volcanoes on Jupiter resemble those on Earth. The Prometheus volcano on Io, for example, seems similar to the Kilauea volcano in Hawaii.

Galileo's mission was extended two more times. The spacecraft's last mission involved five more orbits of the moons of Jupiter, while *Galileo* took pictures and measured magnetic forces. This $1.4 billion spacecraft took its final voyage in 2003, when it was crashed into Jupiter. You might ask, "Why did NASA crash *Galileo*?" The short answer can

be found in a document from the beginnings of space travel. In the mid-1960s, the United States signed the United Nations' Outer Space Treaty. This treaty requires space missions to minimize the transfer of living organisms from one body to another. Since *Galileo* had been traveling through space for over 11 years and might have picked up some microscopic living organisms, it was crashed into Jupiter to avoid contaminating that planet or its moons and possibly transferring any living organisms to that planet.

Exploring Asteroids

The *Near Earth Asteroid Rendezvous (NEAR) Shoemaker* spacecraft, named in honor of the late astronaut Gene Shoemaker, was a project under the NASA Discovery Program, which is a series of small-scale, lower-cost spacecraft missions. *NEAR Shoemaker*, launched in the mid-1990s, was mechanically simple in its design. This spacecraft had a 5' antenna and four solar panels mounted on its outside. See **Figure 4-12.** The scientific instruments were mounted on the side opposite to the antenna. The spacecraft also had a thruster that allowed it to be moved. As spacecraft go, *NEAR Shoemaker* was light and inexpensive—it was about 1774 pounds at launch and cost $223 million to build.

The mission for *NEAR Shoemaker* was to study Eros, a near-Earth asteroid having the potential to collide with Earth within the next 1.5 million years. It took *NEAR Shoemaker* four years to travel the 2 billion miles to Eros. *NEAR Shoemaker* had six instruments for its analysis of this asteroid. The Multi-Spectral Imager (MSI) took both standard and near-infrared pictures of Eros to determine Eros's shape and surface features. Also, the MSI was able to map mineral deposits on the asteroid. The NEAR Laser Rangefinder (NLR), a laser altimeter that allowed scientists to develop a high-resolution topographic profile of Eros, gathered further surface information.

The Near-Infrared Spectrometer (NIS) used information gathered from infrared measurements to determine the distribution and amounts of surface minerals. The X-ray Gamma-Ray Spectrometer (XGRS) was two

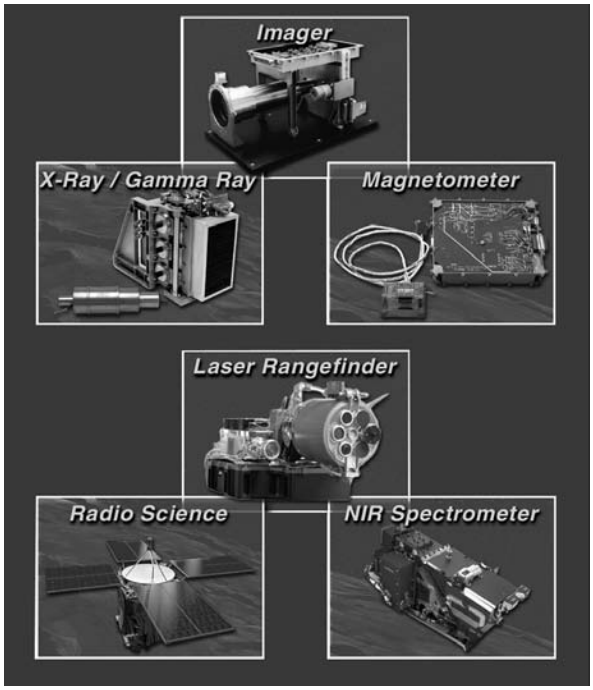


Figure 4-12.
The *NEAR Shoemaker* spacecraft carried six scientific instruments. The Multi-Spectral Imager (MSI)—*NEAR Shoemaker*'s electronic camera—mapped the asteroid's shape, landforms, and colors. The X-ray Gamma-Ray Spectrometer (XGRS), consisting of two sensors, measured key chemical elements such as silicon, magnesium, iron, uranium, thorium, and potassium. The Magnetometer (MAG) searched for a magnetic field on asteroid Eros (and did not find one). The Laser Rangefinder scanned the precise shape of the asteroid. A radio science experiment determined the asteroid's mass by tracking tiny changes in *NEAR Shoemaker*'s radio frequency. Also, the Near-Infrared Spectrometer (NIS) mapped the mineral composition of the surface by measuring the spectrum of sunlight Eros reflected. (The Johns Hopkins University Applied Physics Laboratory)

instruments in one. Together, these instruments detected X rays and gamma rays from elements on the surface. The last two instruments were the Magnetometer (MAG), which mapped any magnetic fields, and a radio transponder, which enabled *NEAR Shoemaker* to establish its position and velocity in space. The design of *NEAR Shoemaker* highlights the new design methodology of NASA—reuse technology whenever possible. The transponders (the core of the communication system) on *NEAR Shoemaker* were modified from those used on the *Cassini* spacecraft (discussed in the next section).

The spacecraft *NEAR Shoemaker* spent one year orbiting and analyzing the asteroid Eros before it landed on the asteroid in 2001. During its time in orbit, it sent back over 160,000 images to Earth, making it another successful project for NASA. The information *NEAR Shoemaker* gathered gave scientists a tremendous amount of information about the composition and history of this asteroid.

Exploring Saturn

The *Cassini* spacecraft, launched in the mid-1990s, is orbiting Saturn and gathering information about the planet; its rings; its principal moon, Titan; and its other satellites. *Cassini* is one of the most complex, largest, and heaviest interplanetary spacecraft ever designed. See **Figure 4-13.** The total weight of the orbiter, *Huygens* probe, launch vehicle adapter, and fuel was 12,346 pounds at launch. *Cassini* is about 22′ high and 13′ wide. This spacecraft is so large and complex because it will conduct 27 scientific investigations related to Saturn. This mission has a large international flavor, with lead scientists representing 13 countries, including the United States, and over 200 scientists from around the world working together on this project. By comparison, 11 countries are working together on the *International Space Station. Cassini*'s mission has a NASA orbiter, an ESA probe, and an Italian communications system.

Cassini took almost seven years to reach Saturn. After it arrived, it released the *Huygens* probe, which landed on Titan, Saturn's principal moon. The *Cassini* spacecraft continues to orbit Saturn, taking measurements. In its data collection, *Cassini* follows the model used during *Magellan*'s mission to Venus. *Magellan* used one large antenna both for communication with Earth and for mapping the planet. Similar to *Magellan,* during its orbit of Saturn, *Cassini* spends about 12 to 15 hours each day observing Saturn. *Cassini* then turns its antenna toward Earth and spends 9 to 12 hours transmitting the science data collected to DSN. This spacecraft uses DSN's 112′ and 230′ antennas at each of the three sites. Over its four-year planned observation mission, *Cassini* should collect and send about 2 trillion bits of data to Earth—the equivalent of 800 sets of *Encyclopedia Britannica.* On its way to Saturn, *Cassini* made observations of Jupiter in conjunction with *Galileo,* which had been orbiting Jupiter for more than five years. Together, the data gathered from these two spacecraft provides more information about Jupiter's weather patterns and volcanic activity on its moon Io. *Cassini* also has made many discoveries about Saturn and its moons, including finding three new moons orbiting the planet. During a flyby of Titan, one of Saturn's moons, *Cassini* found extensive oil and gas reserves. Using data *Cassini* gathered, scientists were able to discover a new ring around Saturn and determine that Saturn's rings are over 4.5 billion years old. As it completes its mission, *Cassini* will no doubt uncover more secrets about this distant planet.

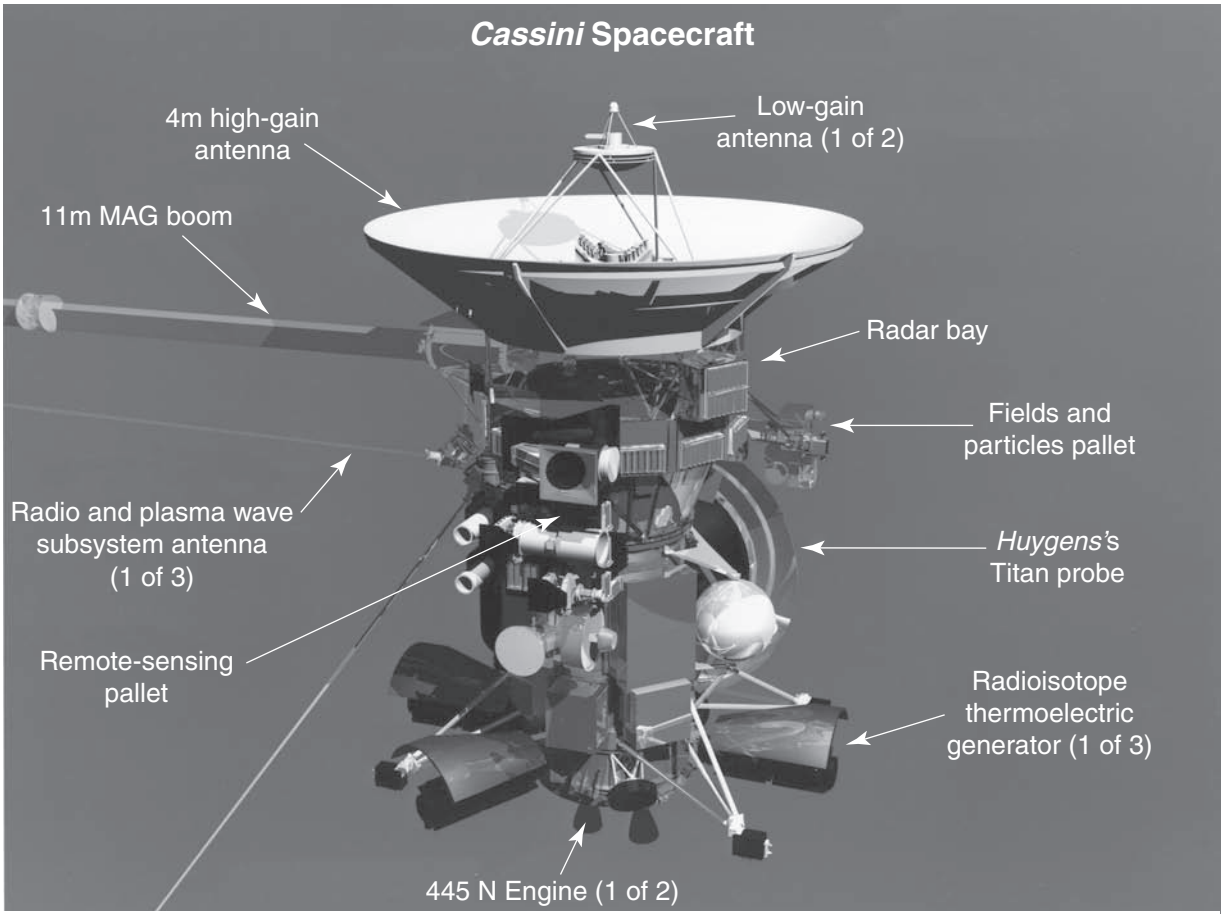


Figure 4-13.
A diagram of the *Cassini* spacecraft. (NASA)

Exploring Mercury

NASA selected *MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER)* as the seventh discovery program of low-cost, scientifically focused space missions. See **Figure 4-14.** Earth spacecraft have not often visited Mercury. Only one other spacecraft has visited Mercury—*Mariner 10* in the mid-1970s. The *MESSENGER* spacecraft is unusual because its design and development were very short—less than five years from preliminary design to launch. How was this accomplished? The basic components used in *MESSENGER* are similar to those of other spacecraft, and the spacecraft's structure is built using light composite materials. *MESSENGER* carries seven scientific instruments and a radio science experiment, which will allow it to map nearly the entire planet in color. This spacecraft was designed to withstand very high temperatures and has a sunshade made of heat-resistant ceramic cloth because Mercury is so close to the Sun.

MESSENGER flew by Venus twice in its journey of more than 2 billion miles to reach Mercury. This spacecraft will fly by Mercury three times before taking up an elliptical orbit around the planet. In its first flyby, the

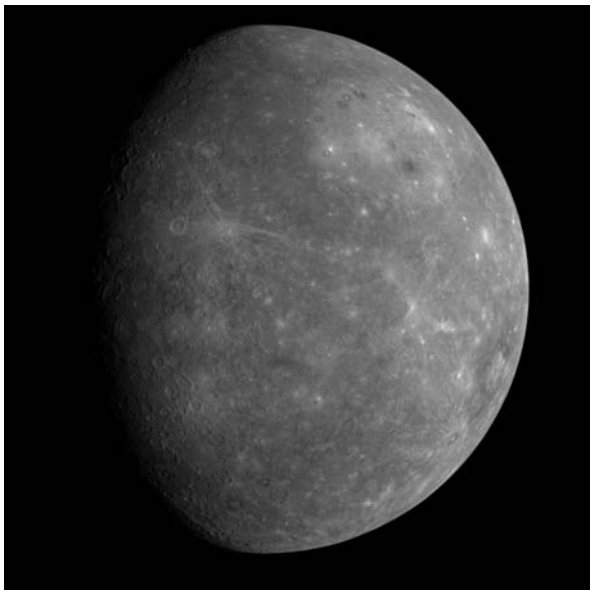


Figure 4-14.
The *MESSENGER* spacecraft was launched to capture high-resolution images of Mercury's surface. This spacecraft was the second spacecraft in history to make the mission. (NASA/Johns Hopkins University Applied Physics Laboratory/ Carnegie Institution of Washington)

spacecraft's cameras and sensors collected more than 1200 images. The three flybys will put *MESSENGER* in position to enter Mercury's orbit sometime early in the next decade.

This spacecraft is designed to answer six scientific questions about Mercury:

- ❏ Why is Mercury so dense?
- ❏ What is the geologic history of Mercury?
- ❏ What is the nature of Mercury's magnetic field?
- ❏ What is the structure of Mercury's core?
- ❏ What are the unusual materials at Mercury's poles?
- ❏ What volatiles are important on Mercury?

Over the next decade, NASA hopes to uncover more secrets about this planet and discover why Mercury is so much denser and richer in metals than Venus, Earth, and Mars.

Exploring Mars

Throughout history, we have looked to Mars as our nearest neighbor. Mars holds a fascination for us, as we consider whether or not there really is life beyond Earth. Each of us can probably think of a movie or book featuring little green men from Mars. Also, it appears Mars is the only other planet in our solar system that could possibly sustain life. So, it is only natural that Mars is the first planet we want to explore.

The first Earth spacecraft to visit Mars was a Russian craft that did a flyby of Mars in 1960. The first successful U.S. mission, that of *Mariner 4,* returned 21 photos of Mars to Earth in the mid-1960s. Since these early beginnings, Mars has been the focus of 29 missions. Some U.S. successes include *Mariner 9,* launched in the early 1970s, which returned over 7000 photos of Mars, and *Viking I* and *Viking II,* combination orbiters and landers that returned over 50,000 photos.

In the 1990s alone, there were eight different missions to study the planet Mars. NASA ran six of these space missions. Russia and Japan funded the other two. Unfortunately, the successes of these missions have varied. A summary of these missions is shown in **Figure 4-15.** Why were so many of these missions unsuccessful?

Despite a few failures, including *Challenger* and *Apollo 13,* NASA had enjoyed an enviable record in space until the late 1990s, but changes were already underway that would lead to the problems that occurred in the exploration of Mars. In the early 1990s, because of shrinking budgets and the large amount of money earmarked for the shuttle, NASA adopted a policy to reduce costs called ***faster, better, cheaper (FBC).*** The goal of FBC was to shorten development time, reduce costs, and increase the scientific output of NASA by having more missions in less time.

International Mars Missions, 1998–2008				
Year	**Mission**	**Sponsoring Agencies**	**Outcome of Mission**	**Cost**
1998	*Nozomi* (Planet-B)	Institute of Space and Aeronautical Science, Japan	During an orbit around Earth, the spacecraft used more propellant than planned. As the mission was being assessed, solar flares damaged the spacecraft. The mission was aborted on December 9, 2003.	$848 M
1998	*Mars Climate Orbiter*	NASA	Destroyed when a navigation error caused it to miss its target altitude by 80 to 90 km.	*
1999	*Mars Polar Lander*	NASA	Presumed lost or crashed during landing.	*
1999	*Deep Space 2*	NASA	Presumed lost on December 3, 1999.	$29.2 M
2001	*Mars Odyssey*	NASA	Reached Mars orbit on October 24, 2001. This mission has collected over 130,000 images.	$300 M
2003	*Mars Express* orbiter and *Beagle 2* lander	ESA, Italian Space Agency, NASA	Reached Mars orbit in December 2003 and collected information about the atmosphere and surface. The lander was presumed lost or crashed during landing.	$369 M
2003	Mars exploration rovers: *Spirit* and *Opportunity*	NASA	The first rover reached Mars on January 3, 2004. The second rover arrived January 24, 2004. They have collected rocks, soil, and images.	$850 M
2005	*Mars Reconnaissance Orbiter*	NASA	Reached Mars orbit on March 10, 2006. Collected images and geological data.	$720 M
2007	*Phoenix Mars Lander*	NASA	Reached Mars on May 25, 2008 and is collecting soil samples.	$325 M
* The Mars Surveyor '98 Program is made up of two spacecraft that were launched separately, *Mars Climate Orbiter* and *Mars Polar Lander.* NASA spent $327 M total on both of these projects. M = million				

Figure 4-15.
International Mars missions from 1998 to 2008.

The first project using the rules of FBC was *Mars Global Surveyor (MGS).* This was an unqualified success. The next three major NASA Mars projects were, however, failures—very spectacular failures.

Two of these failed projects, *Mars Climate Orbiter* and *Mars Polar Lander,* were part of the Mars Surveyor '98 Program designed to study the Martian weather and climate. According to a follow-up report by NASA,

a software flaw probably caused *Mars Polar Lander* to shut off its engines too early in its descent. An even simpler human error, a mix-up over metric and English measurements, destroyed *Mars Climate Orbiter.* The prime contractor, Lockheed Martin, gave data for the navigation program to the Jet Propulsion Laboratory (JPL) team, writing the navigation software program in English units, rather than in metric units. This error caused *Mars Climate Orbiter* to pass too close to the planet and burn in Mars's atmosphere.

The third project was *Deep Space 2,* a mission with two probes designed to send back data on the properties of Mars below the surface. NASA never received any signal from *Deep Space 2,* however, leading it to conclude *Deep Space 2* was lost or crashed. In any case, the loss of three Mars missions over a year's time brought NASA into greater scrutiny.

The future of FBC is in doubt. From a review held after the loss of all three missions, an independent assessment team determined the Mars Surveyor '98 Program was inadequately funded, and the pressure of maintaining the budget led to too many corners being cut during engineering design and manufacture. As a result of trying to do more with less, NASA's FBC strategy went too far and failed. As long as budgets are tight, there is an increased possibility missions will fail, but at the same time, both Congress and the U.S. public are unwilling to return to the days when NASA had a blank check for its work.

In 2000, NASA announced a new plan for Mars exploration, including six new missions during the following decade. In contrast with most previous missions, these Mars missions will include international partners, such as the French and Italian space agencies. The first mission was that of *Mars Odyssey,* launched in 2001.

Despite the three recent setbacks in Mars exploration, there have been successful missions. NASA has been successful in landing two rovers on the surface of Mars, and the two rovers have operated 10 times longer than their originally scheduled three-month mission. The twin robots, *Opportunity* and *Spirit,* have traveled more than a combined 11 miles over the surface of Mars. The rovers act as robotic geologists, taking pictures, performing analyses on rocks and sediment, and measuring soil and air temperatures. They have not been the only Mars success stories in the last decade. A few of the more important missions are discussed in the next sections.

Mars Pathfinder

Mars Pathfinder had two different parts: a lander and a surface rover. *Pathfinder* reached Mars in the late 1990s, entered the planet's atmosphere, and bounced on inflated air bags when it landed. The surface rover, named *Sojourner,* then exited the lander and started exploring the surface of Mars. The main objective of *Pathfinder* was to demonstrate the feasibility of low-cost landings on Mars.

Sojourner, the rover, was tiny—about 11" high, 25" long, and 19" wide—and powered by solar cells. Remote control operated the rover from Earth, although the rover did have a hazard-avoidance system. Since there is a 10- to 15-minute time delay between Earth and Mars, however, it was a challenge to control the rover remotely, certainly nothing similar to the immediate response we get from our experiences using a remote controlled vehicle on Earth.

The mission was designed so the rover would communicate with the lander, and the lander would then communicate with Earth. *Sojourner* could take both color and black-and-white pictures as it moved along Mars's surface. Both the lander and

the rover lasted longer than expected. The lander functioned for almost 90 days, while the rover lasted for 84 days. More importantly, a tremendous amount of data was sent to Earth, including 16,500 images from the lander, another 550 images from the rover, 16 chemical analyses of rocks and soils, and 8.5 million measurements of pressure, temperature, and wind. Overall, the *Mars Pathfinder*'s mission cost approximately $265 million, including the launch and operations.

Mars Global Surveyor (MGS)

MGS included six different parts. This surveyor had a camera taking both high- and low-resolution pictures of the planet's surface, as well as five different instruments measuring Mars's gravity, weather, climate, surface, and atmospheric composition. In addition, *MGS* had an altimeter that is building a topographic map of Mars.

MGS was small and relatively cheap for a space probe. This probe consisted of a rectangular box about 4' on each side, weighed only about 2300 pounds at launch, and cost $154 million to build and $65 million to launch. Actually, the center section was really two smaller boxes on top of each other—the equipment module contained all the instruments and was on one side of the spacecraft, and the propulsion module held *MGS*'s engine and fuel tanks and was located on the other side. *MGS* had two solar panels extending about 39' from tip to tip.

This probe began orbiting Mars in 1997, after a journey of 10 months from Earth, but it did not begin collecting data until 1999. Why the delay? When *MGS* arrived near our neighboring planet, it was in an elliptical orbit that took 48 hours to complete. NASA scientists had to slow *MGS* down and also change its orbit to a circular orbit. It took 16 months to move *MGS* into a circular seven-day orbit around Mars. NASA scientists took advantage of the atmosphere of Mars to slow down the spacecraft. They used a technique called ***aerobraking.*** First, *MGS*'s orbit was moved into the upper portion of the Martian atmosphere. Each time *MGS* then orbited the planet in the atmosphere, it slowed down slightly because of air resistance and lost altitude. Over the 16 months, *MGS* was moved from an orbit of 34,900 miles to 250 miles above the Martian surface. Originally, this aerobraking was scheduled for 4 months, but a malfunction in one of the solar panels delayed the total process for one year.

Despite the problems with its solar panel, *MGS* completed its primary mission of mapping the surface of Mars. *MGS*'s mission was extended, and the probe was given the job of collecting information on potential landing sites for future robotic landers. Since *MGS* could spot details as small as 10', there was a lot of information it could collect for future Mars missions. After studying Mars four times as long as originally planned, the batteries on the *MGS* orbiter died in 2006.

Mars Odyssey

Odyssey is the newest spacecraft, launched in 2001, to study the surface of Mars. See **Figure 4-16.** After *Odyssey* reached Mars, it used the technique of aerobraking that *MGS* successfully used. The focus of *Odyssey* is geology. In fact, its three primary instruments allow scientists to get a complete geological picture of the red planet. All these instruments involve ***spectrometers,*** which are instruments separating light into its different wavelengths to create spectra. Spectrometers allow scientists to determine what elements are present in an object. The Thermal Emission Imaging System (THEMIS) analyzes the distribution of minerals on the Martian surface, while the Gamma Ray Spectrometer (GRS) uses the gamma ray part of the light spectrum to study how Mars has changed over time by measuring the presence of 20 primary elements (including carbon,

oxygen, and iron). The last instrument, Mars Radiation Experiment (MARIE), monitors radiation levels on the surface.

Overall, *Odyssey* has four main goals. The first goal is to determine whether or not life ever existed on Mars. To achieve this goal, *Odyssey* looks for water under the Martian surface and searches for mineral deposits from past water on the surface. The second goal is to study the climate of Mars. The third goal is to analyze the geology of Mars using the THEMIS. The last, and ultimately most important, goal is to prepare for human exploration of Mars. MARIE collects data about radiation levels that will be used for future manned missions to Mars.



Figure 4-16.
The *Mars Odyssey* captured geological information about the surface of Mars, including radiation levels, mineral deposits, and surface climate. (NASA/JPL/Caltech)

Mars Express

Developed by ESA, *Mars Express* is a spacecraft currently in orbit around Mars. ESA named the spacecraft *Mars Express* because of the spacecraft's rapid development time. This spacecraft uses technology from the failed Mars '96 mission to search for water under the surface of Mars. *Mars Express* has seven scientific instruments onboard, including a high-resolution stereo camera, three antennas, and several spectrometers.

In its first four years of operation, *Mars Express* completed 5000 orbits of Mars. *Mars Express* was able to collect enough high-resolution images from the surface, because of its many orbits, that scientists were able to construct a three-dimensional model of a large portion of the planet's surface. ESA released a high-resolution Digital Terrain Model (DTM) of the surface that will allow scientists to virtually stand on the planet. See **Figure 4-17.**

Mars Reconnaissance Orbiter

Mars Reconnaissance Orbiter, launched in 2005, uses a new spacecraft design Lockheed Martin Space Systems created that is more efficient than any previous Mars orbiter. Compared to its predecessors, *MGS* and *Odyssey, Mars Reconnaissance Orbiter* is larger and more complex. During its five-year mission, the spacecraft needs to operate in four distinct mission phases. At launch, certain parts of the spacecraft, the antenna and solar panels, were folded to fit into the nose cone of the launch vehicle. After launch, the spacecraft opened its solar panels to begin power. The spacecraft's antenna also opened so it can maintain communication with Earth. During aerobraking, the antenna was moved to balance the solar panels. When the orbiter entered Mars' orbit, the configuration of the spacecraft changed again. The orbiter's scientific instruments were pointed at the surface of Mars, while the antenna and the solar panels tracked the Earth and the Sun, respectively. See **Figure 4-18.**

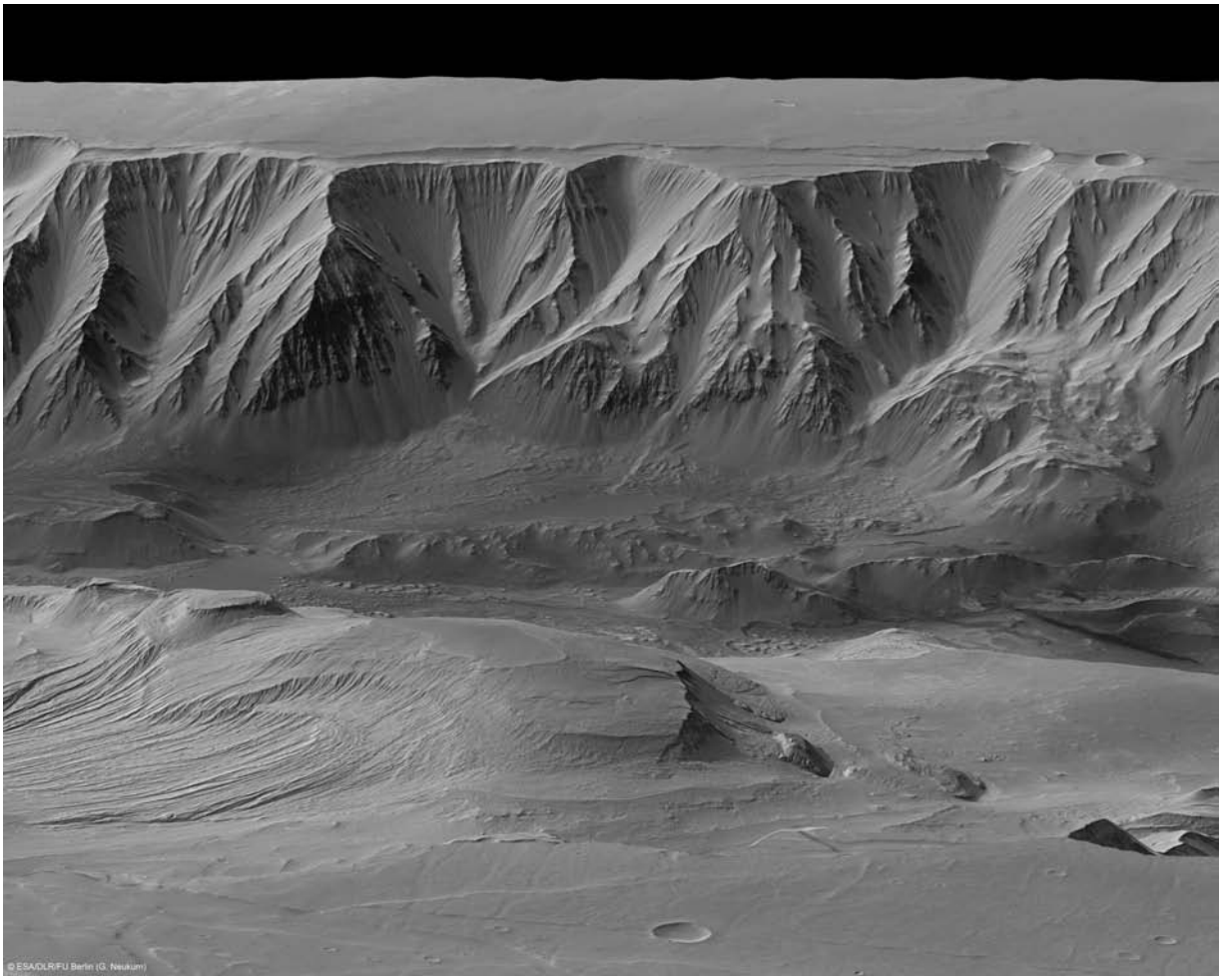


Figure 4-17.
Mars Express took snapshots of Candor Chasma, a valley in the northern part of Valles Marineris, as it was in orbit above the region on July 6, 2006. The High Resolution Stereo Camera on the orbiter obtained the data in orbit number 3195, with a ground resolution of approximately 20 m/pixel. Candor Chasma lies at approximately 6° south and 290° east. (ESA)

During its first half year of operation, the orbiter already sent over 11 terabits of data back to the Earth, equivalent to over 2000 CD-ROMs. *Mars Reconnaissance Orbiter* can collect 10 to 20 times more data than the previous Mars missions because of its complex equipment. During its primary science mission, the orbiter will collect information in three main areas: global mapping of Mars, detailed surveying of several regions, and photos of specific spots on the surface. Many of its observations will involve coordination between its instruments, allowing it to make simultaneous observations of the features of Mars. One instrument on the orbiter is the Shallow Subsurface Radar (SHARAD), provided by the Italian Space Agency, which is being used to look for liquid or frozen water in the few hundred feet below the surface of Mars. Finding water on Mars is an important step for the eventual manned missions to Mars.

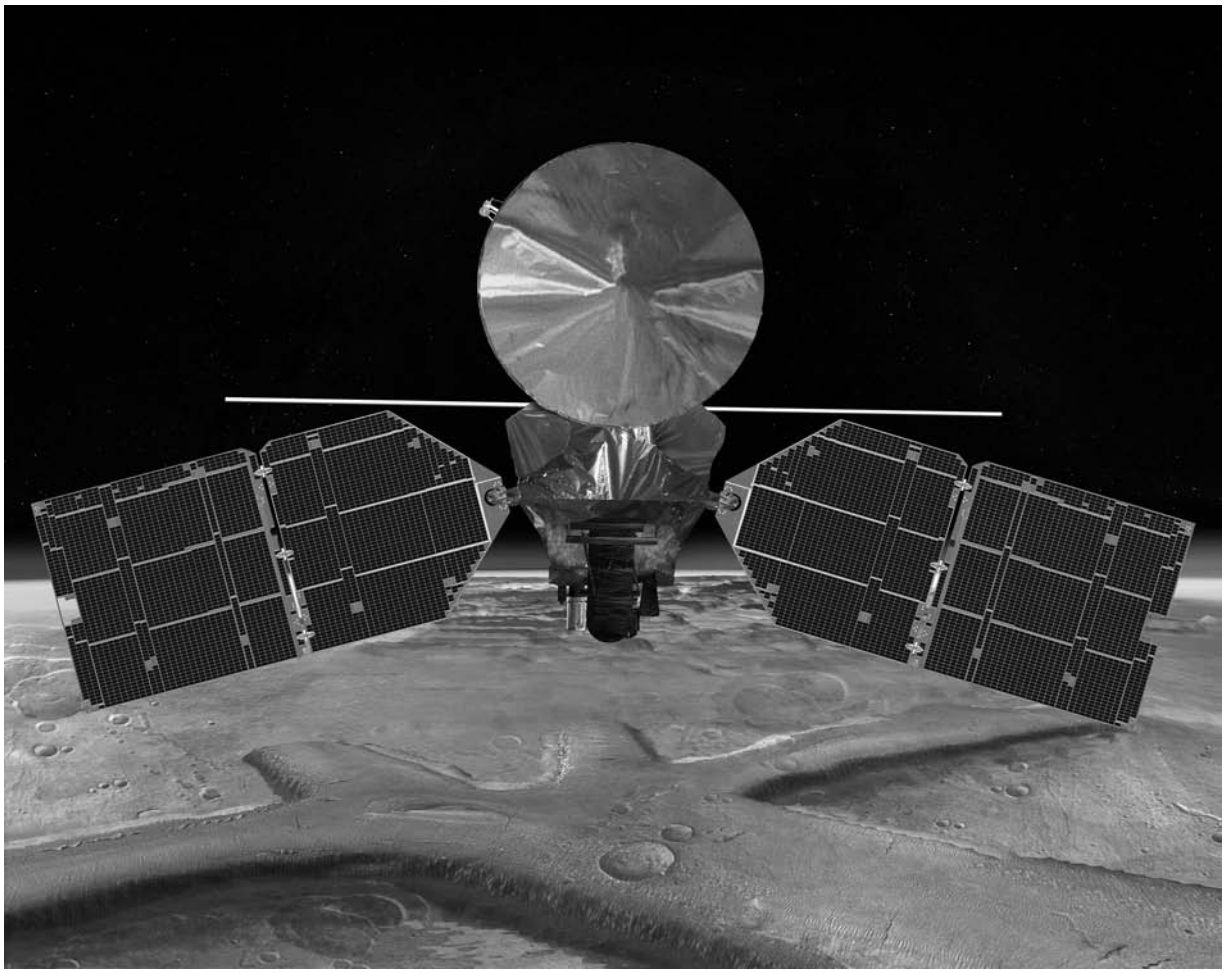


Figure 4-18.
Mars Reconnaissance Orbiter. (NASA)

Mars Reconnaissance Orbiter also will be used to support future Mars missions. The orbiter will use its radio to assist the new spacecraft. When *Phoenix Mars Lander* arrives at Mars, both *Mars Reconnaissance Orbiter* and ESA's *Mars Express* will record its data transmissions and then transmit the files to Earth.

Satellites

The successful launch of the first man-made satellite marked the beginning of man's exploration of outer space. Sometimes referred to as *handymen of the heavens,* artificial Earth satellites transmit communications at the speed of light, serve as military sentries, and explore the universe. These electronic servants are used to locate mineral deposits, provide incredible records of the world's weather patterns, transmit transcontinental phone calls, and guide ships through

darkness and storms. Acting as silent spies in the sky, some satellites maintain surveillance that sustains peace in our volatile world.

Just how many objects are floating around out there? As incredible as it may sound, the NASA Orbital Debris Program Office counted nearly 11,000 objects floating in space, although close to 70% of those items can be classified as ***space junk.*** For example, when satellites are launched into space, the rocket bodies, nose cones, and spent fuel containers all remain in orbit for a certain period of time. Other pieces of space junk are just accidents. In 2001, American astronaut Jim Voss added to the space-junk total when he dropped a foot-restraint system during a space walk on the *International Space Station.* Wherever the junk comes from, the North American Aerospace Defense Command (NORAD) tracks everything and watches objects as they fall from orbit, in order to spot things that should not be there, such as enemy missiles. Less than five decades after the Soviet Union's surprise launch of *Sputnik 1,* there have been more than 26,000 man-made objects shot into space.

NASA estimates there are 3100 active and inactive satellites in orbit. Regardless of who owns them, man-made satellites ultimately lose momentum and, therefore, altitude. Without additional servicing, their orbits decay, and they fall into the atmosphere to disintegrate. If the disintegration is planned, as with *Mir* and the *Compton* GRO, the target is usually the Pacific Ocean, between NZ and Chile, but not all reentries are as successful. *Skylab* crashed in Western Australia in the late 1970s, and a Russian spacecraft hit NZ's South Island. All the debris circling Earth makes it even more likely that unexpected landings will happen in the future.

Satellite Orbits

Just as artificial satellites come in a variety of shapes and sizes, so do their orbital paths around Earth. A satellite positioned in a geostationary orbit, or ***geosynchronous orbit,*** always stays in the same spot over the equator. Located some 22,300 miles away from the planet's surface, the satellites in this orbit move at the speed of Earth's rotation. This type of an orbit provides a prime location for both meteorological and communications satellites. When viewed from Earth stations, these satellites appear to be standing still.

Generally speaking, a satellite tends to remain in an orbital plane the latitude of its launch site defines. For example, a satellite launched from an equatorial site, such as ESA's Ariane base in French Guiana, will remain in an equatorial orbit unless a correction is made. U.S. satellites launched from Cape Canaveral have a lesser angle of inclination with the equator than Soviet satellites launched from higher latitudes do. Elliptical orbits are useful for placing satellites that make scientific measurements at differing altitudes, such as ozone levels. Satellites launched into a polar orbit can observe the entire surface of Earth as the planet revolves beneath them. The military commonly employs polar orbits to position its huge spy satellites. Finally, a Sun-synchronous orbit is one inclined a few degrees beyond Earth's pole. This type of orbit permits an imaging satellite, such as *Landsat,* to create pictures with the sunlight always striking Earth from the same angle.

By definition, a satellite's orbit is a condition in which the outward fling of the craft's speed matches the pull of Earth's gravity. There is an assortment of subtle pressures that can cause a satellite's orbit to decay, including solar flares and outer atmospheric disturbances. If a satellite starts

to wander off course, watchful ground crews can systematically fire its small fuel jets, steering it back into orbit. This procedure must be used sparingly, since the exhaustion of these gases spells the end of the spacecraft's useful career.

Commercial Development of Satellites

In just over 40 years, our society has become accustomed to its reliance on an assortment of satellites orbiting our world. The broadcaster's phrase "live via satellite" doesn't have nearly the luster it once had. Satellites have become indispensable tools to the communications industry, the scientific community, and our military personnel. It did not take long for space scientists to recognize the promise of satellites for the international communications network. Satellites were envisioned and described as great antenna towers in the sky that would be capable of transmitting messages almost instantaneously across oceans and landmasses.

The United States became quite active in the satellite-launching business during the early 1960s. *Echo I* became the world's first communications satellite and one of the largest man-made objects ever sent into orbit. This satellite was actually a huge Mylar® balloon covered with a thin coating of aluminum able to reflect radio signals from coast to coast. NASA launched the world's first weather satellite, called *Tiros 1.* Equipped with twin television cameras, this space farer returned pictures of Earth's surface for several months.

The Bell System's *Telstar I* satellite ushered in the era of live transatlantic television broadcasting. Unlike *Echo 1,* which passively bounced back signals, *Telstar* carried transponders powered by solar cells. These amplified signal strength thousands of times before relaying the signals to their destination. *Telstar* set a pattern for all following communications satellites. Since its orbit was low, it could relay messages only for short periods of time, while it was in the correct position between sender and receiver. If a newsworthy event was taking place in Paris, you might or might not have been able to receive the televised report in New York. In other words, the geostationary belt had not yet been utilized successfully.

Intelsat I was soon launched into a ***geostationary orbit***. Nicknamed "Early Bird," it provided the initial space link for a remarkable venture known as the International Telecommunications Satellite Organization (Intelsat). The Intelsat cooperative, headquartered in Washington DC, provides telecommunications services to over 144 countries using a fleet of 19 satellites. The participating agency for the United States is the Communications Satellite Corporation (Comsat). Intelsat's newest satellite, *Intelsat XI,* can juggle tens of thousands of telephone calls and several television programs simultaneously. By humble comparison, *Intelsat I* relayed up to 240 calls and carried a single television station less than 40 years ago.

Several more benchmark events occurred in the field of satellite technology during the 1970s. NASA launched a series of *Landsat* satellites that sent back television-like pictures and infrared images of distinct features of Earth's surface. These powerful tools have been instrumental in improving agricultural yields, locating oil and mineral deposits, monitoring volcanoes and other geologic events, and mapping optimal routes for railways and pipelines. The current version, *Landsat 7,* can capture and process 250 scenes each day. A joint agreement between NASA and the U.S. Geological Survey (USGS) currently governs the Landsat Program. In this partnership, NASA is responsible for the development

and launch of the satellite, and USGS is responsible for *Landsat*'s operation and for distributing and maintaining the data *Landsat* collects.

The history of space commercialization witnessed a milestone event in the mid-1990s. According to a study by the accounting firm KPMG Peat Marwick, commercial spending in space exceeded government spending in space. Satellite technology continues to progress and improve in recent years, with the addition of new capabilities for Internet and multimedia transmission, and as the number of satellites increases and the costs of these satellites decrease, companies have begun exploiting the untapped market for satellite images. One such company, TerraServer, went into business with a Russian government spin-off, Sovinformsputnik, which promotes and markets products developed through the Russian space program. TerraServer now markets high-resolution images taken from space to customers across the globe.

Along with the increased use of satellites in our daily lives comes increased dependence on them. Often, we are unaware of our reliance on these orbiting stations until a problem happens. The nation was reminded of the role satellites play in our everyday lives when the *Galaxy IV* satellite malfunctioned in the late 1990s and shut down 80% of the nation's 40 million pagers, as well as credit card authorization networks and video for cable networks. In order to restore service, thousands of ground antennas and satellites had to be moved—this process took weeks to resolve. Over the next two years, two other satellites malfunctioned. The first, in the late 1990s, disrupted the transmission of several organizations in the United States, including the Cable News Network (CNN), the Public Broadcasting Service, and the Associated Press. Also, in 2000, a problem in the ground stations interrupted satellite transmission for three hours from a number of U.S. satellites.

As more people in the United States utilize wireless technologies, such as cell phones, and entertain themselves through cable and satellite television, they have an increased dependence on the satellites providing these services. Although most people do not think of satellites as parts of their cable television networks, for example, a disruption would lead to an unwelcome lesson in the importance of satellites to our society. An increasing number of satellites are being launched—about 20 new ones each year. As satellites play an increasingly greater role in our communication, any possible disruptions have the potential to further affect our everyday lives.

Military Applications of Satellites

With increasing frequency, military officials look to the satellite industry for reconnaissance assistance. Subsequently, satellites are presently equipped with visible-light detectors, which can see an enemy's weapons directly, and infrared detectors, which can sense the heat a rocket exhaust plume emits during tests. Navigational satellites are the workhorses of the military's (and civilian) ***Global Positioning System (GPS)***.

The GPS is becoming a popular application of satellite technology for consumers, although it was first developed for military purposes. This system was originally designed to solve a persistent problem in warfare. During the heat of battle, with all the confusion and distractions, it is difficult for soldiers to determine their precise locations. At the same time, in order not to cause damage to their own tanks, trucks, and troops, military managers need to know where their troops are at all times. Since the GPS can give an exact position, it allows for more efficient mobilization of soldiers in battle.

The GPS works using a system of 24 satellites, including 3 spare satellites, positioned so a person on Earth can receive a signal from 4 of them at one time. A GPS receiver finds its location by getting signals from 3 different satellites. The DOD developed the GPS to provide navigation assistance to its forces. The GPS satellites have two different signals—military and civilian. The civilian signal is accurate to about 10–20 m, while the military signal is accurate to 3 m. See **Figure 4-19.**

U.S. forces used the GPS extensively during Operation Desert Storm in the early 1990s. Since the war was fought in a desert, it was very difficult, if not impossible, to move troops, especially during the night or in sandstorms. With the GPS, the soldiers could be moved quickly. This increased mobility led to a swift victory. Over 9000 GPS receivers were used by foot soldiers, on vehicles, on helicopters, in aircraft, and on Navy ships during Operation Desert Storm.

Today, the GPS is used in a variety of civilian applications. During construction of the Chunnel (the tunnel under the English Channel), there were two different starting points, one at each side of the Channel. One crew started from Dover, England, and the other crew started from Calais, France. These crews used the GPS to check their positions, so the two sides of the tunnel would meet. Scientific researchers use the GPS to provide accurate positioning in

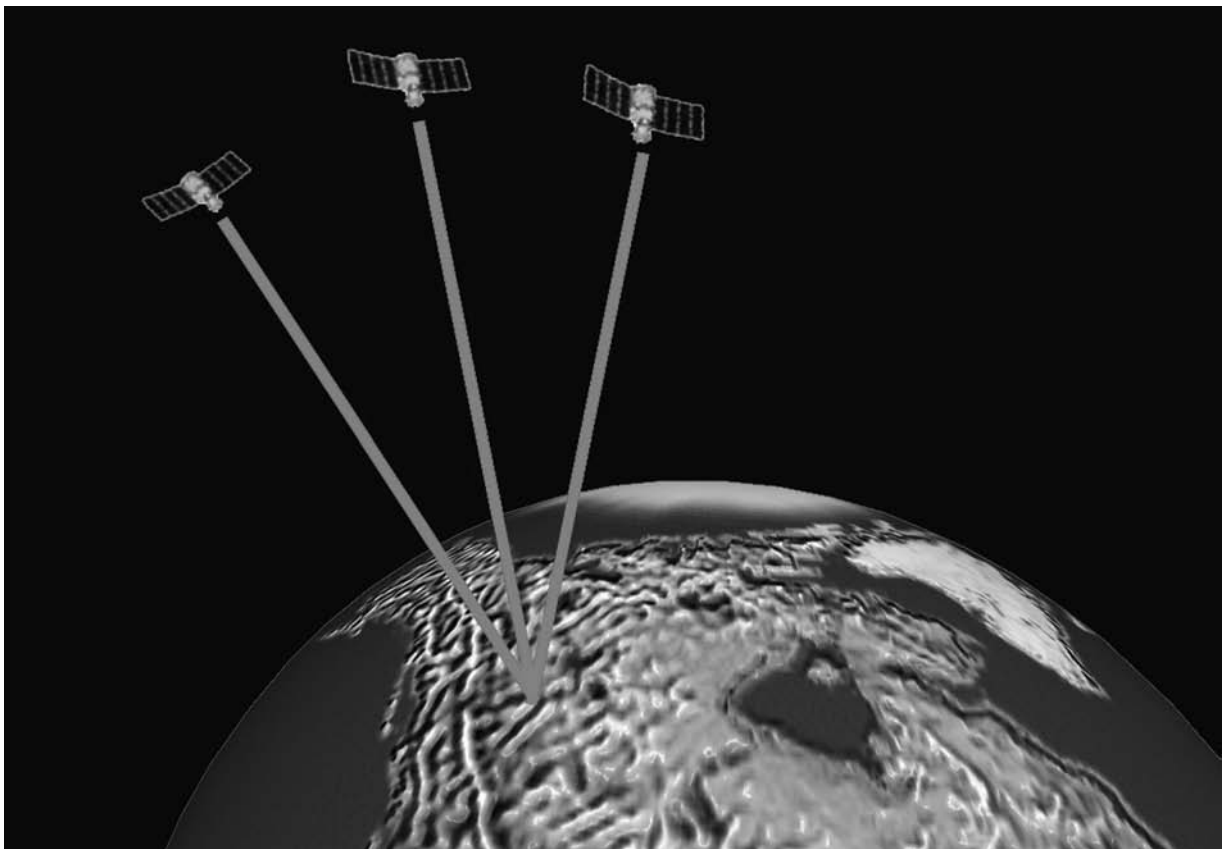


Figure 4-19.
How the GPS works.

survey work and to monitor the movement of the Earth's tectonic plates. Among the hundreds of other uses of the GPS, automobile manufacturers are now offering the GPS as an option in cars. Also, most new cell phones now include GPS chips that emergency services can use to locate a caller dialing 911.

The military uses satellites to provide communications, conduct reconnaissance, collect data for maps and charts, and gather information from natural and man-made disasters. Also, the military is involved in satellite technology that will stop the jamming of a signal. Today, one can buy a Russian GPS-jamming system, about the size of a cigarette pack, that can jam a GPS signal up to 80 km.

Despite the worldwide use of the GPS, other satellite systems are being developed to challenge it for global positioning. Galileo is a new satellite system ESA is developing. Unlike the GPS, Galileo will have 30 satellites and promises to be more accurate than the GPS. There are political motivations behind the development of the Galileo satellite system. The EU, which is co-funding the development, believes Europe should have an independent system so it can control a technology that is being more widely used each year.

As commercialization of space continues, the military is becoming more dependent on commercial companies. As mentioned above, the U.S. military used commercial satellites in Desert Storm for communication. This type of dependence allows for more flexibility, but at the same time, it increases the security threats for the United States. In its recent study on space, the Commission to Assess U.S. National Security Space Management and Organization, sponsored by the DOD, recommended increased funding to address national-security issues in space. This Commission believes future military conflict in space is a virtual certainty. The Commission to Assess U.S. National Security Space Management and Organization recommended that the United States increase funding for space defense and develop superior space capabilities because of the perceived threat of enemy action from space. Whether or not Congress will grant this wish in a time of budgetary constraints is unclear.

Future Developments in Space Exploration

For as long as historians have kept written records of society, they have been mindful of one simple tenet, or principle: A civilization that ceases to explore begins to die. For five decades, government officials around the world have shown interest in space exploration—some more than others. At the same time, however, only a very small percentage of our civilization is involved in space exploration. Since the costs of space exploration are high, the potential benefits might be too small for most people to justify these costs.

The United States and Russia have been the primary players in this exploration game. The Russian government has made slow, but steady, progress toward the attainment of a series of long-term objectives characterizing its national space program. On the other side of the ocean, the U.S. program has made great technological leaps, some of which appeared on the scene in flashy, explosive spurts, toward the completion of short-term projects. It is imperative for the U.S. government to make some hard decisions and then adhere to some reasonable long-term goals in space.

The Future Goals of the National Aeronautics and Space Administration (NASA)

Sally Ride, the first woman astronaut in space, headed a NASA task force in the mid-1980s that looked to develop new priorities for the space program. The task force developed four future scenarios for NASA:

- ❏ Conduct Earth studies to collect information and knowledge for the protection of the world's environment.
- ❏ Accelerate the unmanned mission program to explore the Moon and other planets in the solar system using robotic explorers. As a forerunner to human-tended outposts, NASA should consider launching a robotic lunar prospector to examine the entire surface of the Moon.
- ❏ Resume manned visits to the Moon. These should not be for brief expeditions, but for longer, systematic explorations, culminating in permanent settlements.
- ❏ Conduct a manned expedition to Mars.

As we can see from the recent space expeditions discussed in this chapter, NASA has pursued this strategic plan, particularly with respect to the exploration of other planets in our solar system. Since the mid-1980s, however, there have been political changes on Earth that have dramatically impacted the space program, including the end of the cold war and the high amount of international collaboration in space travel. Both of these events have caused shifts in the future prospects in space from an adversarial competition between the United States and the Soviet Union to cooperative relationships among the Americans, Russians, Japanese, and Europeans. Today, almost no major space mission is conducted solely by one country. Therefore, NASA's future has to be reevaluated in light of this new political environment. Also, the public's support for the space program has waned since the years of the Apollo Program. Unless NASA recaptures the optimistic imagination of the American public, it will be difficult for NASA to fund its ambitious projects in the future. In 2007, NASA released its strategic plan for future space exploration because of its awareness of the changing nature of space exploration. Imbedded in this plan are short- and long-term goals for NASA and NASA's international partners in space. The new vision for NASA has the following goals:

- ❏ Complete the *International Space Station.*
- ❏ Safely fly the space shuttle until 2010.
- ❏ Develop and fly the crew exploration vehicle *(Orion)* no later than 2014.
- ❏ Return to the Moon no later than 2020.
- ❏ Extend human presence across the solar system and beyond.
- ❏ Implement a sustained, and an affordable, humans-and-robotics program.
- ❏ Develop supporting innovative technologies, knowledge, and infrastructures.
- ❏ Promote international and commercial participation in exploration.

As part of its strategic plan, NASA wants to develop the ability to send humans further into the solar system. The vision includes a new launcher to replace the space shuttle, a lunar base, and a series of robotic missions to the Moon and Mars. NASA is hard at work developing the *Ares* rocket to replace the space shuttle as a transport vehicle to the Moon and the *International Space Station.* The *Ares* rocket will launch the *Orion* crew exploration vehicle, which is similar in shape to, but much bigger than, the old *Apollo* spacecraft. The larger size will allow *Orion* to take four astronauts to the Moon and six on missions to the *International Space Station* or Mars-bound spacecraft.

In the future, NASA sees a series of telescopes and remote structures further away from Earth. NASA will rely more heavily on international cooperation in its quest to lead space exploration in the twenty-first century. A challenge of this magnitude might actually foster global unity and a healthy attitude toward living together in harmony on Earth.

Future Exploration of Mars

There are two prongs to future exploration of Mars. In the long term, NASA has the goal of sending a manned mission to Mars. The technical, economic, and social constraints of this manned voyage place it far into the future. For the short term, NASA and the other space agencies are content to send increasingly complex unmanned missions to study this planet. Europe is making a major contribution to the unmanned exploration of Mars with ESA's *Mars Express* mission. NASA has several missions of its own now at Mars (see the previous section "Exploring Mars"). Building on the success of the Mars twin rovers, NASA plans another rover mission before the end of the decade. NASA also wants to add more scouting missions to Mars. These unmanned missions will add to the data the satellites presently in orbit around the planet provide.

All these missions lead to the next logical step, the collection of a sample of Martian soil and its return to Earth, targeted for sometime in the 2020s. Presently, the design of this mission would involve a U.S. lander and rover to collect the samples, which would be returned into Mars's orbit by rocket. A French orbiter would pick up the samples from the rocket and return them to Earth's orbit, where a space shuttle would pick them up. Even at this early stage of planning, the cost for this sample-collecting project is estimated at $1 billion.

These missions and probes are designed for the ultimate goal—a manned mission to Mars. Although far in the future, an international consortium of space agencies is already planning the first steps to this mission. NASA has written its first manual for the Mars manned program, titled "The Reference Mission." The first and most critical aspect is crew safety, which includes both the takeoffs from and landings on Earth and Mars, as well as the long trip and the stay on Mars. Any crew will have to spend about 4 to 6 months in transit to Mars and up to 20 months on the surface. The transit portion of the trip is most dangerous for crew safety, as the astronauts will be exposed to radiation and under conditions of zero gravity. NASA is considering a split-mission strategy, which would use multiple launch vehicles. The surface equipment, surface living structure, and return vehicle would be sent to Mars in a series of three flights. The crew would arrive on a different spaceship 26 months later. The crew would then connect with the surface equipment on their arrival at Mars.

Any manned mission to Mars will require new technologies. Obviously, a mission of this length has never been undertaken before, and along with the development of new technologies, there needs to be increased research on the pressures of living in space for a prolonged period of time. Astronauts will have to live for an extended time in a close situation and will likely feel isolated, vulnerable, and unprotected from the dangers of space. In addition to their technical expertise, these Mars explorers will have to be experts in conflict negotiation and diplomats. All these factors will stress the crews as they undertake their mission.

Bioastronautics

When Soviet cosmonaut Valentina Tereshkova became the first woman in space during the early 1960s, there was more than the normal amount of concern about her well-being. Although she experienced some space sickness, she returned home essentially unscathed, following a successful mission. She later married a fellow cosmonaut, and they gave birth to a healthy daughter, who was the first child to be born of parents who had both traveled in space. This incident calmed some of the fears that spaceflight might expose human hereditary material to damaging radiation. Nevertheless, two decades passed before either the United States or the Soviet Union included another woman onboard its space vehicles.

Throughout the entire space program, NASA has studied and monitored astronauts' reactions to weightlessness and an assortment of conditions associated with prolonged periods of confinement. With the end of the cold war, much of the research on long-term space exposure Russian scientists conducted has become available to other space agencies, including NASA. Also, the joint U.S.-Russian *Mir* missions in the 1990s provided additional information about the effects of space travel on human beings.

Weightlessness is not the only threat to the safety of astronauts. Sanitation is an important issue. Studies from space show that some microbes can multiply quickly in a zero-g environment. This was a severe problem on *Mir.* The space station experienced widespread fungal growth. So, all potential contamination sites in space—dining areas, toilets, and sleeping areas—must be cleaned and sanitized regularly. On the *International Space Station,* garbage and trash are sealed in plastic bags to reduce the levels of dangerous microbes.

When NASA selects someone to ride the space shuttle, the chances are pretty high that one of his first experiences onboard will be throwing up. Don't worry—he won't be the first to encounter this reaction! In the first few days in space, about one half of astronauts suffer from nausea, sometimes accompanied by vomiting. Within the astronaut corps, few emotional subjects are discussed more than space sickness. Although it would rather not discuss its astronauts' complaints in public, NASA refers to this malady as ***space adaptation syndrome.*** This syndrome continues to be a number one medical concern of space agencies internationally. Besides the urge to vomit, other undesirable effects of weightlessness include lethargy, lack of appetite, drowsiness, stomach awareness, malaise, cold sweat, and nausea. As you can well imagine, even the most physically fit person's productivity level is bound to suffer radically under these conditions.

Researchers have found that humans gradually adapt to the microgravity environment, and these afflictions tend to subside. This process of adaptation to an environment devoid of gravity (zero-g) comes with a complement of other side effects, however. After a few days, an astronaut's body experiences what is called *deconditioning,* in which muscles grow weak and the heart and blood vessels do not operate as fast as normal. After a few months in space, an astronaut's body undergoes another change, a loss in minerals that weakens the bones. The two Soviet cosmonauts who spent close to eight months aboard the *Salyut 7* space station could barely stand when they returned home. Their back and leg muscles had atrophied, and their hearts had shrunk, due to a severe loss in blood volume. Much of the calcium had been sapped from their bones.

Physicians and scientists who are interested in this process of adaptation and readaptation in all life-forms have created a science called *bioastronautics.* Quite simply, ***bioastronautics*** is the study of life in space. The discipline grew out of sophisticated engineering feats directed toward a reconciliation, or harmony, between biology and hardware. This is the study of how technology can be used to sustain life (natural biological processes) in space-faring vessels.

BIOASTRONAUTICS
The study of how living organisms adapt to conditions of weightlessness and then readapt to life on Earth.

In recent years, bioastronautical studies have shown that space hardware is not necessarily synonymous with high technology. One problem space doctors were asked to confront involved how to restrain an incapacitated astronaut. NASA's first solution was a cumbersome and costly system of bungee cords. Their next solution came from a recommendation an astronaut who had ridden aboard *Columbia* on the fifth shuttle mission made. He told medical experts to use duct tape to hold them in place! Apparently, he and his colleagues had used a lot of duct tape to stick things down on that particular voyage. Duct tape has since become a standard item in the onboard shuttle first aid kits. An indirect consequence of this incident is related to the fact that hardware development is no longer the main preoccupation of bioastronautics research. In the past few years, increasing emphasis has been directed toward the study of physiological changes in zero-g environments.

The absence of gravity causes acute changes in the cardiovascular system, muscles, bones, and metabolism. As humans adapt to life in space, they unadapt to life on Earth. A sudden return to a one-g environment could overload a weakened heart or snap demineralized bones. Based on the records of the cosmonauts on *Mir,* astronauts today can minimize, although not eliminate, some of the effects of zero-g environments. Astronauts use either a centrifuge bicycle or a treadmill every day to minimize deconditioning of their bodies. Despite intensive exercise while in space, an astronaut's body still is weakened. American astronaut Norm Thaagard spent four months on *Mir* during the joint missions with Russian cosmonauts. When he returned to Earth, he had a 20% muscle loss from his calf muscles and a 10% loss from his thigh muscles. Also, he had anemia, caused by a 20% drop in his red blood cell mass. Two years after his flight, he had not completely recovered from the mineral loss. Muscle loss and bone loss do not appear to be the only problems. A study of all astronauts in the U.S. program since its inception found that astronauts are at an increased risk of getting cataracts because they are exposed to higher doses and different patterns of radiation than pilots on Earth.

It is possible that one of the most serious problems in bioastronautics at present has nothing to do with bioengineering, adaptation, or medicine. A lack of useful data generally cripples space doctors, regardless of their assignments. Ask them a simple question, such as, "Is heart disease more common among astronauts than among the U.S. general public?" Most physicians will tell you that the current sample of astronauts is not large enough to provide a valid response to your inquiry. A fundamental rift between ground-based scientists and the astronauts themselves further aggravates the problems associated with obtaining reliable data. Since astronauts insist on limited veto rights over medical experiments, many potentially significant studies never receive sanction.

In view of all the studies still to be done, bioastronautics has firmly established itself as a scientific discipline for the present and future space programs around the world. Mounting interest in space station habitation has led to enthusiasm in the space-science community. Over the past decade, NASA's budget has included funding research about methods that will improve the health and safety of astronauts. Some space doctors hope their space biology, psychology, and sociology will produce yet another field of study—space civilization.

Summary

It is difficult for most of us to imagine how it feels to be lifted off the ground by huge rockets, onboard a vessel destined for outer space. Unlike the early days of the astronaut program, however, a greater number of people who dream about space travel might actually earn the opportunity to pursue those dreams. Several futurist writers have prepared optimistic scenarios regarding space colonies and the development of a whole new civilization in space. Their portrayals of the future do not seem to exclude the layperson in favor of the scientist or astronaut. Other journalists paint a less optimistic view of our space program, insisting there are still too many unknowns, and a fair percentage of the known factors seem speculative.

The unmanned space missions of today are providing a tremendous amount of scientific information about the nature and origins of our solar system. The impact on the normal citizen, however, is not as clear. People around the world have gazed at the heavens for centuries. The technological devices that have been developed to enhance this age-old pastime are truly impressive. NASA is certainly not without its shortcomings, but its list of accomplishments cannot be ignored. The future will bring more countries into the space race and possibly more cooperation from these countries on joint goals.

The mysteries of space travel have not only intrigued us, but we have also become accustomed to the technological by-products of space travel's investigation. Outer space truly is mankind's final frontier. Our destiny there will unfold for many years to come.

Discussion Questions

1. Identify and describe at least three long-term projects for NASA, as it leads this nation's space program into the next century.
2. In your best judgment, what was NASA's primary motivation when it presented the Space Shuttle Program proposal to government officials in the early 1970s? If you had been a congressional representative at that time, would you have been favorable toward NASA's bid for financing? Why, or why not?
3. Choose one of the orbiting space telescopes. Visit the telescope's Web page and write an essay describing the telescope's contributions to science.
4. What is the difference between a geostationary orbit and a polar orbit? Explain why an operator would request either orbit for the location of its satellite.
5. Prepare a list of pros and cons you would consider for critical evaluation before making a decision to spend 90 days working onboard an orbiting space station.
6. Write a short (500-word) newspaper article on the *International Space Station.*

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Space Imaging's *IKONOS* satellite took this image of Invesco Field and Mile High Stadium in 2001 from an orbit of 423 miles above Earth. *IKONOS* is the world's first and only commercial, one-meter-resolution, Earth-imaging satellite. (Space Imaging)

Chapter 5

Breakthroughs in Medicine

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DATELINE

East Syracuse, New York

This city is the location for the center of excellence for process development and remains the only commercial fermentation plant in Bristol-Meyers Squibb's system. Scientists here make the foundation of a drug that gives breast-cancer patients a new tool with which to fight their disease when other chemotherapies have failed. The company worked on this drug for years following its initial discovery in 1997 and then submitted it to the federal government for approval. The FDA recently approved the IXEMPRA® (ixabepilone) drug for use in patients with metastatic or locally advanced breast cancer. This marks the second time in two years that the East Syracuse facility has worked on a drug the FDA eventually approved.

The IXEMPRA drug is made through a fermentation process. See **Figure 5-1.** This drug is designed to inhibit the growth of cancer cells by binding to their microtubules. Microtubules are structures within cells that support and shape them, also playing a role in their division. The drug has been approved for use by itself or in combination with another cancer drug called *capecitabine.* The first step in manufacturing the IXEMPRA drug is done in central New York, and the product is shipped to Bristol-Meyers Squibb's plant in Swords, Ireland for finishing. The East Syracuse scientists are constantly working on new products, and they were delighted to receive this news during breast-cancer awareness month.…

Introduction

Most of the sociological surveys that have been conducted to determine how people feel about the advancement of technology seem to report at least one common finding. Respondents tend to be in general agreement with regard to the positive influence technology has had on their physical well-being. Technology has made us healthier and increased the average life span for human beings throughout the world. People often look to the medical discipline for examples of significant technological breakthroughs that are beneficial to society.

Technology has made numerous and diverse contributions to medicine over the years. Some historians use the medical field to chart the chronology of technology. It has become increasingly evident over the past few decades that, in our society, science and technology have dominated medicine and the health-care system in general. At the core of most contemporary diagnostic and treatment procedures, one finds a host of technological devices (hardware) and control systems (software). These devices are the machines that can extend our human capabilities and serve to separate us from the perils of the natural environment. An assortment of computerized and electronic control techniques and systems has been developed to monitor, evaluate, and operate these devices.

We are living in an era of medical miracles. Many persons look to doctors as the new "priesthood," who they believe can cure any illness, as long as the doctors have access to advanced technologies and treatments. Some of the more visible medical forces that



Figure 5-1.
Industrial fermentation tanks similar to those used by Bristol-Meyers Squibb in the manufacturing processes for various drugs. (Kafziel)

have entered the awesome war against injury, disease, and distress include laser surgery, electronic painkillers, over-the-counter detection kits, in vitro fertilization (IVF), artificial organs and body parts, genetic therapy, computer-assisted robotic surgery, a variety of new vaccines, stem cell research, antibiotics, and "smart" nanotechnology methods of delivering drugs into the human body. Individuals who would have had a minimal chance for survival less than 20 years ago can presently look forward to a normal, healthful existence. In some ways, these technological accomplishments have begun to serve the purposes that religious ritual once did. Technology conveys the hope and promise of vitality and longevity. In addition to everlasting life in heaven, we yearn for everlasting life in this world.

Despite the many promises medical technology affords, some observers believe the medical profession is experiencing overwhelming dependency on new technology. During the first half of the twentieth century, medicine focused largely on the observation of disease from a relatively passive clinical and diagnostic perspective. Today's medicine is dedicated to the aggressive treatment of disease from an applied scientific point of view. The medical profession embraces and endorses modern technology and the many contributions it has made to the diagnosis and treatment of its patients. The practice of medicine has changed over the years, with

increased access to medical information, the narrowing of both educational and socioeconomic gaps between physicians and patients, and myriad technological changes. In the face of these changes, the importance of the doctor-patient relationship has not diminished.

As with all the other narratives we provide concerning technological advancement, the blessings of modern medicine cannot be counted without also reviewing the negative aspects. It seems the rise of medical technology should be paving the way for better medicine. While technology is doing just that, the burden of absorbing new technical information has landed squarely on the physicians' shoulders. Doctors are confronted with the almost full-time problem of keeping up with new technologies and procedures in order to provide the best patient care (and to avoid malpractice suits). The pace of new discovery in the medical field is so intense, even recent graduates of premier medical schools are likely to be out-of-date in a few years. Dramatic increases in the amount of available clinical information about treatment effectiveness make it even more difficult for doctors to acquire and retain all the information they need to make sure they order all the appropriate services for all their patients.

This makes matters even more stressful because keeping up with the latest advances in one's own field of specialization is not enough any more. Doctors have become anxious about technology in general. In some cases, if they are not familiar with the latest discoveries in other fields, they might be deemed negligent for failing to make a referral. The Internet has led to the evolution of a more informed, educated patient, who is quite interested to take an active role in medical decisions and procedures. The role of the physician is often being altered from one of "keeper" of information to one of interpreter or integrator of information for patients.

Technology, in the medical industry, can be loosely defined as the rational selection and use of devices and procedures toward the achievement of measurable, useful, and relatively immediate human outcomes. There are both costs and benefits associated with the technological breakthroughs that have been made in health care. The first part of this chapter examines the current status of health care and medical interventions in our society. Technology's influence is then examined through a review of some of the major advances that either have taken place recently or are still being developed. The extent to which people are able to afford many of these high-tech miracles is presented as an issue demanding much attention. The authors provide a foundation for discussion that will provide insight, with regard to the following questions:

- What are some of the critical issues needing to be addressed, if the profile of the medical profession and the technology associated with this profession are to retain or regain positive ratings in our society? Can the health-care and wellness-promotion industry function effectively in our contemporary world to respond appropriately to persons in need of physicians' care and assistance?
- Should medical specialists be encouraged to become less dependent on machines in their treatments and diagnoses? Is contemporary medicine addicted to having a technological fix for each and every physical or mental condition?
- Why does it seem that what can be done, in terms of health-care technology (sustain life in a brain-dead patient by machine or other medical intervention), is sometimes a lot clearer and easier to understand than what should be done (shut down the machine, discontinue medication, or use every available resource to sustain life)?

- ❑ What projections are being made with regard to the future cost of high-tech (or even low-tech) medical treatments? What factors influence the cost of health care in the United States?
- ❑ How have the introduction of over-the-counter home health-detection tools and diagnostic-test kits and the availability of medical documents and technical information on the Internet affected the role of the medical profession in society?
- ❑ What sorts of moral and ethical concerns regarding quality of life have surfaced as a result of medical breakthroughs in areas such as minimally invasive (MI) surgery, nanotechnology, and procreation?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

advance directive
amniocentesis
balloon angioplasty
coronary angioplasty
cybermedicine
diagnosis-related group (DRG)
false negative
false positive
fetoscopy
health maintenance organization (HMO)
in vitro fertilization (IVF)
laser
lithotripter
minimally invasive (MI) surgery
nanotechnology
pharmacogenomics
preferred provider organization (PPO)
preimplantation genetic diagnosis (PGD)
ultrasound

A Profile of Health Care in the United States

More progress has been made in medicine over the past few decades than through all of history. Technological innovations including artificial joint replacements, artificial heart valves, heart-lung machines, robotic surgical assistants, cardiac pacemakers, and even brain pacemakers have been introduced. Medical procedures such as organ transplants, microsurgery, coronary bypass surgery, angioplasty, kidney dialysis, MI surgery, and amniocentesis are being performed with increased regularity and success. We have access to new diagnostic systems for studying the interior features of the body, including computerized axial tomography (CAT), magnetic resonance imaging (MRI)—also known as *nuclear magnetic resonance (NMR),* and the use of endoscopic instruments. See **Figure 5-2.** Several very "smart" new drugs, edible vaccines, and chemotherapy agents such as the one mentioned in the *Dateline* for this chapter have arrived on the scene. Advancements in genetic engineering (previously discussed in detail in Chapter 2) and in a discipline known as *tissue engineering* are bringing us closer to being able to treat and possibly cure various forms of cancer and actually design and grow living replacement body parts.

This brief introduction, as futuristic as it might sound, barely scratches the surface of the numerous technological and scientific breakthroughs that have occurred in recent years. The benefits, in terms of increased longevity and human productivity, associated with these accomplishments are very noteworthy. The United States, however, has the absolute highest medical expenditures of any nation in the world. We presently devote more than 16% of our gross domestic product (GDP) to the medical and health



Figure 5-2.
Radiology has emerged from the ranks of fuzzy pictures of broken bones to color images that diagnose brain disorders, heart attacks, and epileptic seizures. The image shown here is a product of an MRI technique. This highly sophisticated technique works by creating a very powerful magnetic field around the patient and bombarding her with radio waves. When these waves are withdrawn, hydrogen atoms in the body emit a radio signal reflecting the difference between healthy tissue and damaged tissue. A primary advantage for the patient is the absence of radiation damage. (El Camino Hospital, Mountain View, California)

care of our citizens. Figures computed in the middle of the first decade of the twenty-first century revealed that approximately $6000 per person were spent on health care per annum in this country. These figures compare with $1500 for each citizen in the mid-1980s, when approximately 10% of our GDP went to health care. This overview of trends in our health-care system indicates that a most critical issue demands effective strategies to contain these soaring costs in the years ahead.

The medical era preceding World War II was a bit simpler, with regard to services practicing physicians rendered. Most family doctors were generalists, and most patients paid what they could afford for their own care. Since patients most commonly had to pay for medical services themselves, doctors often felt obligated to adjust their fees to match individual financial capabilities. During this earlier time period, the number of physicians was much lower than today. Most physicians saw and treated as many patients as they could handle. There was little economic incentive to do any more for an individual patient than was clearly essential. Sophisticated medical technology was not widely available.

More often than not, primary-care physicians were diagnosticians who, having finished medical school years earlier, provided their time, personal attention, general physical examinations, guidance, house visits, advice, and local pharmacy prescriptions. All this has changed dramatically as the technology and organization of medical practice have become more specialized, complex, and expensive. In fact, finding a local doctor such as the one described above in your hometown is becoming nearly impossible, except perhaps in remote rural areas. This might be due, in part, to the smaller number of medical students who select residencies leading to careers in primary care (for example, internal medicine, pediatrics, geriatrics, and family medicine). During the last two decades, a much greater percentage of medical-school graduates opted for specialist practice, in which they were trained to use high-tech diagnostic and therapeutic procedures. In a recent study the Center for Studying Health Systems Change completed, we learned that today's physician workforce is not selecting specialization or practice locations in sync with

the country's medical needs. Among those U.S. physicians who work more than 50% of their work hours each week providing direct patient care, only 37% specialize in primary care. Since the mid-1990s, the supply of medical specialists (such as cardiologists, oncologists, and gastroenterologists) has increased significantly, with a reduction in the supply of primary-care doctors.

The profile of the medical profession in the early twenty-first century portrays a dynamic interplay among several factors—medical-care costs, a better-informed citizenry, phenomenal technological changes, and confusing health insurance and health-care options. Further, U.S. Bureau of the Census projections reveal that we are an aging society, due to the huge size of the baby boom generation (those people born between the mid-1940s and the mid-1960s). See **Figure 5-3.** This fact alone is expected to heighten the overall demand for health care significantly over the next several decades. Furthermore, the types of care elderly people are going to require will often be for serious and complex end-of-life illnesses. The times are not calm for medical professionals. The individuals in our country who are responsible for the practice of medicine to ensure public health and our individual rights to physical well-being are under intense public scrutiny.

There are many other factors emerging to influence health-care systems in the United States. A few of these include government intervention, insurance-coverage and -premium subsidies, changing health-care delivery methods emphasizing more outpatient treatment, lack of price competition among providers, and malpractice litigation. When you add these items together, it is no

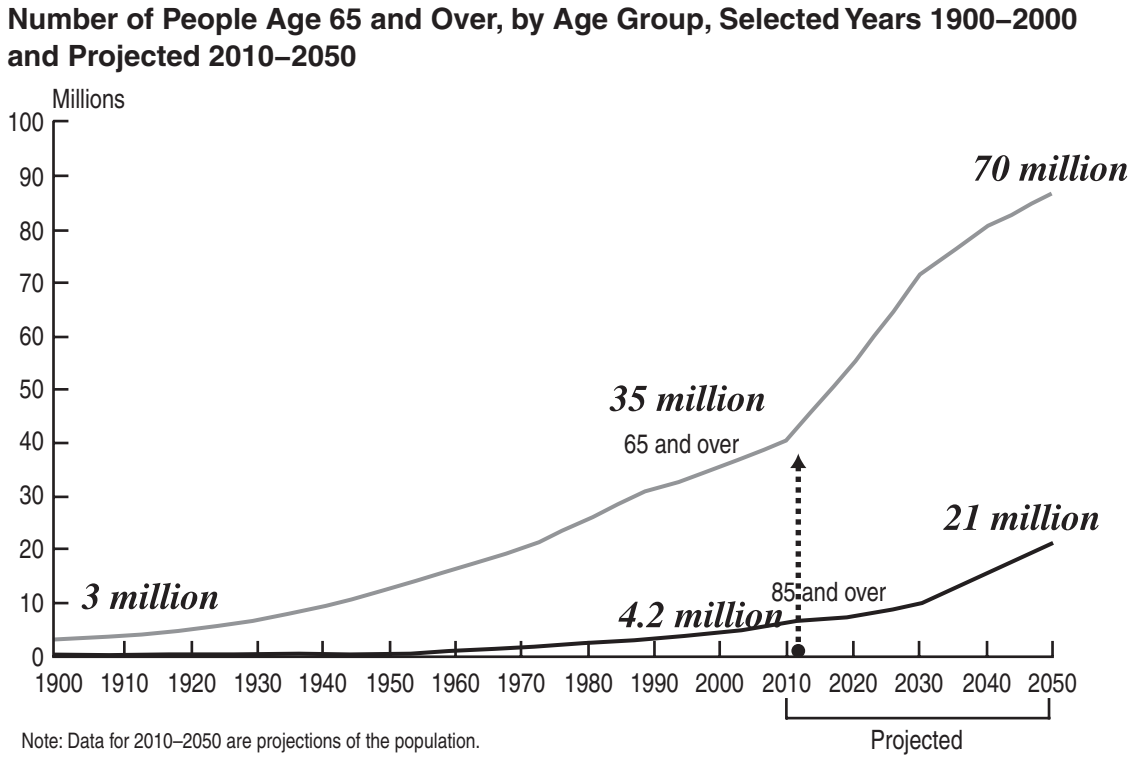
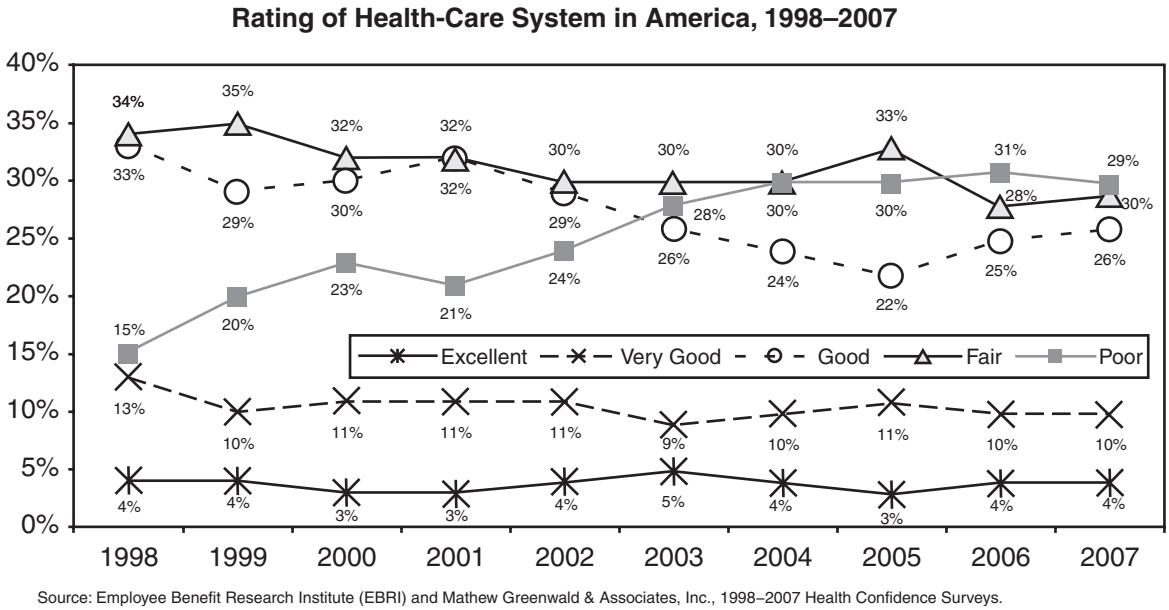


Figure 5-3.
The aging of our society. (Adapted from the U.S. Bureau of the Census, Current Population Reports. 2000.)



Source: Employee Benefit Research Institute (EBRI) and Mathew Greenwald & Associates, Inc., 1998–2007 Health Confidence Surveys.

Figure 5-4.
The EBRI survey results—rating of the U.S. health-care system from 1998 to 2007. (Adapted from EBRI and Matthew Greenwald & Associates, Inc., 1998–2007 Health Confidence Surveys.)

wonder there is growing pressure to contain rising medical expenditures emanating from the general public, government officials, private insurers, and the business community at large.

The results of a mid-1990s Harris Poll revealed that only 16% of Americans believed our health-care system in this country was working pretty well. More recently, in a study the American Society for Quality executed, health-care costs ranked above the Iraq War, the rising cost of fuel, and global warming, as the most pressing concern for adults in the United States. **Figure 5-4** illustrates findings obtained through an Employee Benefit Research Institute (EBRI) study. The results reveal that a much higher proportion of the population rates our health-care system as fair or poor, versus very good or excellent. As one looks further into the data, however, this discontent is due more to high costs than dissatisfaction with overall quality of the care received.

It is imperative to determine what sorts of trade-offs will ultimately be necessary to bring the cost of health care to a tolerable level. By comparison to the more than 16% of our GDP expended on health care, most developed countries with universal coverage have stabilized their health-care costs at right around 8% or 9% of their GDP. It is difficult to admit that, despite our economic sophistication, our scientific expertise and advanced research, and our high-tech medical interventions, we have much to learn from our international partners. The following sections introduce several topics pertinent to the contemporary state of affairs in our nation's health-care system.

A Concern for Quality

We live in a society quite prone to seeking technological solutions to its problems. Our use of and reliance on medical technology to extend and sustain life illustrate part of

this tendency. Medical specialists often adopt and become skillful at using technology more so than generalists, due to their advanced training. Hospitals invest in more expensive equipment in order to present a higher-quality and more prestigious image to the local community. Furthermore, some financing plans and government policies seem to have stimulated the use of technology at almost any expense.

Specifically, the buyers and users (patients and doctors) often make use of expensive and highly specialized technology interventions and breakthrough medications. Hospitals today are grappling with soaring labor, drug, and technology costs. In other nations where there is a single health-care system, reimbursement rates are relatively fixed for physicians, hospitals, and pharmaceuticals. In the United States, our mostly private system makes it possible for brand-name medicines and new medical technology to be available to doctors and their patients more quickly. While none of us really want to reverse the quest for new scientific discoveries, the availability of new interventions means they might be used more often, and perhaps when not necessary. Further, the Medicare Modernization Act of 2003 does not allow Medicare to bargain with drug manufacturers. Therefore, this large federal program is unable to wield its significant purchasing power to bring prices down.

Despite the fact so much money is being spent on health care, the United States encounters serious quality problems throughout its health-care institutions and practices. From time to time, leading national newspapers have run feature stories about quality problems with local doctors, hospitals, clinics, and nursing homes. Undoubtedly, you could find a story of this genre in your local newspaper if you simply reviewed last week's seven issues. Intense policy discussions among physicians' organizations, hospital administrators, quality consultants, and legislators typically follow these types of media releases. One such flurry of dialogue prompted Congress to create the Agency for Health Care Policy and Research (AHCPR) in the late 1980s. This government agency was given a mission to invest in research on the effectiveness of health-care services (what exists); develop guidelines to assist providers in improving quality (what should be); and make recommendations to Medicare and Medicaid, regarding the drugs and medical devices these agencies should cover.

As numerous studies the AHCPR directed were completed through the late 1980s and early 1990s, it became evident that our nation's health-care system continued to experience serious and widespread quality problems. One of the agency's studies that nearly caused AHCPR's elimination in the mid-1990s focused on the creation of guidelines for the treatment of acute lower-back pain. The agency's recommendations ultimately angered a number of back surgeons who feared they would lose patients. The AHCPR barely survived congressional actions in the mid-1990s, but it emerged with a new name, with a reduced budget, and stripped of its authority to establish Medicare and Medicaid payment levels. Today, the Agency for Healthcare Research and Quality (AHRQ) remains our country's lead federal agency for research on improving the quality of health care, bringing costs down, and expanding access to service.

As one reviews the extensive body of literature devoted to the quality of patient health care, three types of quality problems can be categorized. The first group refers to patients who do not receive beneficial health services. This is an example of underuse. Underuse of appropriate and effective interventions is pervasive across the delivery of preventive care, acute care, and chronic care.

Underuse problems are often aligned with financial barriers (lack of insurance or coverage for specific preventive care). Recent studies estimate that the number of uninsured persons in the United States will increase from 47 million to 56 million by the year 2013. Underuse exists in other segments of our population where persons distrust physicians in general and might avoid the health-care system altogether.

The second category of quality problems is apparent when patients are subjected to treatments or special procedures from which they most likely will not benefit. This is called *overuse.* One probable cause of overuse stems from the fact that doctors are overly enthusiastic about the potential value in new medical and surgical interventions. These newly developed technologies are sometimes used in absence of reliable evidence supporting their effectiveness. As noted many times in this textbook, Americans are infatuated with technology and might implore their physicians to use whatever it takes to cure their maladies. Less than two decades ago, a middle-aged man who went to his doctor for a routine physical would have his blood pressure checked and be asked to provide blood and urine samples for simple tests. Today's visit adds a cholesterol test, a colonoscopy, and an antigen test for prostate cancer. Some, if not all, of these tests might be examples of overtreatment for a significant portion of the population. On the other hand, many persons really benefit from these proactive inquiries.

Finally, a third type of quality problem emerges when patients receive appropriate medical services, but those services are delivered poorly, directly exposing recipients to additional risk of preventable complications. This is misuse. Most of you have, at some point in your lives, heard about one or more medical malpractice suits. In fact, Academy Award–nominated films have documented in a dramatic fashion the health problems incurred as a result of misuse in the medical profession. Litigation in the actual (not dramatized) court battles commonly is focused on errors made in hospitals, a percentage of which includes patients who are injured as a result of negligence. A significant proportion of quality problems due to misuse occurs when competent professionals make mistakes and the systems fail to prevent their mistakes from causing serious harm. Doctors, after all, are as human as the rest of us, but it is easy for us to forget that when we are counting on them to save our lives. When you stop to consider how many different persons touch a patient either directly or indirectly during her hospital stay, the number of tasks that must be performed with precision, and the fact that many of the patient's records are still managed on paper charts, it is difficult to imagine the patient being discharged totally unharmed.

Solving this vast array of quality problems has become an imperative and timely challenge in our current health-care system. Over the past few decades, American automobile manufacturers and producers of consumer electronics goods have made great progress in improving the quality of their products and services. The extent to which similar improvements have been made in health care is discouraging. One obstacle to improvement is the lack of competition, due to the overwhelmingly local nature of health care and wellness in our society. In many ways, competitive pressures from higher-quality products built in Japan and other nations transformed our automobile and consumer electronics industries. It seems unlikely that hospitals and clinics in St. Louis will lose patients to competitors in Los Angeles (let alone Tokyo) just because those other institutions have earned higher quality ratings. Competition in primary health care is local, much like competition in the grocery-store business.

Other obstacles to improvement include an absence of quality guidelines backed by empirical evidence; a lack of return on investment; a lack of demand for improvement, since consumers often just want to feel better right away; and a void in leadership, with regard to solving quality problems on a united front. While the AHRQ in our government might be looked to as a source of leadership, we have witnessed a political trend against government intervention in society—especially toward efforts at health-care reform. Universal health care continues to be a political hot button on the minds of candidates who present platforms for office (federal, state, and local) in our nation.

Medical-Care Options

The steady rise in health-care costs, coupled with the availability of sophisticated medical technologies and advanced drug therapies, has produced a variety of medical plans. The major payers of health-insurance premiums are the government and private employers. Each of these has initiated steps to eliminate the incentives for excessive treatment and utilization and abuse of technology.

Diagnosis-related groups (DRGs)

The ***diagnosis-related groups (DRGs)*** are a patient-classification scheme originally developed at Yale University as a method of reviewing the relationship between the types of patients a hospital treats and their incurred costs over a year. In the early 1980s, Congress enacted a DRG-based, prospective payment system for all Medicare patients. Instead of being reimbursed for Medicare patients on the basis of charges or costs, hospitals are paid fixed sums for each type of patient, by diagnosis. The Health Care Financing Administration (HCFA) holds the responsibility for the maintenance and modification of DRG definitions. An operating division within the Department of Health and Human Services, the HCFA (now called the *Centers for Medicare and Medicaid Services*) updates the Medicare DRGs annually. Many states and large insurance programs have adopted the DRG structure for non-Medicare patients.

DIAGNOSIS-RELATED GROUP (DRG)

A medical care classification system that groups patients who are similar clinically, in terms of their diagnosis, treatment, and expected consumption of hospital resources. The scheme allows for the comparison of resource use across hospitals with varying mixes of patients. This system is used primarily in the United States as a method to fund hospitals—for example, a determination of costs for specific medical procedures and medications.

DRGs classify patients into clinically cohesive groups demonstrating a similar consumption pattern of hospital resources and duration of stay in the medical facility. Besides reimbursement, DRGs also evaluate the quality of care, and they assist in assessing the utilization of services. Each DRG represents the average resources needed to treat patients assigned to that DRG, relative to the national average of resources to treat all Medicare patients. In the late part of the first decade of the twenty-first century, there were 590 HCFA Medicare DRGs in use. For example, the payment for simple pneumonia (DRG 89, 90, or 91) is based on nationwide average costs for treatment and an average length of stay ranging from 2.89–4.78 days. A reconfiguration and perhaps simplification of the DRG system has been under review in recent years.

Fee-for-service payment

Fee-for-service medical care was standard practice when health insurance was introduced in the middle of the twentieth century. Indemnity insurance programs were designed to pay the participant's health-care bills. In this system, an annual premium was paid. In return, the insurance company paid for at least a portion of an individual's medical bills. Through the years, these plans became more complete, and health insurance was regularly included in the benefits packages employers offered. For a time, employees seemingly lost sight of the fact that the medical treatments they received were costing money. Some observers contend that this situation prompted patients and doctors alike to buy or recommend excessive amounts of medical care, regardless of expense. More recently, however, workers have become much more aware of the out-of-pocket costs for health care. In the late 1980s, 76% of all U.S. businesses offered health coverage to their employees. By the middle of the first decade of the twenty-first century, this figure had decreased to 60%, leaving hundreds of thousands of full-time workers uninsured.

The advantage of fee-for-service coverage is that the patient can choose any desired provider. Any qualified physician who offers a recognized health-care service can submit a bill to the insurer. If any emergency occurs, care can be sought at any site with the expectation of at least partial reimbursement. Indemnity policies generally have an out-of-pocket maximum per annum, beyond which the insurance plan pays the fee for covered benefits. Virtually anyone can buy individual insurance to cover fee-for-service care, but the cost for an individual policy might not be affordable for the average, middle-income wage earner. For those of us whose employers do not offer health-care benefits, the only way to obtain coverage is in the individual insurance market. Independent insurance brokers provide both single-client and family plans.

Managed-care plans

A majority of Americans who are fortunate to have medical insurance are enrolled in managed-care plans that cover a wide range of health and wellness-promotion services. Doctors who participate in these plans are listed as network providers. This means patients have less flexibility in choosing their personal physicians. Individuals are commonly charged a co-payment fee each time they see either a primary-care physician or a specialist who is on the list of in-network providers. Similarly, most managed-care plans have a list of prescription drugs they cover. The enrollee's cost (co-payment fee) depends on whether or not the medication required is included on the list and if the drug is a brand-name item or generic product.

Health maintenance organizations (HMOs) represent one type of managed care system. They have long been noted for a focus on prevention and wellness and require enrollees to receive most of their treatment from a primary-care physician who is a member of the HMO. In this type of medical plan, the provider offers a binding estimate of what a given amount of health care will cost the average patient for a one-year period. Individuals who enroll in the plan pay that amount annually. If total costs go higher than the sum of these prepayments, the HMO loses money. If the costs stay below the estimate, the HMO operates in the black.

In actuality, the HMO is a merger of an insurer and a provider of health care. As an insurance company, it collects annual premiums from subscribers and then absorbs the risk that this cumulative income will cover its expenses. As a provider of medical services, it has its own staff of physicians and might also contract services out to other facilities. Enrollees must choose a primary-care physician, who is often viewed as the "gatekeeper" and is authorized to

refer patients to medical specialists. For example, if a person develops a skin rash, she must first see her primary-care physician, in order to receive an approved referral to a dermatologist. The theory is that HMOs have an incentive to deliver quality health care and also stay within their budget.

Critics of these prepaid plans hold that HMOs can often place too much pressure on doctors to limit care, for the sake of protecting their profit margin. HMO networks also tend to get overcrowded. This means appointments with doctors might be difficult to schedule.

Another form of managed care is known as the ***preferred provider organization (PPO).*** PPOs are hospitals or groups of physicians offering their services at a fixed price, in exchange for a guaranteed supply of patients. The insurer (business firm, production facility, or state agency) represents its clients by initiating a cost-comparison search within the medical marketplace. This insurer next contracts with a group of providers who agree on a predetermined list of charges for all services rendered. After the rate is paid, the patients are covered for the medical-care services the preferred providers offer. Unlike an HMO, if you want to see a doctor of your choice not connected with the PPO, the plan might pay a percentage of the medical bills, very similar to an indemnity plan.

In today's health-care marketplace, PPOs provide more flexibility in the selection of a physician. They usually have higher premiums and higher annual deductibles, however, than HMOs. Persons enrolled in a PPO-type plan generally do not need a referral to see a specialist or to receive other types of care.

On first glance, it might seem that the options for health-care coverage have become too confusing. In the middle of the first decade of the twenty-first century, consumer-directed health plans (CDHPs) had begun to surface as a small share of the private insurance market. They represent an emerging approach to health-care coverage that requires consumers to accept more responsibility for the cost and quality of their medical care. CDHPs generally include three basic components: a high deductible, an account to pay for medical expenses below the deductible, and decision-support tools regarding general health and wellness programs. We might ultimately look back on this time as a period of experimentation. In any event, our society is determined to develop a system in which the highest quality of medical care is provided at the most reasonable price. As we continue this quest, the medical profession cannot allow the pressures to cut costs to have an adverse effect on the quality of treatment administered.

Health Priorities

Economists tell us that increase in demand is one of the main factors contributing to rising costs of health care in this country. Several agents have fueled this increase, including the availability of health insurance, changes in our lifestyle, an awareness of the effects of the environment on our physical well-being, a larger and more specialized population of health-care providers, and technological progress. Advances in medical technology have increased demand by offering diagnostic and therapeutic procedures previously not available. As noted above, the quality problems related to overuse and overtreatment are often a result of the "if the technology is available, use it" syndrome.

Undeniably, technological advances in medicine have actually lowered the cost of health care in various cases. The polio vaccine eliminated the need for the expensive iron lung, and the rubella vaccine reduced the incidence of disease among pregnant women and cut down on the birth of

babies with mental retardation. The use of mind-stimulating drugs in the treatment of patients with mental illnesses has also yielded expenditure-cutting results. Conversely, the conquest of infectious diseases, such as pneumonia, has increased our life expectancy. The most dramatic improvements can be seen for those who have chronic health conditions. Persons who, for example, experience congestive heart failure subsequently remain alive to incur much higher health-care costs long after they have been "cured." Advances in surgical techniques have also influenced health-care expenses.

Continued research efforts will add to the complexity of the technology, cost, and human-need problem. The concept of technology overkill will not disappear in the near future. In a general sense, technological progress in medicine often makes what can be done much clearer than what should be done. The numerous technical manipulations and procedures can be defined with much conviction. It is far more difficult to decide when and where such technological interventions should be utilized.

If advanced technology continues to inflate the cost of health care, it might no longer be accessible to all people who might be able to benefit from its use. One of the authors of this book battled Stage IIA breast cancer in recent years. The cost of her chemotherapy treatments alone exceeded $60,000. Add to that figure thousands more dollars for numerous laboratory tests, surgical procedures, and multiple radiation treatments. Without access to medical insurance, the tumor would ultimately have metastasized (spread to other parts of the body), causing a much earlier death for this woman. Some medical experts believe we might be approaching a day when we will be forced to think about rationing costly high-tech procedures. Making life-and-death decisions about the use of costly medical technology is an exercise in which few legislators and even fewer doctors want to engage.

Over the past several decades, technological success in medicine has intensified political pressure for public access to the advances. The subsequent expansion of health insurance coverage increased access to new technology. Insurance coverage also provided incentives to develop newer, more effective, and inevitably more costly technological devices. Coming to grips with the cyclical nature of this moral and ethical dilemma might be the central challenge for the present generation of medical professionals.

In a recent study designed to assess the attitudes of the American public regarding the U.S. health-care system, researchers found that we are definitely changing the way we seek medical treatment. Some of these choices are good. Others, such as delaying seeing a doctor or not filling prescriptions, have the potential to be damaging. Most interestingly, three-quarters of those who have employer-provided health coverage stated they would prefer $7500 in health benefits to an additional $7500 in their paycheck as taxable income.[1]

Contemporary Technology in Medicine

A number of recent medical-technology breakthroughs were mentioned in previous sections of this chapter. The next few sections endeavor to summarize the technical explanations and the social ramifications of just a few of these "miraculous feats." Extensive R&D is ongoing across numerous fronts in the medical world (for example, hospitals, universities, industrial centers, and government research labs). The examples cited in this section are accompanied by a

[1]EBRI. 2007. 2007 health confidence survey: Rising health care costs are changing the ways Americans use the health care system. *EBRI Notes* 28 (11): 2.

vast array of equally compelling diagnostic and therapeutic techniques, all of which are totally reshaping the way we practice medicine today and the way we might be practicing it in the near future.

At the onset of the twentieth century, the average life expectancy for American men and women was less than 50 years. Today, these figures exceed 75 years, for men and women alike in this country. Changes in lifestyle certainly account for a portion of this gain, but many recent discoveries in medicine also play a major role. As with other fields of specialization, the capacity for scientific research and technological applications to change the way our minds and bodies feel and function continues to accelerate at a breakneck pace. Medical knowledge doubles at a rate that defies physicians to remain current. (You should by now realize, however, this rate of change in critical facts and figures is not unique to the medical industry. This rate is characteristic of most contemporary technology fields.)

Today's medical researchers and doctors keep working to make inroads toward developing treatments for various forms of cancer. Current developments in biotechnology are discussed in Chapter 2, many of which are driving emerging and future breakthroughs in medicine for humans. The HGP is now complete, thus decoding the sequence of one complete set of human genes (previously discussed in Chapter 2). Emphasis in research is now shifting to the study of how DNA varies from one person to another. These variations, however minute they might be, might help determine which patients particular drugs might harm and which groups will benefit most from these drugs. Slight genetic variations among individuals are called *single nucleotide polymorphisms (SNPs),* or more simply, they are the substitution of one letter of the DNA alphabet for another in a person's genes. Amazingly, these small differences can make a huge impact on how a person responds to a given medication.

This field of study carries the label ***pharmacogenomics,*** a term that arrived in the medical literature not long ago. We are truly living through an era of transition in medical therapies—moving out of the "one size fits all" drugs venue, where all patients receive the same prescription, and toward a time when drugs are personalized and geared to the specific genetic makeup of groups or individuals. Eventually, it might be possible for you to review a readout of your own genome with your doctor in his private office. This information will provide indications of whether or not a particular medication might be dangerous for you to take and which health-care options are optimal for you.

A few genetic tests developed for specific diseases had been introduced to the market by the middle of the first decade of the twenty-first century. Tests to determine which lung-cancer patients would respond to certain medicines and which breast-cancer patients would metabolize the widely prescribed tamoxifen drug are two examples. The approval of Roche's genetic test (the AmpliChip® test) signaled the potential for pharmacogenomics to be more widely accessible. This new test works by detecting specific variations in a person's genetic code for two essential drug-metabolizing enzymes—CYP2D6 and CYP2C19. These enzymes enable human beings to break down 25% of all drugs, including those most commonly prescribed and taken in the United States (such as painkillers, antidepressants, blood pressure medicines, and cough syrups). As you might imagine, the cost of the AmpliChip test is expensive and not usually covered by insurance. Even still, if doctors know their patients are poor metabolizers ahead of time, serious medication-linked side effects can be avoided.

Looming large on the health-care horizon is an exciting field in which the technological tools are microscopically small. ***Nanotechnology*** includes the science and engineering devoted to the design and application of very small devices, systems, and materials measured in nanoscale increments. Nanomedicine is the application of nanotechnology to medicine, such as the use of nanometer-sized particles and systems to detect and treat diseases at the molecular level. **Figure 5-5** illustrates the nanometer scale (one nanometer = one-billionth of a meter).

In the foreseeable future, the most important clinical applications of nanotechnology will likely be found in pharmaceutical development and the delivery of antigens for vaccinations. Other promising uses for nanotechnology in medicine include imaging, gene therapy, dental care (especially orthodontia), orthopedics, and cardiac care. Applications of nanotechnology in molecular diagnosis are generally labeled *biochips* or *microarrays,* but they should more accurately be called *nanochips* and *nanoarrays.*

DNA nanoarrays, more commonly referred to as *DNA chips,* are DNA-covered wafers manufactured out of silicon, glass, or plastic, capable of analyzing thousands of genes at a time. These chips have great potential to join our ongoing quest to eliminate all forms of cancer in our lifetime. DNA chips potentially provide a whole new way of detecting cancerous cells in a person's body. This type of testing promises to be earlier, easier, and more precise than current methods. If they are not already doing so, pathologists expect to soon be using DNA chip–based tools to spot genetic differences between cells. There, illuminating differences can be used to detect cancerous cells long before symptoms (for example, symptoms such as a chronic cough, intense pain, or an internal lump) develop and it is too late for treatment. Further, DNA chips can be employed to provide a genetic profile of cancerous cells, allowing medical professionals to distinguish one form of cancer from another.

The dream of a bionic body is seemingly becoming a reality. Doctors have been able to replace the human heart, pancreas, kidneys, limbs, blood vessels, and hip joints with synthetic devices. See **Figure 5-6.** In some cases, the technological substitute might actually function better than its organic counterpart.

Surgeons replace organs with plastic parts and vaporize tumors with laser rays. They know how to perform delicate lifesaving

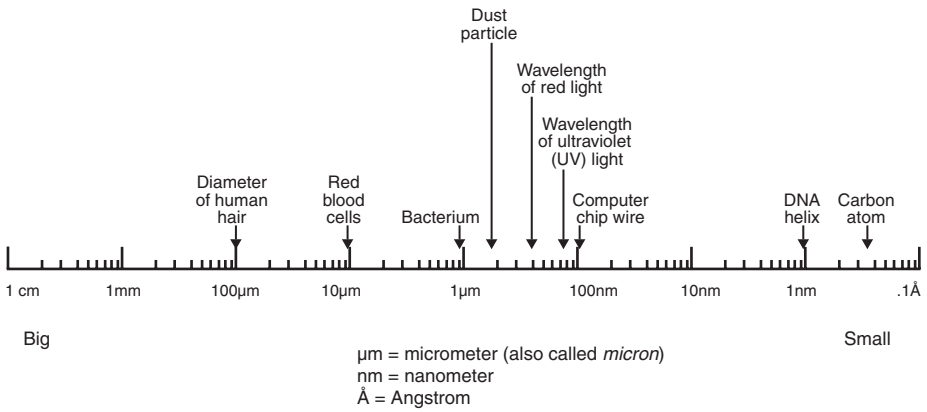


Figure 5-5.
The nanometer scale—one nanometer = one-billionth of a meter.



Figure 5-6.
Using synthetic devices, doctors can now perform surgical procedures, such as this one involving a hip joint replacement. (El Camino Hospital, Mountain View, California)

operations on human fetuses in utero. Arthroscopic surgical techniques facilitate the treatment of joint problems and sports injuries and have nearly perfected the diagnostic accuracy of knee-pain conditions. Haptic simulators are being used in medical schools to train physician candidates to perform traditional procedures (such as catheter insertion) and to learn new procedures (such as deep brain stimulation). The term *haptic* is from the Greek *haptikos,* meaning "to grasp or perceive." Haptic simulation exercises provide a realistic way for doctors and nurses to practice their techniques without causing harm to patients. In recent studies, researchers have been exploring ways to incorporate the sense of smell into haptic surgical simulators. Computerized scent-production devices could be used to help medical students recognize the important role their olfactory sense plays during both diagnosis and surgery.

In an even more incredible fashion, the field of tissue engineering promises that we might soon be able to design and grow living replacement body parts. A number of biotech firms are aggressively engaged in basic and applied research, which might lead to ready availability of replacement heart ventricles and bladders. Already, there is a small number of tissue-engineered products on the market, including skin, bone, and cartilage implants. These breakthroughs are aligned with recent advances in biomaterials that are compatible with living cells and a much better understanding of cellular behavior.

Try to picture a collaborative medical scene where you are the patient lying awake on an operating table, answering questions posed to you, while doctors perform deep brain-stimulation procedures. The objective of the prodding is to enable the patient to help doctors properly implant a neurological pacemaker inside the brain. If this sounds futuristic, think again. Similar to heart pacemakers, which have been in use since the late 1950s**,** brain pacemakers consist of an electrode permanently implanted in the brain to help maintain neural equilibrium. Heart pacemakers use electrical stimulation to maintain optimal cardiac rhythm. The U.S. FDA approved the first use of brain pacemakers in the late 1990s to treat a few forms of tremor, including the one associated with Parkinson's disease. Other candidates for treatment using this form of electronic brain stimulation include people who suffer from severe depression and others afflicted with obsessive-compulsive disorder (OCD). By the middle of the first decade of the twenty-first century, only a few studies had been done among persons who suffer from OCD. Researchers report that the implanted devices provide benefits for about half of those patients with OCD in the studies. These persons experienced a reduction in paralyzing anxieties, which decreases their compulsion to engage in repetitive (and often dangerous) routines.

Coronary angioplasty, also called *balloon dilation therapy,* is one of three standard medical interventions for coronary artery disease. The other two are medication and open-heart, or bypass, surgery. ***Balloon angioplasty*** can sometimes replace coronary bypass surgery to open clogged arteries. The goal of the procedure is to push the fatty plaque back against the walls of the artery to allow more room for blood to flow. This procedure can be performed by snaking a thin tube with an uninflated balloon at the tip through a patient's femoral artery (which is found in the upper-thigh or groin area) into the heart and the pulmonary artery. Once the balloon-tipped catheter is at the site of the blockage, it is inflated for several seconds to clear the clogged area of fatty deposits. Once clear, the catheter is removed and replaced with a stent, which is a wire-mesh tube to keep the artery open. This medical intervention can be done for a fraction of the cost of bypass surgery, and the period required for recovery is significantly shorter (most patients are free to return home after just 24 hours). Another form of angioplasty has the capacity to treat clogged arteries in other areas of the body, including the brain, neck, kidney, and abdomen. In the early 2000s, angioplasty procedures were performed on more than 1 million persons annually in the United States, with a high rate of success.

Cutting edge laboratory research involving stem cells derived from human embryos, as well as adult bone marrow, is taking place in institutions across the country. As you might recall from your biology courses, most cells in the human body are specialized to perform specific functions within specific tissues. In the past decade, we have discovered that stem cells can form a number of different tissues. In theory, this area of study might lead to our ability to rebuild human hearts after heart attacks, reverse the effects of Parkinson's disease, and improve the lives of people who suffer from Alzheimer's disease. Efforts are underway to combat these and other debilitating diseases using stem cells found in adult tissues (sources of cells include skin, bone marrow, the brain, the liver, and the pancreas). Research using embryonic stem cells shows great medical promise as well, but ethical and political debates continue, which will undoubtedly influence the future of this technique in the United States and other nations around the world. Early in the Bush administration's first term, the decision to withhold federal monies for research using new stem cell lines created an enormous regulatory maze. Midway through the decade, private philanthropy was also affected. Neither the American Heart Association nor the American Cancer Society was saying yes to embryonic stem cell research proposals at that point in time.

Given just this short list of breakthroughs, it is apparent we live in an era when some new spectacular medical discovery is reported on a monthly basis. Perhaps some of us look forward to a world where safe and effectively proven medical tools and techniques are evident to combat any organism that causes disease among humans. Still, medical progress is continually slowed by its share of bottlenecks. Doctors are making great headway, but the complexities of acquired immunodeficiency syndrome (AIDS) stymie them. Patients with AIDS are using various prescriptive cocktails, but new cases keep emerging around the world. An effective vaccine to prevent the disease is not yet available. Many other diseases, from Alzheimer's disease to lung cancer, still elude the healing touch of medical specialists.

To complicate matters further, medical breakthroughs generally do not emerge overnight. They are often forced to go through a series of political obstacle courses.

The FDA is the regulatory agency that decides which drugs and devices will be allowed to be used. Some researchers view the FDA as a bureaucratic barrier to innovation. Others hold that it does not require sufficient laboratory tests before human patients are allowed to serve as guinea pigs.

There is also, then, the issue of the medical entrepreneur. As with genetic engineering and the entire field of biotechnology, research on artificial body parts has spawned a number of private industrial start-up firms. The flagship technologies developed in these centers might prove to be controversial amidst cost-conscious groups and those who are skeptical about the quality of the research conducted. Nevertheless, as illustrated in the following paragraphs dealing with surgery, procreation, and home testing kits, medical science marches on with persistence in the face of these obstructions.

Minimally Invasive (MI) Surgery

During the last quarter of the twentieth century, the medical profession underwent a paradigm shift, with regard to methods used to perform surgery. For many procedures, the invasive nature of operating-room surgeries was greatly curtailed. In some settings, the term *noninvasive surgery* was even introduced. Advancements in video imaging, endoscope technology, and instrumentation have combined with computers and robotics to reduce the need for open surgeries performed with a scalpel. A few medical interventions falling under the heading of ***minimally invasive (MI) surgery*** include the use of lasers, arthroscopes, shock waves, nanotechnology or nanosurgery, and robotics to achieve a specific end result inside the patient's body. In today's medical circles, the topic of MI surgery is no longer the exception in mitral valve repair for cardiac patients, in hip-replacement procedures, or for treating malignant tumors.

MINIMALLY INVASIVE (MI) SURGERY

A group of new medical technologies employing endoscopic devices, laser beams, shock waves, or nanotechnology, instead of a scalpel, to penetrate the damaged or affected area of the patient's body.

Laser is actually an acronym for "light amplification by stimulated emission of radiation." A laser consists of a glass rod or tube filled with a gas whose molecules can be stimulated to produce an intensely powerful, concentrated beam of light. Today's sophisticated lasers use many different gases (for example, argon, carbon dioxide, and krypton) that shine at varying wavelengths. During several kinds of surgical procedures, the laser beam simultaneously cuts and coagulates the tissue at which it is directed. In laser stitching inside the body, the beam of light fuses the protein of the tissues. As the wound heals, the coagulated tissue is absorbed by the body and replaced by new proteins.

For women, gynecological laser surgery has been shown to be a safe and effective alternative to having a hysterectomy. In performing this MI technique, the physician uses a 10"-long telescopic instrument called a *hysteroscope.* This tool is inserted into the endometrial cavity through the cervical canal. At the tip of the scope are optical fibers and lenses, which enable the physician to view the walls of the cavity and locate the problem. Another optical fiber that transmits the laser beam is next threaded through a small channel in the hysteroscope.

The cost of hysteroscopic surgery is significantly less than the standard charges for conventional open surgery. This surgery also eliminates most of the postoperative problems, such as pain from incisions, intestinal cramping, and extensive recuperation periods. Since the laser cauterizes as it vaporizes tissue, it stops bleeding and reduces the chances of infection and hemorrhaging.

Hysteroscopic laser surgery represents one of many applications for this technology. Laser beams can be transmitted through optical fibers in thin tubes (technically called *endoscopes*) that are inserted into hollow organs of the body. This characteristic makes the technique equally useful in pulmonary medicine, urology, and gastroenterology.

Another form of MI surgery employs the use of an arthroscope to repair injured joints. The arthroscope is a sophisticated needlelike, metal device housing a fiber-optic light source. This device is only 2–6 mm wide. See **Figure 5-7.** The arthroscope can easily be inserted, under local anesthesia, into a knee, an ankle, a hip, a shoulder, or a wrist joint, through a small puncture. Conventional joint surgeries require general anesthesia, longer stays in the hospital, and extended recovery periods. For example, a surgeon can use the arthroscope to repair damaged knee cartilage. The physician inserts this small viewing instrument into the knee joint through a 1/4″ incision. Working through the scope and two additional 1/2″ incisions, the surgeon can insert slim surgical implements to repair the damaged cartilage. Although some people might require general anesthesia, the entire procedure can be viewed on a television with the patient wide-awake.



Figure 5-7.
Arthroscopic knee surgery is one type of MI surgery. A small viewing instrument, called an *arthroscope*, is inserted into the patient's body through a 1/4″ incision. An arthroscope is a needlelike, metal device with a fiber-optic light source inside. This instrument is 2–6 mm wide. An arthroscope can be inserted into a knee, an ankle, a hip, a shoulder, or a wrist joint through a small puncture, under local anesthesia. The surgeon works through the scope and two additional 1/2″ incisions, through which slim surgical tools are inserted to repair the damaged knee cartilage in the procedure shown here. (El Camino Hospital, Mountain View, California)

Technology associated with robotics has great potential to make MI surgical procedures available to a much larger group of patients. Already, robotics technology has influenced the process used to remove a person's gallbladder. Doctors who know how to perform robotic-assisted surgery equate their control of long-stemmed, narrow instruments to using chopsticks to complete the operation. In the case of cardiac operations, advancements in computer-assisted procedures mean the patient can be spared the pain and trauma involved in cracking open the chest and using a heart-lung machine while the heart is stopped. At the turn of the twenty-first century, less than one-third of U.S. surgeons were performing this form of surgery, due to the highly specialized training required.

Medical regulators in our government, however, are enthusiastic about robotically assisted surgery. The FDA approved the million-dollar da Vinci® Robotic Surgical System manufactured by Intuitive Surgical®, Inc. of Sunnyvale, California in the late 1990s. See **Figure 5-8.** A three-year study in the early 2000s evaluated the use of the da Vinci robotic technology to perform MI cardiovascular surgery in patients who required mitral valve repair. The mitral valve is a complex biological structure

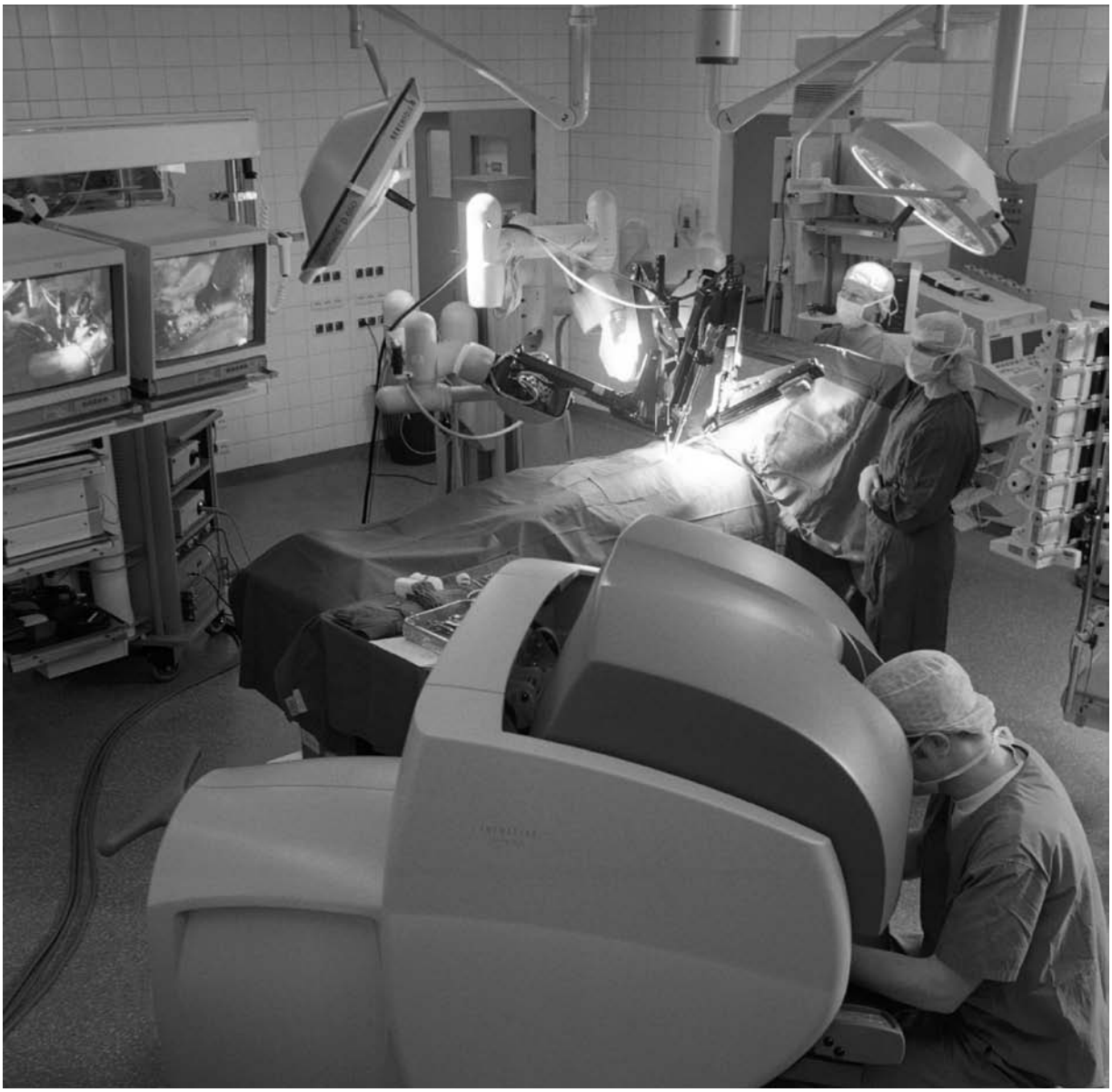


Figure 5-8.
The FDA approved the da Vinci Robotic Surgical System, manufactured by Intuitive Surgical of Sunnyvale, California, for use in operating rooms. (©1999 Intuitive Surgical, Inc.)

controlling blood flow through the left side of the heart. Researchers concluded that totally endoscopic mitral surgery can be performed safely and effectively with robotic instrumentation.

Other robotic surgical devices are likely to be cleared for market release, and medical students will increasingly receive training in the use of these new tools of their trade. The potential advantages for robotics in the operating room are many. The physicians

robots are assisting are more successful, as the robotic arm holds and positions the video camera with great accuracy and steadiness, and patients endure less trauma since the procedure is less invasive to their bodies. The patients experience less blood loss and recover more quickly.

One more MI surgery involves the use of extracorporeal shock wave lithotripsy (ESWL) to remove painful kidney stones from a patient's body. The FDA first approved the ***lithotripter*** in the mid-1980s. This form of treatment employs an energy source to generate shock waves, which are directed at the stones within the kidney or ureter. Physicians make use of ultrasound technology to locate the stones and focus the shock waves. The repeated force the shock waves create causes the stones to be fragmented into small pieces so they can be flushed out of the body without difficulty. Early lithotripters required patients to be submerged in a water bath, and an underwater electrode was used to emit bursts of shock waves to the sites of the kidney stones. The waves were administered at a rate and rhythm corresponding to the patient's heartbeat. Throughout the procedure, two fluoroscopic X-ray units were attached to television monitors to help the doctor pinpoint the exact locations of the stones. Today's machines allow the patient to lie flat on a table, and a water-filled pillow is placed on the body. Although general anesthesia can be used, ESWL is normally administered to patients who are heavily sedated.

In light of the fact that MI surgical techniques are becoming more widely accepted and available, prospective patients should be aware of the drawbacks. In lithotripsy, if the shock waves are improperly focused, they can damage the kidneys and other internal organs. Other side effects, such as internal bleeding and blockages, can also occur. To date, arthroscopy and laser surgery appear to have low incidences of side effects. They are not foolproof, however. Laser surgery is heat intensive, and repeated treatments can cause permanent tissue damage. The person who opts for arthroscopy might ultimately need to undergo further treatment or even open surgery if the ligaments or tendons need more work. **Figure 5-9** lists the advantages and disadvantages of MI cardiac surgery.

Individuals are also advised to review their medical-insurance coverage to determine policies regarding MI and robotics-assisted

Advantages	Disadvantages
Reduced pain	Learning curve
Smaller incisions and scars	Longer operating-room and cardiopulmonary bypass (CPB) times
Less bleeding and need for blood product	
Fewer complications, such as stroke	Requires complex and costly equipment
Shorter hospitalization	Not suitable for all patients
Faster recovery	Reduced cardiac exposure and safety?
Greater patient satisfaction	Unknown long-term benefits?
Improved hospital-resource utilization	Increased costs?
Better visualization of intracardiac structures	

Figure 5-9.
The advantages and disadvantages of MI cardiac surgery. (Adapted from "Minimally Invasive Cardiac Surgery: New Challenges for the Surgeon and the Anesthesiologist," *Techniques in Regional Anesthesia & Pain Management*.)

surgery. Insurance is presently available for most laser and arthroscopic techniques. The average insurance policy might not cover all the newer procedures.

Procreation

"Where do babies come from?" is a timeless childhood inquiry that is just as difficult for young parents to answer today as it was centuries ago. These days, however, our answers are considerably less fictional and perhaps more controversial overall. Advances in medical technology have essentially revolutionized the process of human reproduction. Around the world, childless couples are investigating a variety of reproductive-assisting options, including IVF, artificial insemination, surrogate motherhood, embryonic transfer, cryopreservation, and preimplantation genetic diagnosis (PGD).

In vitro fertilization (IVF) is a procedure in which eggs are removed from a woman's ovaries and fertilized outside her body by the father's sperm in a laboratory dish. Once conception occurs, the fertilized egg is reimplanted in the woman's uterus. In order to have any chance for success, IVF requires a number of well-timed and well-executed procedural steps. The woman who cannot conceive is first given hormones to induce her ovaries to produce more than one egg during her next cycle. Hormonal levels are closely monitored to detect the precise moment at which the eggs are ripening. To extract an egg from the ovary, a small incision is made in the patient's abdomen, through which a fine hollow needle is inserted. The mature egg is deftly retrieved and placed in a medium that further enhances maturation prior to fertilization.

Comparatively, the father's sperm is obtained and placed in a carrier solution that prolongs its ability to fertilize the ovum. The two media containing the eggs and sperm are combined and diluted to simulate the normal conditions found in the fallopian tubes. The resulting zygote is transferred to another solution, which supports cell division and allows the embryo to mature. Some 48 to 72 hours later, the embryo is transferred into the mother's body. A large percentage of the embryos IVF medical teams transfer fail to implant in the uterus, and repeated attempts are usually necessary. The first test-tube baby was born in England in the late 1970s. In the late part of the first decade of the twenty-first century, approximately 50,000 babies were being conceived (and born) through IVF in the United States each year.

One social innovation that has culminated through the availability of IVF technologies in human procreation is surrogate motherhood. A typical situation occurs when an infertile woman and a man enter into a contractual agreement with another woman. The surrogate agrees to be artificially inseminated with the father's sperm. After carrying the resulting fetus to term, she is expected to return the child to the original couple. In these instances, the baby has the genetic characteristics of the father and the surrogate mother. Another variation of surrogate motherhood arises when the female partner is not infertile, but she is incapable of carrying a fetus to term. In this type of case, an egg from the woman is fertilized with a man's sperm in vitro, and the resulting embryo is implanted in the surrogate's uterus.

As you can well imagine, the heightened anxiety and ambivalence the surrogate mother experiences are substantial. Financial remuneration cannot offset many of the physical and emotional commitments associated with pregnancy. The couple is obliged to the surrogate and must generally rely on her good faith to relinquish the child.

Embryo transfer is another reproduction-assisting technology that has become available to couples who are unable to conceive a

child on their own. This technology might be employed for women who cannot produce eggs, but who can carry a fetus to term. Once again, the couple pays a fee to a fertile woman, who agrees to be inseminated with the man's sperm. It is critical for this egg donor to be matched with the woman, in terms of their ovulation cycles.

Also, the hormone levels must be the same in both women for a successful transfer to be possible. Four to five days after fertilization, the embryo is flushed out of the female egg donor and inserted into the woman's uterus. A variation of this procedure is known as *embryo adoption,* in which a male donor other than the woman's husband provides the sperm. As with IVF procedures, the success ratio for these procreation options is not very high.

Through a technology known as *cryopreservation,* a woman's eggs can be fertilized and cooled to –321°F in liquid nitrogen. It is plausible that embryos could remain frozen in that state for centuries, awaiting implantation in a human uterus. This technology could enable a young couple in their 20s to preserve their own genetic offspring to be born at a later point in their marriage. In other words, neither partner would need to be fearful of infertility, and the proverbial biological clock might not seem as threatening. Frozen embryos present a host of major ethical and legal concerns. Some of these concerns are reviewed in the final section of this chapter.

Complementing these scientific procedures designed to assist in the reproductive process are several prenatal diagnostic technologies. Medical scientists have made monumental efforts to identify and treat a wide array of chromosomal abnormalities, metabolic disorders, and other hereditary diseases. Among others, their research has developed and made available the following procedures:

- ***Amniocentesis.*** A long, thin needle attached to a syringe is inserted through the lower wall of the pregnant woman's abdomen. The amniotic fluid, which contains some live body cells the fetus has shed, is withdrawn. The chromosomes are karyotyped (tested for specific characteristics of a cell nucleus, including chromosome number, form, size, and points of spindle attachment) in order to identify any abnormalities and determine the sex of the fetus. If the fetus is found to have a severe chromosomal or metabolic disorder, therapeutic abortion might be offered to the mother. This procedure is normally performed early in the second trimester of pregnancy. The test is expensive and might not be covered by the patient's health plan unless the doctor believes the mother's or child's medical welfare is of concern.
- ***Ultrasound.*** This procedure uses sound waves directed into the abdomen of the pregnant woman. Pulse-echo sonography presents a visual image of the fetus, uterus, placenta, and other internal features. See **Figure 5-10.** This noninvasive technology is painless for the patient and reduces the need for X-ray scanning procedures. Ultrasound is one of the medical

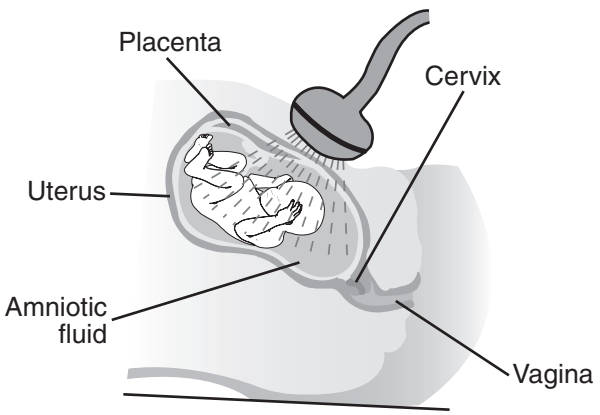


Figure 5-10.
A fetal ultrasound.

breakthroughs that significantly impact the possibility of performing in utero fetal treatments. By 18 weeks gestation, ultrasound can often provide views of the baby's head, spine, internal organs, appendages, and genitalia. When a clear view is obtained, the sonographer can determine how many chambers are in the heart and if the spine is intact. As with amniocentesis, ultrasounds are expensive, so they are generally used to gather information pertinent to the medical care of the mother and her baby.

- ***Fetoscopy.*** This application of fiber-optic technology enables the doctor to study the fetus inside the uterus. The fetoscope is inserted through an incision in the woman's abdomen under the direction of ultrasound. Fetoscopy has been used to give blood transfusions to diseased fetuses. This application has considerable potential for introducing medicines, cell transplants, or genetic materials into developing fetuses to treat a number of diseases in utero. It is atypical to perform a fetoscopy, unless there is a high chance that the fetus is not normal or there is a family history of birth defects, because fetoscopy can cause problems for the mother and fetus.
- ***Preimplantation genetic diagnosis (PGD).*** PGD is a testing procedure executed after an egg is fertilized in vitro, but before the resulting embryo is transferred to the mother's uterus. In the late part of the first decade of the twenty-first century, clinics in the United States charged between $6000 and $16,000 for this procedure, which allows prospective parents to select specific embryos before their pregnancy begins. The technology makes genetic tests available for a growing number of illnesses, some of which are not necessarily all that serious. Recent studies reveal that some couples are using IVF and PGD to select embryos according to gender. In time, couples might also choose their unborn children on the basis of hair color, height, and skin tone. Avowedly, these motivations are not the intended purpose for the development of this medical breakthrough, but there are clinics that will perform these tests for very high fees.

Home Health Care (HHC)

Less than a decade after the first home pregnancy tests were introduced on the market in the late 1970s, a whole new generation of sophisticated self-diagnostic products began to appear on drugstore shelves. Home health care (HHC) has become a very fast-growing market in the United States. Products range from walkers and wheelchairs to thermoscan thermometers and other self-diagnostic aids. Home intravenous (IV) therapy increased significantly when managed-care organizations designated this common hospital procedure to be a reimbursable home benefit. A walk down the aisles of the local convenience store might reveal do-it-yourself devices for pinpointing ovulation and monitoring blood sugar levels. Detection tests are also available for numerous conditions, such as high cholesterol levels, the presence of illegal drugs, venereal disease, HIV, urinary tract infections, colorectal cancer, menopause, and hypertension. In the late part of the first decade of the twenty-first century, the global market for consumer diagnosis and testing products is approaching $7 billion annually.

A fair amount of self-diagnosis was being practiced even before there were hospitals. The NIH, in its timeline of pregnancy testing, reports that ancient Egyptian societies used self-test procedures as early as 1350 BC. More than 3000 years ago, a woman who

suspected she might be pregnant urinated on wheat and barley seeds for several days. If the barley seeds grew, she believed she would have a son. If the wheat grew, it meant she would bear a female child. If neither one took root to grow, she believed she was not pregnant. Apparently this theory was tested in the mid-1960s. Interestingly enough, 70% of the time, the urine of pregnant women did stimulate growth of the seeds, while the urine of both men and nonpregnant women did not! There do not seem to be any records regarding the test's accuracy for gender prediction, but the key to its success otherwise is probably linked to the elevated levels of estrogen in pregnant women's urine.

Several distinct social and technological changes have stimulated the contemporary movement toward increased self-diagnosis. The first change relates to lifestyle and a trend toward wellness. Generally speaking, our society is much more health and fitness conscious than it has been in the past. Along with the emergence of numerous general-health journal and magazine titles, jogging, fitness classes, nutrition awareness, and regimens of megavitamins, it seems people are taking much more interest in their own medical care. Some people exhibit an almost insatiable desire to know more about how their bodies function. Subsequently, many of us know all about resting heart rates, lean body weight, metabolic rates, various muscle groups, and the importance of personalized exercise programs. It is probably safe to assume that the average person who you might have approached in a 1970s neighborhood grocery store would not have been able to tell you much about her optimal target heart-rate zone. The availability of diagnostic kits for at-home use fits perfectly into society's significant interests in its physical well-being.

Another reason for the increased use of these products involves the soaring costs of medical treatment. Getting sick or suspecting a medical problem generally meant a trip to the doctor's office. A lengthy wait for laboratory-test results often accompanied these visits. The evolution of the test-kit industry is providing people who might be ill with a different set of options, often with considerable cost savings, greater convenience, and more privacy. For instance, for a nominal sum of money, a person can purchase a detection-test kit to determine the presence of blood in the feces. According to the American Cancer Society, hidden blood in the stool can be an early indication of colorectal cancer. Some people believe it is no longer cost-effective to pay for a rectal exam with a physician unless this type of self-test is done first and shown to be positive. Also available is a very accurate and affordable home test for people to check blood-cholesterol levels. Coronary heart disease remains a leading cause of death in America, and elevated levels of cholesterol play a significant role in as high as 50% of those deaths.

A third development that has strengthened the growth of the self-diagnosis movement involves a series of successful technology R&D projects. As computer chips have become less expensive and more miniaturized, self-diagnostic kits have become more accurate and easier to use. The development of MAbs has also contributed to the substantial increase in the accuracy of the tests performed at home.

As you learned in Chapter 2, MAbs are hybrid cells created through genetic engineering techniques. MAbs have the potential to recognize a particular chemical structure. They can, therefore, act as sensitive probes for illnesses or physical conditions, from pregnancy to cancer. For example, the over-the-counter pregnancy tests first marketed in the late 1970s were found to be about 75% reliable. They did not make use

of biotechnology. Pregnancy-test kits that became available during the mid-1980s were shown, on average, to be 95% reliable—a substantial increase in accuracy, due to this technological breakthrough. Most of the HHC test kits on the market today tout accuracy levels above 98%.

Taking a bird's-eye view of the drugstore shelves, there appear to be three categories of self-testing products. The first group is used to help diagnose a condition or disease in people who possess given symptoms. The most common example here is the pregnancy-test kit, which is normally used after a woman notices a change in menstruation. The second type includes screening tests identifying indications of diseases in people without symptoms. Tests designed to detect hidden fecal blood fall into this category. A third classification includes monitoring devices to provide continual checkups on an existing condition. These are often purchased under the advice of a physician. Good examples of this type are kits people with diabetes use to measure the level of glucose in their blood and those women use to determine when they are ovulating. All tests that examine body specimens, such as blood, urine, saliva, and so forth, are called *in vitro tests.* **Figure 5-11** illustrates several typical self-diagnostic products available without a prescription.



Figure 5-11.
These self-diagnostic products and kits are available over-the-counter at your local drugstore. (Michael Dafferner)

An unfortunate situation can arise if users translate *self-test* to mean "self-diagnosis." Essentially, some of these test kits can shift the diagnosis of disease from the doctor's office to the home medicine cabinet. This might be construed as a quiet revolution in health care, which has received mixed reviews from practicing physicians.

Some health professionals believe properly administered self-tests show great potential for improving public health, as long as they are performed in conjunction with medical guidance. Home diagnostic testing devices are most valuable when they plug major gaps in current medical care. People who are concerned enough to take the first step and spend a reasonable sum of money on test kits might be equally concerned to follow up and make appointments to see their doctors. There is a significant benefit procured when the results of an off the shelf test prompts a person to get necessary medical care earlier than would have occurred without the test. Furthermore, there is certainly the possibility for more effective treatment when a doctor can say to the patient, "Here is an explanation of your condition. I would like you to go home, test yourself periodically with this test kit, and report the results back to me in three weeks." In some cases, the test kit being recommended might actually be covered as a prescription by the person's insurance.

On the downside, other physicians feel quite uneasy about this self-test health phenomenon. Some fear patients might substitute the kits for a doctor's opinion. Diagnosis by a physician normally involves an evaluation of the patient's medical history, a physical examination, a series of tests, and possible consultation with other medical experts. Another concern expressed involves the fact that people might test for only one disease, without knowing that the same symptom can be signaling an even more serious malady.

There is also the chance kit users might perform the test incorrectly or misinterpret the results attained. When this happens, the patient receives what are called *false positives* or *false negatives*. For instance, a woman might perform a test for pregnancy and conclude that she is not pregnant, only to find out three or four weeks later via a doctor's examination that she is pregnant (***false negative***). You can well imagine the severity of this type of event if the woman had, for example, ingested some form of prescription drug not recommended for use during pregnancy. Similarly, a ***false positive*** result, in this case, might cause premature elation or even unnecessary anxiety. Other causes for concern involve the shelf life of the test kit and the kit's estimated reliability.

In any event, self-test kits are here to stay. We can most likely expect further R&D pursuits to improve the existing products and to also expand the market considerably. The FDA's Center for Devices and Radiological Health (CDRH) regulates medical devices. This center requires devices developed for a layperson to use to comply with the same regulations as the devices used in professional laboratories, to ensure safety and effectiveness.

While this sounds reassuring in print, self-tests present several variables that are not as evident in the professional sector. For one thing, professional labs are designed, managed, and maintained specifically for scientific testing. Although medical labs are not infallible, their test results are generally more reliable and uniform than those obtained in your home. This is because they are acquired in a controlled environment (with proper lighting, chemical storage requirements, sanitary conditions, and instrument maintenance). Another factor stems from the fact that most laboratory technicians have had formal training and experience that have enabled them to develop expertise in conducting the tests. When we purchase a test kit, most of us must rely entirely on the written instructions or diagrams provided inside the package.

In sum, there appears to be a gradual shift taking place in the home diagnostic market from monitoring chronic illnesses to diagnosing serious or potentially fatal diseases. The FDA continues to warn consumers that they should be wary about buying and using kits on their own. More importantly, the FDA routinely finds unapproved home tests being sold on the Internet. The FDA affirms consumers can feel more confident that it has cleared home test kits purchased from a reputable drugstore or pharmacy. For peace of mind, before you decide to buy a self-diagnostic kit or monitoring device on-line, the FDA encourages you to consult its Web site. The CDRH's Office of In Vitro Device Evaluation & Safety is one of several databases updated regularly for consumers to use.

Quality-of-Life Ethics

Several times throughout this chapter we have made note of the fact that human beings are living longer than in the past, which is indeed a key mark of success in public health and medical care. On the other hand, more people are living the last few years of their lives with progressive illness and disability. Better medical interventions, coupled with healthier lifestyles, are giving more individuals the opportunity to grow old, accumulate a myriad of chronic conditions, and die slowly. Until a little over half a century ago, most Americans died of infections, accidents, and organ-system failures, usually resulting in a quick end to life. In contemporary society, by the time many Americans reach their mid- to late 40s, they have already experienced the loss of a loved one living out the end of life with

unrelieved pain or an incurable medical condition. People say they feel lucky when a person close to them lives well, despite fatal illness, and then dies peacefully. These end-of-life scenarios are replete with emotional reactions related to quality-of-life ethics. They illustrate the demands made on family members, who are often subjected to difficult care burdens for which they are not adequately trained, and the expectations we have from the nation's health-care industry.

It is difficult, if not impossible, to begin to understand the health-care system in our society today without recognizing the pervasive influence of technology. Medical professionals, patients, and business leaders have attributed positive values to numerous technological procedures and devices used to treat illness and prolong life. Technology has become the core of modern medical diagnosis and treatment. In achieving that stature, technology often has the power to divert the attention of health-care providers from issues of human value to the expedient selection of technological solutions. Many of the scientific miracles in our midst are raising difficult ethical questions about how these lifesaving tools should be used. The decisions regarding who should pay for these treatments also loom over the heads of our medical policymakers.

Some researchers are suggesting that one of the most basic precepts of the medical profession might no longer be useful or even valid. For centuries, physicians abided by the philosophy that they should do everything in their power to sustain the lives of their patients. New medical technologies and the economic realities of contemporary medical practice have confused this basic belief. We have reached a point where living longer might not necessarily mean living better. Quality of existence is not always the issue receiving much attention when technological decisions regarding medical treatment are being made.

The authors give a simple definition for the elusive term *quality of life* in Chapter 11 of this textbook. One of many quality-of-life indicators is linked to a person's physiological, psychological, and mental well-being. Quality of life is an interdisciplinary concept with application and relevance in several areas, including medicine, law, religion, and philosophy. In legal settings, quality-of-life issues surface when it is necessary to make decisions about a person's life, especially in the context of withholding or withdrawing life-sustaining medical technology or other interventions.

The many powerful new drugs and prescriptive cocktails being used to combat serious diseases can cause psychological damage to the patient who places too much hope in their healing potential or curative capabilities. A traditional interpretation of healing has been the process of helping people lead a full existence by allowing them to retain autonomy, protect their dignity, and maintain a greater measure of control over their bodies. Modern life-support technologies might be truly irresistible, but they can serve to evade these goals. New pharmaceutical technologies have the ability to keep various tissues disease free, but often at great financial expense to the recipient. The machines of technology are often used to sustain life that many people would not deem worth living. Death is no longer viewed simply as part of the natural order of human existence, but as a failure of medical technology. In such situations, the legal system might be called on for ruling.

Courts utilize the quality-of-life standard most commonly in the cases of terminally ill patients. Years ago, courts used the patient's autonomy to preserve quality of life. In other words, a person's self-determination constituted protection against artificial prolongation of life, and his own wishes represented informed consent. People who reject life-sustaining treatment base

their decision on personal preferences and knowledge about whether or not a prospective future medical state is very painful or degrading. In their minds, this is an unacceptable quality of living.

The ability of courts to rule in this manner breaks down considerably when the patients in question do not possess decision-making capacity. Quality-of-life judgments for people who do not have autonomy to decide for themselves whether life support is or is not desirable are extremely complicated. As you can well imagine, it is difficult, if not impossible, to determine how much discretion should be given to the family of an incompetent person for deciding to terminate her life. These situations are made only slightly less agonizing for jurists, judges, and legislators when the incompetent individual had exercised personal autonomy while she was competent.

An ***advance directive*** enables a competent person to give instructions about what his wishes are or who should be able to make decisions for him. These advance instructions are given in the context of medical treatment and relate to a person's rights to refuse or change treatment in a disabling chronic or terminal illness. The person must write and clearly articulate these types of directives while in a competent state of mind. In other words, if you simply mention to your significant other that you would not want to live in a comatose state, your statement would not be sufficient to hold in court. Although individual states have different laws, there are basically two kinds of advance directives, including the Health Care Proxy and living will.

A Health Care Proxy is a legal document in which an individual is able to appoint a health-care agent. Most often, this is a close friend or relative who is entrusted to make decisions about the individual's medical care in the event she becomes incapacitated. This document is also referred to as *durable Health Care Proxy power of attorney.* State laws determine who might be deemed ineligible to serve as the patient's health-care agent. For example, in the state of New York, a person cannot appoint his doctor or another employee of the hospital or nursing home, unless the individual is a relative or had been appointed before the patient was admitted. Health Care Proxies can be written for a specific medical procedure, such as abdominal surgery, to expire on its completion.

A living will is a formal declaration a competent adult writes, stating a wish or an expectation that, if she becomes so mentally or physically ill that there is no prospect of recovery, any procedures designed to prolong life should be withheld. Individuals often assemble living wills with the help of an attorney. This type of document takes the decision out of the hands of a medical team who might be inclined to administer treatment under the doctrine of necessity. When these two advance directives are used together, the Health Care Proxy names a person to make medical decisions for the patient, and the living will provides guidelines for the decision-making process.

In the United States, the first legislation to recognize the living will was the Natural Death Act in California in the mid-1970s. Since then, many states have enacted legislation recognizing advance directives and serving the following purposes:

- ❏ Prescribe conditions for the execution of living wills.
- ❏ Endorse the validity of living wills.
- ❏ Release medical professionals and institutions from civil and criminal liability.

Modern medical technology can and will continue to save more lives each year as we move further into the twenty-first century. For many people, quality-of-life issues and personal values might lead to their decisions to prepare advance directives. These documents

are just another side effect of highly advanced technology in a discipline existing to preserve human life. It is now possible to register advance directives with the U.S. Living Will Registry. This agency stores them electronically and makes them available to health-care providers when necessary.

Other Issues Associated with Medical Technologies

High-tech medicine can provide society with a reduced incidence of disease, but the costs are enormous. Technology in medicine often alienates the patient from the health-care professionals themselves. The beeps and squeals of the cardiac monitor, the printed output of a CAT scan, or the sound of a bedside respirator can obscure issues of human value. High-tech medical procedures can often interfere with family support mechanisms that have historically served as a source of encouragement for a person's well-being, dignity, and sense of self-esteem.

On the economic front, the scenario looks even more complicated and disturbing. There is a definite limit to the economic resources we can devote to health care. Governmental officials have repeated that we might have exceeded those limits for the past several years. In this setting, how can we decide who should receive these new forms of treatment and, in some cases, who should not get them? Major-organ replacement is both technology intensive and cost intensive. This type of replacement provides a visible example of this ethical quagmire.

Organ transplantation is unique among modern medical technologies because it is dependent on human tissue obtained through consent. This characteristic places constraints on the use of this potentially lifesaving procedure when the supply of suitable donors falls short of the demand. Some medical observers and professionals advocate a system of presumed consent. This means the organs of an individual who dies can be used, unless he has explicitly forbidden that use. This type of system has already been instituted in several European countries. A policy with these parameters places the burden of dissension on the individual. Some individuals and groups resist this approach and view it as a legislative intrusion. Think about this for a moment. Have you ever contemplated being an organ donor? Do you feel that this is a decision you alone should be allowed to make, or should silence on the issue imply consent? These types of provoking questions often prompt individuals to write advance directives as described above.

In 2008, according to the United Network for Organ Sharing, there were 112,300 persons awaiting transplants; 27,964 organ-transplant procedures completed; and 14,208 persons (deceased and living) whose organs were donated. Further, it reports that a new name is added to the national transplant waiting list every 11 minutes and an average of 18 persons die each day while waiting for a transplant. Avowedly, the demand for human organs exceeds the supply, and the cost for the necessary surgical procedures is often more than needy patients can afford.

The process of establishing the criteria for selecting the beneficiaries of new transplant technologies poses another ethical issue. It often seems the patients with families who have the ability to attract public attention and can also afford the steep price of transplantation are the first ones chosen for available organ donations. While it is still debatable as to whether or not total expenditures for organ replacement should be a matter of public policy, an individual's ability to pay should not affect the decision to replace a failing organ. It seems both moral and logical to base the choice on the person's medical need and the extent to which the results are projected to be beneficial for the long-term.

These criteria still would require an accounting of the cause of organ failure, the age of the patient, the availability of a suitable donor, and the projected ability of the patient to recover. For instance, a good candidate for a heart transplant might be a previously healthy young adult who has a terminal heart disease unresponsive to therapy. With this in mind, is the middle-aged adult who has a history of alcoholism a less desirable candidate for a costly liver transplant? How would you respond to this question if you were on a hospital patient-selection committee? Future decisions concerning organ replacement or any new technology will not be any easier to make from the ethical or moral perspective. Economic constraints might inevitably lead to mandatory rationing of certain medical technologies. The medical profession will have to agree on a credible list of criteria for the selection of patients who are "good risks" for organ-transplant surgery.

The subject of technology and procreation also prompts an array of difficult legal and ethical questions. Who ultimately has legal and moral responsibility to care for the offspring of artificial procreation? Who decides what is best for a child when the traditional mother-father roles are no longer precise? Will surrogate motherhood become commercialized in the next several years? What sorts of emotional reactions might occur when a person learns she is the product of the fertilization of an anonymous donor sperm and a donor egg in a petri dish? What becomes of unused embryos?

This last question is crucial when, for example, an IVF team creates more embryos in the laboratory than can be safely reimplanted in the mother's womb. Disposing of these surplus embryos or using them for further research purposes opposes the view some hold that an embryo is a human being who has a right to life. Others say that, until the embryo develops to the point when it is capable of experiencing something, it is not plausible to view it as a human being. Current stem cell research activities, coupled with the scientific feats in cryopreservation, might lead to an increased practice of freezing embryos for later use. This area of study is fraught with much debate and controversy. An even more disturbing question arises if the parents die without leaving specific instructions about the disposal of the embryos. If property could be legally attached to embryos, imagine the surprises relatives might receive during the reading of their loved one's will. Astonishingly, in the early 2000s, the Supreme Court of Massachusetts issued a landmark decision (Woodward v. Commissioner of Social Security, 435 Mass. 536 2002) affirming that a posthumously conceived child could share equally with the other living children in their late father's estate.

On another front, since we are now integrating individual genetic and genomic information into clinical practice and health-care provision, we must be aware of the increased potential for genetic discrimination. Citizens express fears that genetic information might be used to prevent them from acquiring jobs, home mortgages, life insurance, or long-term care insurance. Further, knowledge of a person's genetic code might damage his social status or prevent admission to the military or an educational institution. In response to this, the U.S. Congress seems positioned to pass the Genetic Information Nondiscrimination Act, designed to protect individuals against mistreatment based on their genetic information, with regard to health-care insurance and employment.

Finally, the brave new world of ***cybermedicine*** is attracting significant attention at this time. The transition of key medical services to the WWW has created

the term *cybermedicine.* As medical-care providers and pharmaceutical companies shift into the virtual cyberspace world, our health-care systems around the world will face challenges to traditional approaches to risk assessment, quality assurance, regulation, and confidentiality of medical records. Some of the Internet's currently available cybermedicine sites deliver advice in several ways: generalized text content presented as frequently asked questions (FAQs); open forums for discussion; and personalized, interactive chat or e-mail sessions between clients and the site experts. The term *expert* might be misleading, since health-care licensure is state regulated, but the cyberspace world can ignore real-world geographical boundaries determining jurisdiction or limitations. Pharmaceutical companies are aggressively promoting their products to consumers via the Internet. Legislation regarding product liability needs revision to keep pace with this shift in medical marketing. Cybermedicine technology is relatively nascent, but it will certainly be a very significant part of your future health-care options.

Medical technology will probably not cease to advance due to an absence of answers for these and other ethical inquiries. Nor will government officials be responsive with new legislation for each and every individual's unique circumstances. The responsibility for directing the course of this technology's development and utilization remains with all of society. While a small percentage of the population will join the ranks of tomorrow's medical specialists, most will continue to play the role of consumer or beneficiary. Both sectors must share value-laden decisions about new technology in medicine.

Summary

Technology has had a positive influence on the practice of medicine in our society. Amidst an impressive array of computer-assisted diagnostics and life-sustaining pharmaceuticals and devices, the cost of health care remains an urgent matter of international concern. The advent of DRGs and HMOs is evidence that some progress is being made toward solving this problem.

Current demographic figures indicate the average life expectancy for American men and women has surpassed the 70-year mark and is rapidly approaching 80. Recent technological breakthroughs in the medical field have played a major role in this shift. Several feats in MI surgery and the use of technology to enable infertile couples to bear children have been described in this chapter. These areas of specialization were selected to illustrate that science and technology in medicine are here to stay—and we are not likely to reverse this trend to move backward. A cost-to-benefit analysis of these revolutionary techniques must emerge to continually assess social ethics and the moral responsibilities of our physicians. Several factors have stimulated a definite trend toward self-diagnosis in the United States. A diversified collection of self-diagnostic, home health test kits and medical devices has become available on the shelves of local drugstores. They have been met with mixed reactions among practicing physicians. The greatest challenges for contemporary and future health-care professionals will continue to focus on the following issues:

- ❑ Curtailing the rampant increase in the cost of medical care.
- ❑ Appropriate and efficient use of medical technology.

- ❑ Continued monitoring of medical procedures integral to the trend toward self-diagnosis.
- ❑ Preservation of social ethics related to quality of life.

Discussion Questions

1. With reference to the cost of health care, why do you think the United States spends such a large percentage of its GDP on medicine, in comparison to other industrialized nations?
2. What are the three categories into which the huge number of quality problems in our nation's health-care system can be classified? Give a detailed example of a patient condition or treatment to illustrate each of these limitations in contemporary health care.
3. Identify the primary features characterizing a modern HMO. Provide a specific example of an HMO in your area and retrieve a copy of an information brochure from it, if possible. Be ready to present your findings during an upcoming class discussion.
4. How does the relationship among technology, human needs, and medical costs present a cyclical problem for the health-care industry?
5. Explain what the term *MI surgery* means. How does this type of medical treatment differ from a conventional surgical procedure? Provide at least three contemporary examples in your explanation.
6. What are the three categories into which most self-diagnostic products can be classified? Make a trip to your local drugstore to take a survey of the self-diagnostic kits available without a prescription. Provide a detailed description of the function and usage of at least one of the products located. Identify reasons you believe these types of home health-testing kits have become so popular in our society.
7. Do you feel that today's medical professionals are overly dependent on technology? Give reasons to support your position. What effect does the use of technology have on legal and ethical standards in society?

Suggested Readings for Further Study

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Chapter 6

Manufacturing and Production Enterprises

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DATELINE

A nightclub in Barcelona, Spain gives its patrons the option of being implanted with a RFID chip, in order to maximize their experience at the nightclub. The club's director, Chase, began using the RFID chip made by VeriChip because he wanted to provide better service to his customers. "I believe we should use new technology to provide our customers with the best service and entertainment," Chase told CNN.…

Introduction

During the last 30 years, the United States experienced the erosion of its steadfast leadership position in the manufacturing arena. The nation, faced with numerous challenges to rebuild antiquated factories, retool production lines, and rethink industrial management paradigms, lost a significant portion of its competitive edge in manufacturing. The casual reader need only pick up yesterday's *Wall Street Journal,* this morning's *New York Times,* or an issue of *Fortune* from last year to review yet another bleak forecast regarding the decline of America's manufacturing base. Workers around the country relate their stories about being laid off unexpectedly, as their employers decide to relocate production facilities to overseas sites with lower hourly wages. Overall, the manufacturing share of total employment in the United States has fallen 60% since 1970. In 2008, manufacturing was less than 10% of the total employment in the United States.

Without question, all American manufacturing firms have been confronted with a dramatic increase in foreign competition. In one attempt after another to match foreign competitors' low labor costs and more relaxed regulations, garment makers, appliance manufacturers, and electronics-components companies moved their operations overseas. These decisions were made to enable the home facilities to focus on research, design, development, and the production of fewer products. In most instances, these companies took this action to remain competitive. They ultimately became marketing and distribution centers, however, for products made outside of the United States.

There appears to be yet another series of revolutionary trends emerging across the playing field of American manufacturing. Companies nearly paralyzed by unfair trade practices, reverse-engineering feats, and a lack of long-range strategic planning in the 1980s have come charging back. Across the nation, manufacturing employers have embraced an attitude of "can-do optimism," as they breathe new life into manufacturing and production enterprises that had all but been pronounced dead just a few years ago.

Some examples of America's manufacturing resurgence were displayed when manufacturing firms recognized that an overdependence on large-scale flexible manufacturing systems (FMSs) and across-the-floor automation is potentially detrimental to their success. A contemporary automation paradigm, or pattern, is being spotlighted and applauded as corporate executive officers pursue an ingenious balance among computer networks, human operators, and automation. En route, these firms have discovered it is often much more cost-efficient to use hand labor alongside software networks, versus sophisticated robots. Too much automation results in lower profitability,

especially when dealing with odd-sized components, a large variety of complicated machine tools, and tight tolerances. By taking some of the automation out of a facility, a U.S. manufacturer can ironically outdistance foreign competition in such critical measures as time to market and manufacturing flexibility.

General Electric (GE) is gaining an impressive market share abroad because of the exceptional time to market and environmental design of its locomotives at its 100-year-old Erie, Pennsylvania locomotive plant. GE invested 6 years and more than $250 million into creating a new locomotive that reduces emissions by 40%. The Evolution locomotive GE produced was the first to meet the U.S. EPA Tier 2 emissions standards.

Another example of flexible automation can be viewed at Alcan Aluminum's Oswego Works (Oswego, New York). Oswego Works recycles aluminum cans. In the process of recycling cans into aluminum, unmanned vehicles dart back and forth between the machines to deliver and pick up material. These office desk–sized vehicles are not similar to the carts in Japanese FMS installations. The Japanese carts travel in rigid patterns along wire routes imbedded in the factory floor. Innovative technologies allow the automated guided vehicles (AGVs) at Alcan to run around anywhere. Each vehicle has a range finder that bounces laser beams off targets placed around the factory floor to let it know where it is headed. See **Figure 6-1.** Computer-directed radio signals from a control center dictate the vehicle's pickups and deliveries.

As one culls the literature associated with manufacturing and production enterprises, a huge assortment of technical acronyms becomes evident. Perhaps more than any other discipline, the array of alphanumeric abbreviations in manufacturing is overwhelming. Most of you are at least somewhat familiar with terms such as *computer-integrated manufacturing (CIM), computer-aided design (CAD), computer-aided manufacturing (CAM), FMS, just-in-time (JIT), material requirements planning (MRP),* and *statistical process control (SPC).* Recent years have brought us new constructs, such as lean manufacturing, agile manufacturing, rapid prototyping (RP), and CE. We are also being challenged to decipher a host of new terms and their acronyms. These acronyms include *manufacturing resource planning (MRP II), group technology (GT),* and *design for manufacture and assembly (DFMA).* Each of these technical terms is identified in the Key Concepts section. Recognize that this is only a small sampling, however, of what is everyday jargon in industry. Manufacturing managers are continually



Figure 6-1.
Laser guidance for an AGV. This guidance works by use of a laser scanner mounted onboard the AGV. Referencing an onboard map of the layout of the factory, the vehicle determines its position by sweeping its beam across reflectors placed on walls or columns. (Stefan Karlsson, AGV Electronics)

being charged to learn about, evaluate, and potentially implement one or more of what might be labeled *integrated automated process technologies,* to launch their firms into future successful ventures.

The focus of this chapter is to discuss the new and emerging technologies affecting the manufacturing environment in the United States, as well as overseas. Some of the questions we address include the following:

- ❑ Will integrated automated process technologies enable manufacturing enterprises to grasp and hold onto leadership positions in the global arena?
- ❑ Why do some corporations remain reluctant to recognize and enthusiastically support the procedures central to CE?
- ❑ When should the decision to automate be made? Is there such a thing as too much automation on a production floor?
- ❑ Assuming that lean manufacturing is more efficient than traditional manufacturing, what strategies can an organization use to become leaner and more agile?
- ❑ What is the difference between MRP and JIT? What are the advantages and disadvantages of each in a manufacturing environment?
- ❑ How do present-day workers respond to the presence of robots in their daily work environments?
- ❑ What new manufacturing and production enterprises are on the horizon? In which disciplines do they show the most promising applications?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

agile manufacturing
bar coding
computer-aided design (CAD)
computer-aided manufacturing (CAM)
computer-integrated manufacturing (CIM)
concurrent engineering (CE)
design for manufacture and assembly (DFMA)
flexible manufacturing system (FMS)
group technology (GT)
just-in-time (JIT)
lean manufacturing
manufacturing resource planning (MRP II)
material requirements planning (MRP)
product lifecycle management (PLM) software
quality function deployment (QFD)
radio frequency identification (RFID)
rapid prototyping (RP)
statistical process control (SPC)

Organization of the Work Environment

In one way or another, every new change on the production floor challenges traditional assumptions and contemporary procedures. Old ways in manufacturing are slow to die. The horizon seems much brighter, however, than it did just a few years ago. Is manufacturing on the rise in this country? Although the spread of new technology and innovative strategies across the nation is uneven, the following discussion reveals numerous examples of an exciting U.S. manufacturing renaissance.

As the average consumer attempts to make sense of manufacturing buzzwords,

it becomes apparent that manufacturing-technology systems generally share three common features: integration, automation, and computerization. A simple explanation of any manufacturing system is an entity providing concept implementation, starting with design, continuing through realization of the product, and culminating with customer satisfaction. A CIM setting implies a situation in which all components essential to the production of an item are integrated.

In the broadest sense, ***computer-integrated manufacturing (CIM)*** encompasses a diverse array of manufacturing strategies in use today. These strategies include the initial stages of planning and design, all the way through the final stages of manufacturing, packaging, and shipping. In actuality, CIM is not a specific technology that can be purchased one week and installed the next. Even though much has been written about the CIM factory of the future, it is not as much a technology as it is a management philosophy of operation. CIM involves strategic and aggressive efforts to combine all available technologies to manage and control the entire business of bringing new products to market. Several of the manufacturing strategies that can make for a successful CIM enterprise include CAD, ***computer-aided manufacturing (CAM),*** artificial intelligence (AI), expert systems, GT, RP, automated materials handling (AMH), robotics, manufacturing planning and control systems, automated inspection methods, and continuous quality improvement.

COMPUTER-INTEGRATED MANUFACTURING (CIM)

A host of automation technologies in the manufacturing environment. This type of manufacturing does not refer to one specific technology, but to the integrated use of computers in all sections of the enterprise, from the planning of production, through the design and manufacture of a product, to the assurance of good quality.

Although CIM is a unifying philosophy of manufacturing production, almost every company using CIM implements it differently. Also, the tools each company uses in its CIM implementation are dependent on many diverse factors. From this ever-expanding list of technology-based activities, it should be obvious that company-specific planning is imperative. While CIM might be regarded as a unifying force among the basic functional areas of design, production, and management, management is the central integrating force. The computer is a tool for execution. Basic to an effective CIM strategy is a strong commitment to intracompany communication. Success in the long-term requires a spirit of cooperation from the highest level of management, through each level of production, on down to the shop floor, sustained by employees who are not afraid to accept new technology.

Researchers involved with MIT's International Motor Vehicle Program initially popularized the term ***lean manufacturing***.[1] To become leaner, manufacturers must remove obstacles preventing them from manufacturing with high velocity. Obstacles, such as complicated setups, excessive material handling, poor physical flow, and production interruptions, interfere with an organization's ability to design and build the best-quality products in the shortest time possible. Lean manufacturing often begins with lean design. Although lean manufacturing began in Japan, American and European manufacturers have adapted this philosophy into their manufacturing plants. One such plant is New United Motor Manufacturing, Inc. (NUMMI), a joint venture between General Motors and Toyota, located in Fremont, California. See **Figure 6-2.**

An essential element of a successful lean manufacturer is the use of ***concurrent engineering (CE).*** This innovative approach to product development is a method of

[1]Womack, J., D. Jones, and D. Roos. 1991. *The machine that changed the world: The story of lean production.* New York: Harper Perrenial.

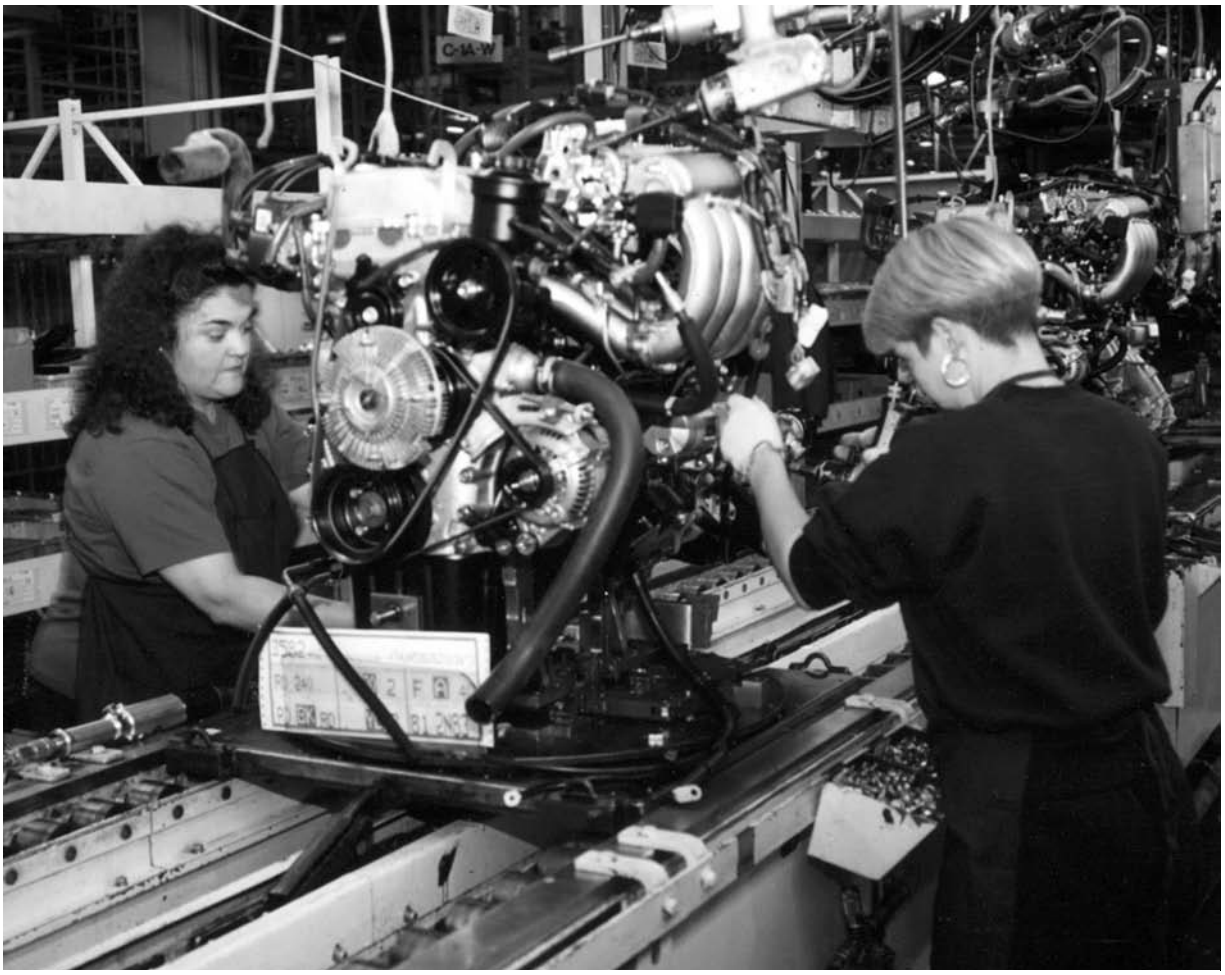


Figure 6-2.
NUMMI's production method is based on Toyota's lean production system. The system is an integrated approach to production using machinery, material, and labor as efficiently as possible.

simultaneously integrating the many aspects of product design, development, and manufacture. CE contrasts with the traditional linear approach. In the linear approach, marketing experts conceptualize the product, design engineers design the prototype, and the manufacturing and purchasing departments make all decisions regarding the production process and parts suppliers. Fundamentally, the results of decisions made at each stage, in the traditional linear approach to product design, are thrown over the walls metaphorically existing between the various departments in an organization, with little, if any, interaction among departments. In contrast, CE increases the interaction between designers and manufacturers before the product goes to the manufacturing floor. Under CE, once a new product is designed, there should be no problems in its manufacturing. As companies discover the advantages of getting things right the first time, the benefits of CE are hard to dispute.

Design for manufacture and assembly (DFMA)

is a tool used for product simplification. This tool is an analysis technique requiring a strict evaluation of product complexity and systematic development of design alternatives that simplify the product and improve the incidence of defect-free manufacturing.

The core objective of ***just-in-time (JIT)*** is to achieve low-cost, high-quality, on-time production by minimizing instances of idle equipment, facilities, or workers and reducing excess work in the process. Instead of making parts to stock, JIT emphasizes having the right parts, at the right time, in the right quantities, on the manufacturing floor. JIT keeps inventory costs down. This philosophy, however, also demands well-structured supply lines and very cooperative employees.

JUST-IN-TIME (JIT)

A manufacturing philosophy attempting to eliminate waste throughout the system, including inventory at both ends of production and all machinery and manpower not adding value directly to the product. JIT has its roots in the Japanese automobile industry, which sought to get rid of excess, waste, and unevenness.

In addition to the manufacturing changes in the last 30 years, organizations worldwide have undergone restructuring to reduce the layers of management and increase profits. These leaner manufacturers are fundamentally different from their historical counterparts. Traditionally, U.S. manufacturers had many layers of management separating the assembly line, or blue-collar workers, from the company's president. Each layer of management reported to and created reports for a higher layer. Most of the middle management existed to report and summarize the work of the employees below them and to give this analyzed information to the employees above them. Beginning in the 1970s, companies began restructuring the management hierarchy. The organizational structures of companies began to flatten. Instead of six or seven layers of middle management, companies reduced middle management to one to three layers. This flattening of the organizational structure has a direct effect on manufacturing enterprises because it puts more responsibility and decision making in the hands of the assembly line workers and their first-line managers.

These are not the only challenges for the modern manufacturer. There has been an increasing amount of competition in manufacturing, not only from traditional economic competitors such as Japan and European countries, but also from developing countries. A growing focus on the quality of products and quality assurance strategies remains in the forefront of operations planning. New and improved engineering materials are being introduced on a routine basis. Selecting the most effective manufacturing system takes time. Start-up costs are often exorbitant. Companies making systematic and informed choices will remain competitive and emerge as international manufacturing leaders well into the next century. These agile organizations will most probably be the ones contributing to the global market with a host of functional products made in the United States. Manufacturing managerial decisions are constantly reshaping the profile of tomorrow's factories. The implementation of integrated, automated systems will most likely have a visible impact on the U.S. lead in production, as well as on the credentials of the present and future workforces of the United States.

Computer-Integrated Manufacturing (CIM)

Forming the backbone of a CIM system is an integration of the mechanical, electrical, and informational subsystems. A successful CIM operation makes it possible for the computer workstations that management, design, and manufacturing personnel use to communicate with one another. Data can be entered from the operations of the entire plant. The resultant information is continuously processed, updated, and sent on demand to any employee for efficient decision making. CIM allows in-plant design systems to obtain data from management, on the current cost of raw materials, and also from manufacturing, regarding ways to adapt design for more efficient production. Likewise, manufacturing cells on the factory floor have a direct link to design data, in order to more effectively plan the steps for making products. Finally, managers and operators at all levels can work from their computer terminals to acquire up-to-date information from both design and manufacturing databases. Ostensibly, this feature of CIM allows for maximum coordination and centralized control of many industrial engineering operations. See **Figure 6-3.** If one takes a bird's-eye view of a CIM enterprise, computers are found being used throughout to accomplish the following:

- ❑ Provide design assistance.
- ❑ Translate specifications into drawings, parts lists, and routings.
- ❑ Schedule work based on machine availability and promised delivery dates.
- ❑ Reassign personnel to various tasks to keep in-process inventories at a minimum.
- ❑ Control machine tools.
- ❑ Provide vital, up-to-the-minute information for management.
- ❑ Execute routine clerical tasks.

None of the departments in a modern manufacturing facility can be allowed to consider itself a closed cell in its daily operations. In order to realize all the potential benefits, all employees—in design, engineering, manufacturing, and administration—must be able to work in unison from the same manufacturing database. Among other items, such a centralized database might consist of the following elements:

- ❑ Computerized drawings of parts (CAD).
- ❑ Files for parts programs to be used in numerically controlled machines (CAM).
- ❑ Files on routing that detail the workstations through which various parts must be processed.
- ❑ Files for all workstations listing production schedules, tools required, and operators assigned for each shift.
- ❑ Files on all tools and equipment, detailing maintenance, and depreciation timelines.

A large variety of tangible benefits have been reported among CIM users. Several of these benefits follow:

- ❑ A reduction in the duplication of data entry concerning product specifications, tolerances, order quantities, inventory levels, and raw materials.
- ❑ Fewer discrepancies in the data. These discrepancies can occur when a number of people gather information from different sources at different times in the production cycle.
- ❑ Prototypes can be prepared and tested more quickly, resulting in more precise estimates for customers as to when they can expect delivery of their orders.
- ❑ Lower energy bills.
- ❑ Less scrap and rework problems.

Manufacturing managers are more inclined to implement CIM strategies when they realize a sizable list of intangibles, such as better quality control; higher competitive

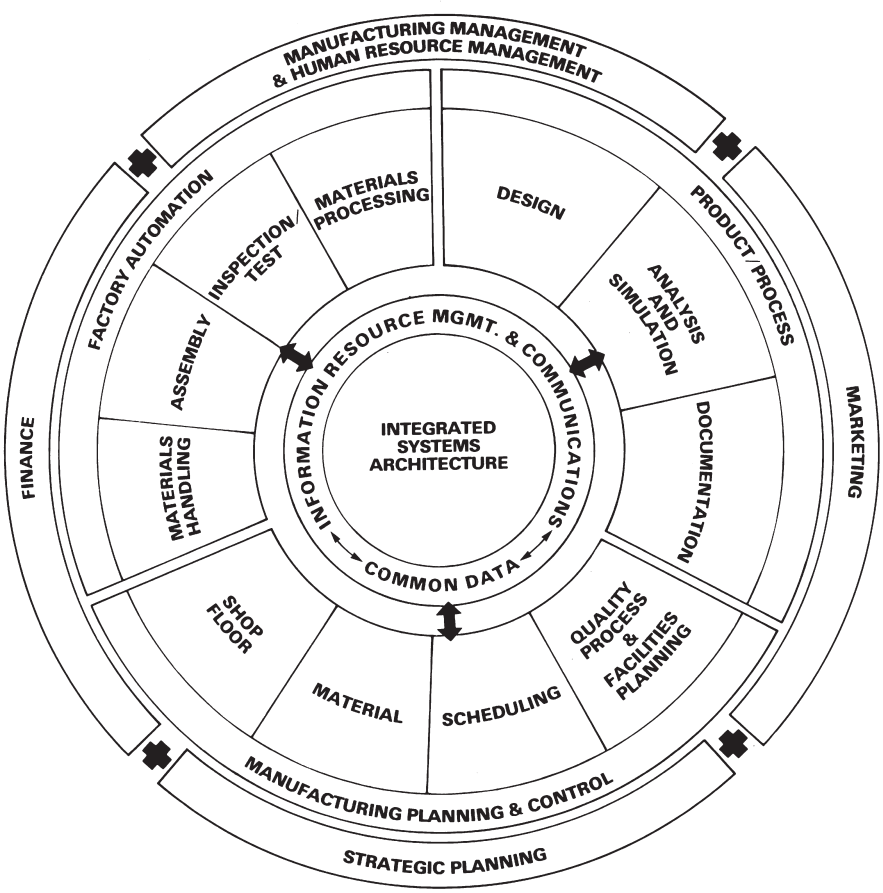


Figure 6-3.
This schematic from the Society of Manufacturing Engineers (SME) illustrates one perspective via a logical diagram identifying many of the foundational components of CIM. This framework implies the need for critical integration among all subsystems of a manufacturing enterprise. CIM can include many other manufacturing processes. These processes include CAD, CAM, FMSs, and automated storage and retrieval systems (ASRSs). (Technical Council of the Computer and Automated Systems Association of SME)

standing; faster product introduction; and increased flexibility in design, product mix, production volumes, and process routings.

The increasing use and availability of communication technologies, particularly the Internet, has expanded the possibilities of CIM. Many companies are integrating CAD, CAM, 3-D product visualization, and product lifecycle management (PLM) software to allow distributed design and engineering. Companies such as GE, United Technologies, and Toyota use their tools, along with offshore engineering and manufacturing, to facilitate global product development. Boeing uses advanced ***product lifecycle management (PLM) software*** that Dassault created, to allow an international community of people to use the Internet to collaborate in the design of Boeing's 787 Dreamliner. Boeing designers and engineers worked directly with component suppliers virtually at 135 sites around the world during the

design process, thereby reducing the time to market for the new plane. The ability to work with suppliers during the design stage dramatically reduced the cost of the finished product. Most successful manufacturers have recognized the need to maximize their in-house expertise and expand it by utilizing experts across the world to improve their productivity to stay in business. To remain both solvent and competitive, manufacturers are learning to formulate ways to get new products into the marketplace at an ever-increasing rate of speed.

The Concurrent Engineering (CE) Design Environment

The CE approach to developing a new product is a way of integrating the many aspects of product design, development, and manufacture. The progression of steps central to product design must proceed concurrently within the boundaries of the manufacturing system's infrastructure. Contemporary design engineers must regard their design function as a pervasive activity influencing such labor functions as research, development, process planning, manufacturing, assembly, quality assurance, packaging, distribution, and marketing. At the bottom line, design must truly represent the dedicated delivery of a solution to a problem within the parameters of profitability, customer satisfaction, and the prosperity of the social community.

There is no one set way for a new product to come to market. The time allowed to develop new products is shrinking because of the competition existing today. Four years used to be common from the problem-definition stage to the release of the new product. Now, we are seeing time-to-market periods of 6 to 18 months.

Perhaps you have heard the saying "If you can design it, we can build it!" The unspoken caveat or concern here has to do with cost and time-to-market cycles. When the sky is not the limit, DFMA becomes an important aspect of CE. Also referred to as *design for manufacturability (DFM),* its goal is to ensure a design inherently efficient and economical to make. The overall economy of manufacture is directly proportionate to the firm's success in controlling the manufacturability of the design. Design engineers must be articulate and knowledgeable in the fundamentals of the manufacturing processes applicable to their areas of expertise. These fundamentals include properties of materials; materials forming and processing; machining; fastening techniques; tool design and selection; electronics-packaging, -fabrication, and -distribution requirements; and geometric dimensioning and tolerancing.

How does CE differ from traditional design engineering? The key difference is increased communication among the different stages of the design process. In traditional design, engineers design a new product with little or no input from manufacturers. Today, with CE, the focus is on increased input and feedback in the design stage. The goal is to reduce the product costs by designing a product that can be manufactured from the beginning without any problems. It is not only manufacturers, however, that get involved in CE. Quality assurance supports all functions in the cycle by verifying design reliability, maintaining supplier assurance programs, creating and maintaining inspection procedures, and monitoring processes. Other departments that might be involved include material engineers, marketing, and personnel. Usually, the departments work together in cross-functional teams with the goal of producing a product with a short time to market and a low development cost. Individual companies differ as to the composition of their product-development

teams. No matter what the team composition, however, the use of CE has significantly reduced the time and cost in bringing a new product to market.

Lean Manufacturing and Agile Manufacturing

Sports teams might be referred to as *lean and mean.* The connotation is one of streamlined fitness and competitive aggression. When the word *lean* is used as a modifier for terms such as *production* and *manufacturing,* we are inclined to think of the same descriptors. Lean production, in contrast to craft production and mass production, relies on teams of multiskilled workers at all levels of the firm. These workers operate flexible, automated workstations to produce items in varying lot sizes. The craft producer employs highly skilled workers or artisans to build very high-quality products customized for the consumer. The mass production methodology employs narrowly skilled people to design standardized products. Semiskilled laborers crank out these products in large volumes.

Lean-manufacturing environments tend to use fewer resources—less space, less inventory, and less workers—to manufacture a given product than traditional assembly lines do. Also, workers in a lean system are given more authority. Instead of quality control occurring after the product is completely built, the emphasis is on prevention. Workers are encouraged to stop production if they find a defect and work together to solve any problems.

Lean manufacturing was developed by Toyota in Japan and is part of the Toyota Production System this company developed. Using lean manufacturing, a company can implement JIT and move away from a made-to-stock organization to a made-to-order organization. Since the perfection of lean manufacturing by Toyota, thousands of manufacturers have implemented lean-manufacturing techniques. For these manufacturers, the result has been an increase in product quality and productivity. *Industry Week*, a weekly business magazine, has been giving "Best Plant" awards since the early 1990s. An analysis of the winners shows that the majority of winners use lean-manufacturing techniques in their plants. In addition, these plants have been collaborating with their supply-chain partners, while continually pursuing a standard of excellence.

Two of the *Industry Week* "Best Plant" winners are Maytag and Blue Bird. The Maytag plant in Jackson, Tennessee is the sole manufacturer of dishwashers for Maytag. Maytag began its lean transformation in 1999 and so improved its plant that it was 1 of the 12 recipients of the 2004 Shingo Prize for Excellence in Manufacturing. Using lean-manufacturing methods, Maytag transformed a single assembly line into eight assembly cells. This allowed it to increase its manufacturing flexibility, while maintaining quality. Also, Maytag's implementation of lean manufacturing reduced scrap and rework by 64%, increased product quality to 99%, and reduced worker injury rate by 65%.

The Blue Bird North Georgia plant manufactures school buses that carry many of the students in the United States to school each day. As could be expected, safety is a prime concern for the manufacturers of school buses. Blue Bird began its lean program in 2003 and focused on continuous improvement for the entire manufacturing plant, including senior management. In less than five years, Blue Bird posted a 100% on-time delivery rate and an 83% reduction in in-plant defect rates.

Lean manufacturing is not, however, the only new manufacturing technique. In recent years, the word *agile* has been added to the manufacturing lexicon. If a person is described as being agile or having agility,

you most likely envision one who moves quickly and easily, with great balance, in a seemingly effortless manner. How does this relate to manufacturing enterprises? With more companies competing worldwide, the pressure is on for organizations to design and build the best-quality products in the shortest time possible. Delivering a top performance today requires agility, as well as ability.

In industry, the agile manufacturer is fastest to market with the lowest total cost and the greatest ability to meet varied customer requirements. The ultimate measure of its agility is its ability to delight and satisfy its customers. With this explanation in mind, it is logical to conclude that agility is industry specific. The criteria for being agile in the textile industry are quite a bit different than those the automotive industry specifies. Even still, both types of manufacturing enterprises must adopt strategies enabling them to streamline the physical flow of materials; integrate processes; and close the distances among supply, production, assembly, distribution, and customer fulfillment.

Although there are similarities, agile manufacturing and lean manufacturing are not the same. Lean manufacturers see themselves in partnerships with their suppliers. They generally cultivate long-term relationships with suppliers to ensure quality. Agile manufacturers focus on the customer and meeting the customer's needs. They continually find and switch suppliers, depending on their product needs.

Whether a company is lean or agile, several of the current technologies underlying a firm's transition are also beneficial for reducing product defects. On a short list of management techniques used to reduce product defects you might find quality function deployment (QFD), risk management, DFMA, design for defect reduction, and statistical process control (SPC). Several of these concepts are explained a bit further in later sections of this chapter. It is essential to note their particular influences on a company's success in achieving ***agile manufacturing.*** First and foremost, if the products being shipped are not acceptable to the customers, those customers will quickly take their orders elsewhere.

Supply-Chain Management

In the 1920s, the Ford Motor Company River Rouge Complex was the ultimate manufacturing plant. Ford put all the steps in automobile production in one location. These steps included blast furnaces, a glass-manufacturing plant, a tire plant, and the assembly line. At River Rouge, Henry Ford reached a level of total self-sufficiency and a complete vertical integration in automobile production. Each part of the Model T® vehicle was built at the River Rouge complex of plants. Today, companies no longer build all the assemblies and parts going into their products. Manufacturers are streamlining their operations and outsourcing their manufacturing to reduce the overall cost.

Companies are now using supply-chain management to make significant changes in the way they manufacture a product. Most companies, in contrast to the River Rouge plant, have always used suppliers to provide parts. The goal of supply-chain management is to manage these suppliers so production is maximized. Inventory is a key aspect of all supply chains. Too much inventory has a negative effect on the bottom line. Too little inventory causes production delays. It is not only the amount of inventory that matters, however. The relationships among the manufacturer and its suppliers change as well.

How does supply-chain management work? Companies today, in their quests to

be lean and agile, are specializing as never before. As specialization increases, there is more dependence on external suppliers or the outsourcing of an increased percentage of manufactured components. Since other companies are now supplying critical components, a manufacturer becomes dependent on these external suppliers for the overall quality of the product. Part of supply-chain management includes the certification of suppliers. These suppliers then are considered part of the product team.

Boeing is using supply-chain management to achieve lean production. The company wanted to reduce the time a plane is at each workstation. Also, it desired to reduce the immense amount of inventory it had in stock. One technique was to have Boeing's parts suppliers do more work on the subassemblies before delivery. This way, the subassemblies could be delivered right to the assembly line. They could be installed faster at the assembly line. Boeing implemented lean manufacturing in its development and manufacture of the two X-32A Joint Strike Fighter concept demonstrator aircraft for the DOD. See **Figure 6-4.** The results of this lean manufacturing are staggering. Boeing was able to build these aircraft in half the time of previous comparable aircraft with almost no rework. This is practically unheard of when building a plane for the first time. Also, the project came in under budget. Overall assembly costs were 30%–40% below the company's estimates.

This company is not the only American company utilizing supply-chain management. Companies from Campbell Soup to Hewlett-Packard to Walmart have used these techniques to reduce costs. Although their implementations of supply-chain management differ, each of these companies built new and improved supplier relationships to increase their efficiency and, in most cases, profitability. The widespread use of the Internet in managing supply chains is a new development. Supply-chain-management software packages can link the manufacturer with its suppliers both in the United States and across the world. When part supplies run low, the software automatically notifies the suppliers to ship more parts through the Internet.

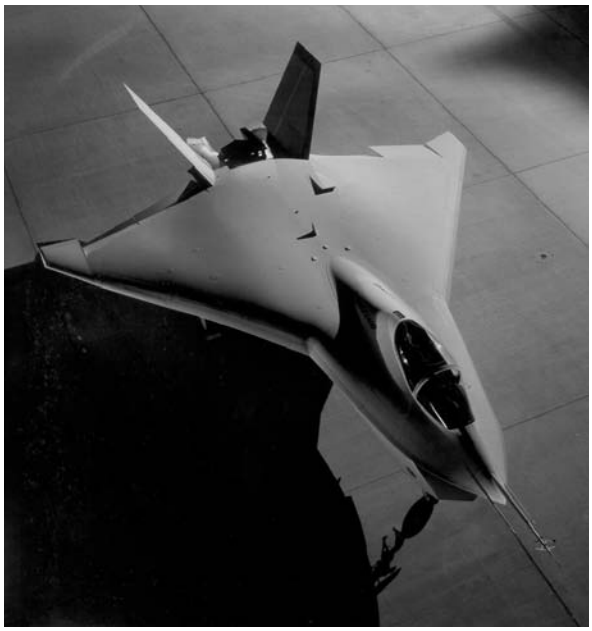


Figure 6-4.
The structurally complete X-32A Joint Strike Fighter concept demonstrator is moved from final assembly to structural proof testing. (NASA)

Just-in-Time (JIT)

JIT is a management philosophy that has been in practice in Japan's production facilities for over five decades. This philosophy was a crucial part of the systematic changes developed at Toyota beginning in the 1950s. The overall system is called the *Toyota Production System.* Many other companies across the globe have imitated it since its popularization in the 1980s. Interestingly, the model for the Toyota Production System

was the American supermarket. Taiichi Ohno, a Toyota executive, traveled to the United States in the mid-1950s to visit American automobile plants. During his trip, he was impressed with American supermarkets and the way shoppers got the products they wanted, in the amount they wanted, when they wanted them. Also, he noticed that the shelves were restocked quickly, either from a stockroom or through deliveries. This observation led him to think of the Toyota car factory as a type of a supermarket. Each workstation would get its supplies from an upstream workstation—an ultimate expression of the "supply and demand" principle at work.

This philosophy is an attempt to achieve agility by reducing work-in-process (WIP) to an absolute minimum. This attempt has gained notoriety and praise in a number of American firms. A core objective of JIT is the elimination of waste that interferes with agile performance. Waste appears in the manufacturing arena in many forms. These forms include lead times for start-up, setup, and changeover periods; defective parts; excess inventory; unsatisfactory raw materials; and unnecessary material handling.

Within a JIT operation, production processes are viewed as the only means of adding value to the product being manufactured. The indirect, but necessary, tasks of transportation, inspection, and storage are looked at as wastes that should be minimized or eliminated whenever possible. JIT managers recognize the dynamic nature of manufacturing and subscribe to a philosophy of continuous improvement, synchronization, and simplicity. In practice, JIT focuses on achieving integrated, highly consistent, short-cycle operations requiring minimal WIP inventory. The JIT approach is a departure from conventional systems. In conventional systems, the emphasis is on automating indirect operations that do not add value to the product, rather than eliminating the indirect operations. These conventional efforts can lead to "islands of automation." On these "islands," there is a lack of continuity in the flow of materials between production stages.

JIT assumes the production rate at the final assembly stage is stable. External to the JIT plant, the company's suppliers are expected to provide parts in smaller batches on a continuous basis. A manufacturer's close rapport with its suppliers can ultimately ensure quality materials, as well as patience from the suppliers when they are asked to deliver smaller amounts more often. The hallmark of JIT purchasing seems to require the steady purchase of parts in small lot sizes (just in time for use on the line), as opposed to conventional purchasing practices. In conventional practices, raw materials are ordered from suppliers in anticipation of future production. A major drawback of this approach occurs if a key supplier's plant shuts down due to a labor strike, natural disaster, or financial failure. Also, since there are reduced inventories, there must be increased quality, both from the parts suppliers and on the manufacturing floor. Since parts are ordered in the exact quantity needed, defects become more disruptive to the manufacturing line.

Another feature of JIT is the reduction or elimination of setup times at the individual machines. Ideally, all setup should be done off-line. If a plant is making two different products on a JIT line, the setup for product two will be occurring off-line while product one is being assembled. It is then a quick switch to product two on the main line. Although this is a fairly simple example, it illustrates a fundamental difference of JIT from traditional manufacturing. Since the setup does not add value to the product, it should not be done on the line. The line

can be more efficiently used to produce the product. The reduced setup times lead to another feature of JIT—reduced lot sizes. Since setup times are reduced or moved off-line, a smaller lot size of each product can be produced at one time. This allows for more flexibility on the production floor and also allows the company to produce the products needed. Since the production floor has more flexibility, a company can switch from one product to another if the sales demand changes.

One critical component of JIT production control is the use of the kanban. The word *kanban* translates to mean "signboard." An item called a *kanban card* or *ticket* usually accompanies WIP parts. A withdrawal kanban reveals the type and amount of product the next process should withdraw from the preceding one. A production kanban specifies the type and quantity of product the upcoming process must produce. See **Figure 6-5.** The kanban tickets, illustrated in **Figure 6-6,** are used in place of job orders and routing sheets. They emphasize small lot sizes. Subsequently, less paperwork is required to coordinate planning and control operations. JIT is a pull system. In this system, the user department pulls the parts or subassemblies from supplier departments. The items necessary to keep production on schedule are pulled from the preceding workstation only as required. This contrasts with the push system characteristic of traditional manufacturing. In this system, items are pushed indiscriminately onto the succeeding workstation, even if that center is not ready to receive and process them. The basic difference between a pull system and a push system is the relationships of these systems to demand. A pull system such as JIT starts production as a reaction to current demand. A push system starts production in anticipation of future demand.

Most companies that have adopted the JIT philosophy have also established quality circles in their workforces. These employee groups are encouraged to make suggestions that might lead to improvements in the company's operations. They strive toward the goal of simplified synchronous production and often help to improve design methods, cut down lot sizes, reduce lead and setup times, minimize scrap losses, rearrange process flow, and solve vendor problems.

Through most of the last three decades, JIT strategies have been used for mass-produced items in the United States, Japan, and parts

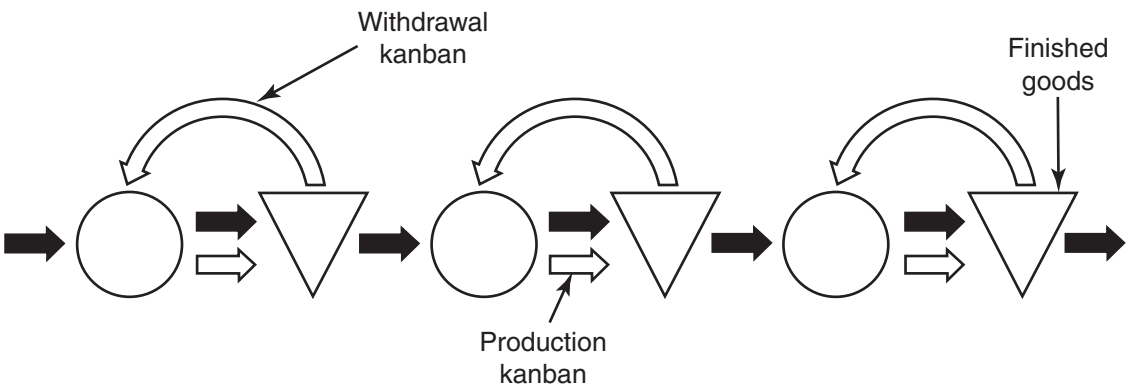


Figure 6-5.
Kanban control. The dark arrows represent the movement of parts. The light arrows show the circulation of kanban cards. Machines are shown as circles. Buffers are shown as triangles. The last buffer is the finished-goods inventory.



Figure 6-6.
An example of kanban move tickets. These tickets are an essential ingredient in JIT production. A typical kanban card contains information such as part number or name, quantity, previous operation, and production routing and schedule. (New United Motor Manufacturing, Inc.)

of Europe. Success stories usually make claims about increased labor productivity, reduced inventories, reduced quality-rejection rates, and reduced need for plant space. General Motors implemented the JIT strategy in the early 1980s and reduced its annual inventory-related expenses from $8 billion to $2 billion in a few short years. Black and Decker reported in the mid-1980s that, with the application of JIT concepts, it was able to increase its volume of throughput by 300% and reduce manufacturing lead times by 50%. Harley-Davidson took its top management team to Japan in the early 1980s to study JIT factory operations. The company subsequently regained lost market share. The motorcycles it built in the early 1990s were 99% defect free, as compared to 50% prior to the trip to the Far East. At its Heilman plant in Indianola, Pennsylvania, Medrad, a medical-device maker, had inventory savings from implementing JIT of over $1 million per year. Medrad also increased overall productivity by 30% and increased its revenue by 15% annually. Appliance makers including GE, Westinghouse, and Motorola have also made great strides in the implementation of JIT manufacturing and purchasing methods in their plants. Despite the numerous advantages cited for using JIT, firms still report a variety of limitations and shortcomings. These limitations include faraway suppliers, unreliable freight systems, loss of individual autonomy, poor quality of delivered parts, and worker resistance to change. This simply verifies that no philosophy, JIT or otherwise, is a panacea, or cure-all, for the many challenges confronting contemporary manufacturing and production enterprises on a daily basis.

Material-Handling Procedures

Material handling refers to the manual, mechanical, or automatic treatment of material when the intended purpose is to move, hold, or control objects either individually or collectively. This treatment might entail controlling material quantities, location, timing, sequence, orientation, alignment, or condition. ***Bar coding*** is the most widely used and accepted automatic ID technology, particularly in material handling. This technology is an excellent example of a technological tool that has revolutionized the movement of material through all areas of a CIM facility. The familiar black bars and white spaces all appear to look pretty much the same. There are, however, a variety of code types, called *symbologies,* created to handle different data sets for specific applications. The most common symbology is the Universal Product Code (UPC). The UPC is widely used in retail functions. Data that bar code scanners gather is being used to control and drive complex conveyor systems. Critical data is available instantly

and automatically for sorting, order verification, distribution, and shipping. Bar coding affects virtually every facet of the material-handling sequence.

It has been estimated that, in traditional manufacturing environments, material handling and associated activities consume more than 90% of a product's time spent in the manufacturing cycle. For this reason alone, the effects of material handling on product quality demand serious attention. The major negative effect of material handling on product quality might cause damage to the point that the product is no longer fit for use. Inappropriate material-handling methods can lead to product-quality degradation, as a result of positioning errors in fixtures or jigs, weather, dust, static electricity, or contaminating vapors. The selection of suitable material-handling procedures requires the thorough analysis of materials and process requirements. Ideally, material-handling systems should be viewed as an integral part of process and facilities design. Specifically, quality assurance specialists must take into account the number of times each product is handled, the distances over which moves occur, and the length of time the product spends being handled. Analysis and control of these three main variables should result in reduced incidences of product-quality degradation.

Some of the most common material quality–related characteristics a manufacturing firm must deal with are fragility, surface finish, sensitivity to electrostatic discharge, sensitivity to magnetic fields, sensitivity to the environment, and shelf life. From a material-handling perspective, fragility might translate into impact, vibration, temperature-change, friction, and weight-support tolerances. Furthermore, a product's sensitivities to weather exposure, moisture, temperature conditions, ambient pressures, dust, and contaminating vapors demand specific tolerances. These tolerances subsequently lead to decisions regarding appropriate material-handling methods, movement paths, and storage locations. Two direct strategies used to enhance product quality throughout the manufacturing process are to minimize the number of times materials must be handled and to shorten the distances of travel between workstations. Several of the CIM and lean-manufacturing strategies described earlier seem to respond directly to these recommendations.

Material Requirements Planning (MRP)

Material requirements planning (MRP) is a technique for planning future purchase orders and manufacturing lots according to what is required to complete a master production schedule. ***Manufacturing resource planning (MRP II)*** is a dominant application software structure manufacturing managers are using. MRP II commonly includes planning applications, customer-service applications, production control, purchasing, inventory product–data management, and various financial functions. Essentially, MRP II creates a dynamic closed-loop management system integrating all the major subsystems of the organization.

While Japanese manufacturers were adopting JIT in the 1970s, American manufacturers were pursuing a different approach to production control. This approach was MRP. MRP is a computer-based system designed to handle the ordering of supplies and the scheduling of work in the manufacturing plant. An MRP system builds on a product's list of materials, called a *bill of materials (BOM).* The MRP system integrates all the individual BOMs and the forecasted demand for the individual products into an overall master production schedule. See **Figure 6-7.**

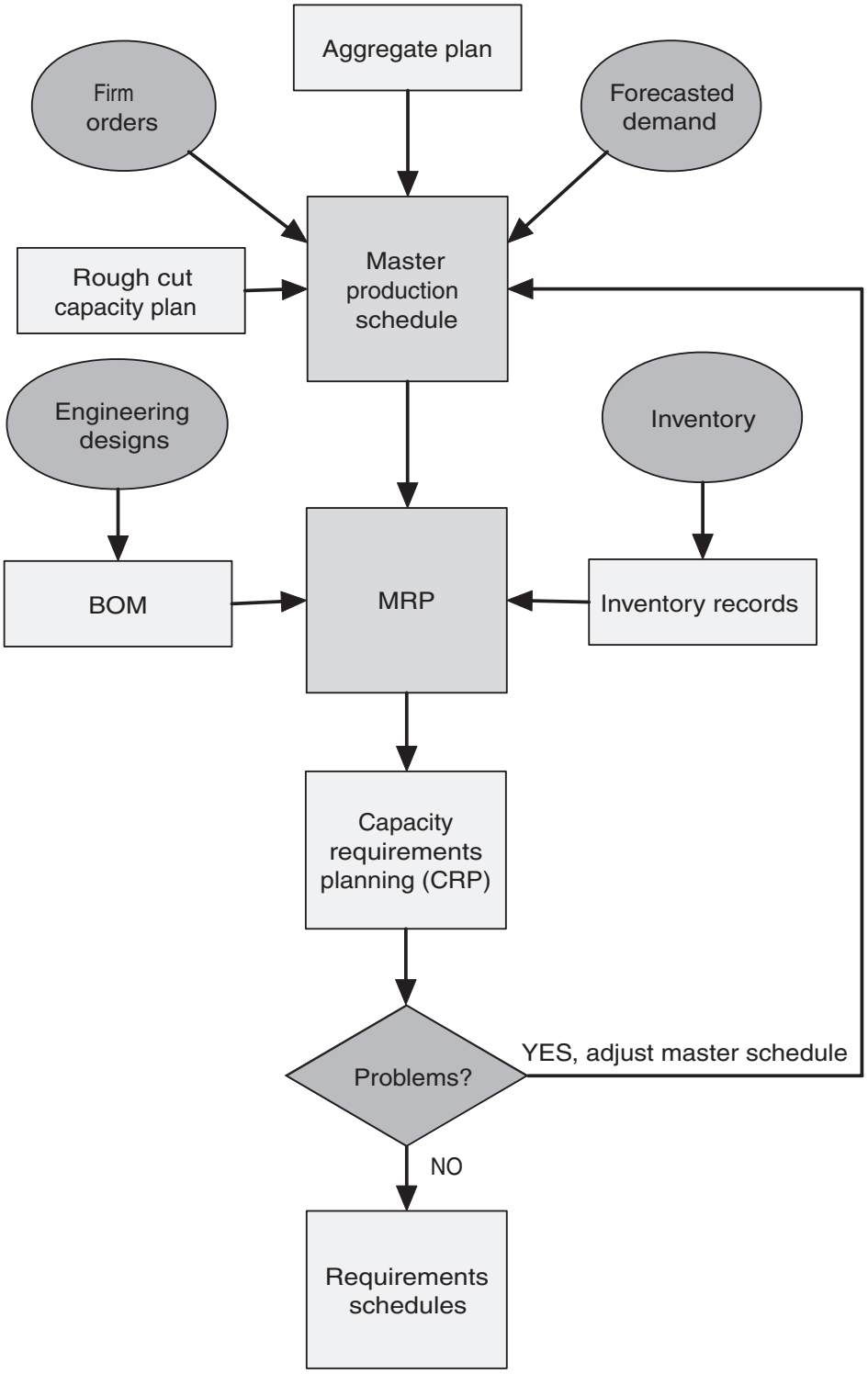


Figure 6-7.
An overview of MRP.

Demand forecasting provides an estimate of the demand for each type of product sold. An organization does long-term forecasting to develop an overall plan for one to five years, to allow the organization to acquire new facilities, hire people, and buy new equipment. Short-term forecasting is usually done from one month to one year and focuses, instead, on the manufacturing of the company's products.

Once demand is determined, an aggregate production plan can be developed. Typically, the sales and marketing departments make demand forecasts that are a combination of orders on hand and anticipated forecasts. These estimates must be reconciled with the manufacturing constraints of the plant (such as plant capacity and workforce). Since a firm can make thousands of products, this data is usually combined at some manageable aggregate level—therefore, the term *aggregate planning.* One of the major uses of an aggregate plan is to level the production schedule so production costs can be minimized. Since the aggregate plan does not provide a plan for individual manufactured products, this plan must be subdivided into another plan specifying quantities of manufactured items by time period. This resulting plan is the master production schedule. The master schedule states which items are going to be manufactured, the quantities of these items, and when these items are needed. This schedule divides the planning into several time periods. The duration of these time periods varies greatly from company to company.

After the master production schedule has been developed, rough cut capacity planning (RCCP) is performed to determine if the master production schedule is feasible. In rough cut planning, some broad guidelines are used. The guidelines usually relate to a key resource (such as equipment or direct labor). If the master production schedule meets the rough cut capacity, the detailed production requirements can be planned.

Once MRP is completed, a detailed capacity analysis is done to determine whether or not the production schedule exceeds the capacity of the plant. If the capacity limitations cannot be resolved, the master production schedule is altered. The process repeats itself. The process of evaluating the capacity requirements begins with the due dates of each order. Using lead times, BOMs, and routings, each order is back scheduled from the due date through the required operations to determine when individual workstations will be used.

As time passed, various operational functions were added to extend the range of tasks in MRP systems. These extensions include master production scheduling (MPS), RCCP, capacity requirements planning (CRP), production activity control (PAC), and purchasing. The combination of these functions is termed *closed loop MRP.* With the addition of certain financial modules, as well as the extension of MPS to deal with master planning and the support of business planning in financial terms, this extended MRP was labeled *MRP II.* MRP can be used with JIT, although the structured environment of MRP makes JIT more difficult to accomplish. In these cases, JIT is used for parts ordering. The schedule is maintained through MRP.

Which is better—JIT or MRP? This is an impossible question to answer. In an assembly line where production is constant, MRP provides a stable way to manage and plan for production. In a factory where different products are produced on a daily or weekly basis, JIT is generally more successful. Either approach requires extensive training and expertise to operate efficiently.

Emergent Manufacturing Technologies

The future state of the manufacturing environment, especially for those firms that have already implemented lean-production technologies and JIT strategies in all phases of their operations, will most assuredly feature aspects of soft, custom production. Soft manufacturing brings yet another approach to the automation mix. This manufacturing delivers with it much greater agility to the plant. Sophisticated software-driven computer networks that a skillful and dexterous human workforce uses and operates represent the backbone of what some experts refer to as the *digital factory.* Companies are discovering they can customize products literally in quantities of one, while churning them out at mass production speeds.

Robots, if they are found at all, play a much less omnipresent role in the soft-manufacturing firm. Over the last 25 years, a number of U.S. manufacturers realized that an overdependence on automation through the installation of huge ***flexible manufacturing systems (FMSs)*** actually cost them profits. Large, expensive, complicated systems might be more vulnerable to failure than smaller, more manageable cells of machines. In places where dexterity and judgment are critical, human operators are back in assembly. Now this is a paradigm shift—"Humans replace robots!" Several well-recognized companies are currently reaping the rewards of soft, or custom, manufacturing, based on their abilities to outdistance foreign competition in such critical measures as time to market and manufacturing flexibility.

As CAD equipment and RP machines continue to evolve, the world will enter yet another new age of custom manufacturing. ***Computer-aided design (CAD)*** systems have evolved from digital drafting software to digital prototype systems that provide a complete digital simulation of the entire end product. Where can an avid cyclist find a replacement part for an upscale Italian Ducati® motorcycle when it breaks down on a country road in northern Maine? In a few short years, the rider might simply catch a ride to the nearest town and hand over a thumb drive containing all pertinent design files for the motorcycle to the operator at the town's corner parts factory. You thought 24-hour copy shops were a convenience!

Contemporary manufacturing is moving toward an era of mass customization. While this sounds like an oxymoron, the earlier examples of agile manufacturing hint at a trend toward customized fabrication. The entire suite of sciences and technologies we have referred to as ***rapid prototyping (RP)*** provides the foundation to this developing approach to manufacturing. This is indeed new territory. RP is ground, however, where U.S. R&D teams have already established solid footing. Researchers are presently experimenting with and creating intelligent materials that can anticipate failure, repair themselves, and adapt immediately to changes in the environment.

Rapid Prototyping (RP)

Before any firm commits to the mass production of a new item, it builds different prototypes for design, ergonomics, safety, ease of assembly, and fitness for use (quality). In recent years, RP has emerged as a well-regarded manufacturing technology in the CE design environment. The aim of RP systems is to make full use of prototypes early in the development stage to identify errors in design and make necessary modifications. This expanding technology has the potential to allow designers to produce a prototype within minutes of completing a CAD

drawing of the part, thus obtaining a physical model of a proposed design, while avoiding the lengthy and costly use of conventional tooling and casting processes. See **Figure 6-8.**

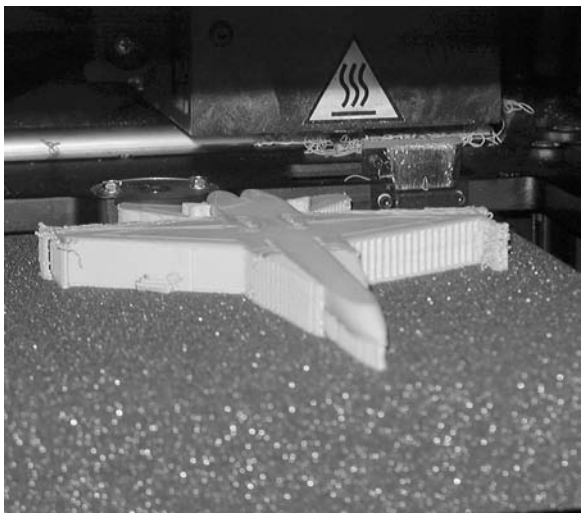
RP systems use data from a 3-D CAD file to construct a model. Charles Hull patented one of the first RP systems in the mid-1980s, with the founding of 3-D Systems, Inc., to develop commercial applications for the process he called *stereolithography.* The number of commercially available RP systems has increased considerably to include laser modeling systems, solid ground curing, fused deposition modeling, fast casting, and laminated-object manufacturing. The purchase of these highly sophisticated systems exclusively for internal use is often prohibitively expensive for many companies. For this reason, a large number of companies outsource their rapid-prototype manufacturing requirements.

Remember our broken motorcycle? In an example of the use of prototyping to replace the motorcycle part using fused deposition modeling, a machine tool receives a geometric description of the broken part from the CAD file on the disk. The program then divides the model into evenly spaced layers. Each layer is as small as a few thousandths of an inch. The model is built layer by layer from the bottom up. The program instructs the tool to deposit thin layers of liquid, one layer at a time. These layers subsequently fuse together to build a complete part.

A new, and cheaper, RP technology has recently emerged on the market—3-D printing. 3-D printers work by printing new layers on top of existing layers to create a 3-D object. Unlike stereolithography, 3-D printing is faster, cheaper, and easier to use. This printing is particularly useful for companies in the conceptual stages of engineering design. In these stages, they develop prototypes of



An RP System



A Prototype

Figure 6-8.
RP machines use high-performance engineering materials to create parts with superior strength, heat resistance, and chemical resistance. The FDM Titan™ from Stratasys is the only RP system that can build parts from high-temperature, high-performance, and durable engineering plastics, such as polycarbonate, polyphenylsulfone (PPSF), and ABS plastic. This partially completed prototype of a model airplane was built using an RP machine. (Joe Hiemenz, Stratasys; Phoenix Analysis & Design Technologies)

new products. Timberland, a designer and manufacturer of footwear, used a 3-D printer Z Corporation developed to create new prototype shoes from CAD files. Prototypes that previously cost $1200 and took one week to carve now cost the company $35 and take 90 minutes to create.

Almost every issue of *Machine Design,* a trade weekly, contains an advertisement for new and improved types of product prototyping. There is no denying the benefits of this technology. Prototype parts can save costs because they allow the engineer and manufacturer to see the final product early in the design stage. This saves expensive revisions and rework. RP itself has expanded into two additional areas: rapid tooling and rapid manufacturing. Rapid tooling refers to the use of RP to develop molds for use in production. Rapid manufacturing is the use of RP for low-volume production. There is no doubt that its use will continue to expand in the future, as more companies exploit this technology to decrease costs and reduce development time.

Cellular Manufacturing

Cellular manufacturing is a type of equipment layout in which the machines are grouped into cells, rather than being placed on an assembly line or divided into different functions (for example, all drills together or all lathes together). The parts produced in a particular cell determine the layout of the cell. In order to have an effective cellular arrangement, a company has to group its products that use similar manufacturing processes. All parts in one group (called a *family*) follow the same route in the cell, although individual products might spend more time at a particular machine than other products in the same family.

Historically, the layout of manufacturing facilities was classified as a job shop, flow shop, or fixed layout. Cellular manufacturing is a new type of production layout. ***Group technology (GT)*** is used in order to achieve cellular manufacturing. GT is an approach to manufacturing that seeks to maximize production efficiency by grouping together similar and recurring tasks, procedures, problems, and bottlenecks. A key feature of GT is the segregation of parts according to their designs, manufacturing features, or a combination of these. When similar parts are grouped together, each collection can ultimately share setups and machine tools. This sharing reduces production costs. GT is applicable to both automated and nonautomated manufacturing and can be used in new or existing facilities.

This technology has attracted a great deal of interest from manufacturing firms because of its proven capacity to simplify material flow on the production floor. The GT approach is a marked improvement over traditional batch-processing methods. Experts estimate that most manufacturing is still done in small batches, ranging from a single workpiece to several thousand pieces. In many cases, these parts cannot flow smoothly through the manufacturing process since different parts require different setups or must be transferred to another machine. The application of computerization to manufacturing enabled managers to improve the production of both small and large batches through the use of scheduling software, sequencing software, and MRP systems.

It also became feasible for companies to identify and track the thousands of different parts being produced through the use of GT methods. Design engineers have found they can use GT systems to determine whether or not an existing part can be used in a new application, thus eliminating the need to design a new part. This potential to eliminate design duplication and the parallel need to build a new jig or fixture can yield significant economic benefits.

Basically, a GT database is a computerized filing system that speeds up the retrieval of parts information, facilitates the design process, and enhances the communication among individual functional areas inside the plant. GT systems also improve the accuracy of process planning and aid in the creation, layout, and operation of manufacturing cells. GT is a critical building block for CIM. A GT database can contain detailed information about the parts a company produces, the machines and equipment available to produce those parts, and the best processing methods to complete the job on time as promised. Other advantages of adopting GT strategies include reduced material-handling costs, improved flow of materials, small in-process inventory, reduced changes in production planning and control, less floor space needed, reduced design modifications, easier design retrieval, more accurate cost and delivery estimates, and improved quality and productivity through the workplace.

One of the salient benefits of GT is a direct result of using a formal coding system. In this system, each part receives a numeric code or an alphanumeric code describing specific characteristics or attributes. To be most useful, the code should be able to describe the part from both a design perspective and a manufacturing perspective. Such physical features as the external and internal shapes, dimensions, threads, grooves, and splines describe the geometric form (morphology). The structure and chemistry of the raw material, the surface finish, various tolerance requirements, and the need for heat treatment are examples of manufacturing specifications. It is easy to visualize a code with a large number of characters if one tries to capture all significant attributes. A number of GT coding schemes have been developed, including Metaalinstituut CLASSification (MICLASS) (12 digits), Decision CLASSification (DCLASS) (8 digits), Vuoso Praha (4 digits), and Opitz (5 plus 4 digits).

Figure 6-9 provides an example of a principal GT coding system called *Opitz,* serving to illustrate this key aspect of GT. Once the parts are coded, they are further grouped into families. As you can see, the Opitz code classifies a part according to its external shape, its internal shape, the machining of its surface, and its additional holes and teeth. The part receives a score from zero to nine for each digit in the Opitz code.

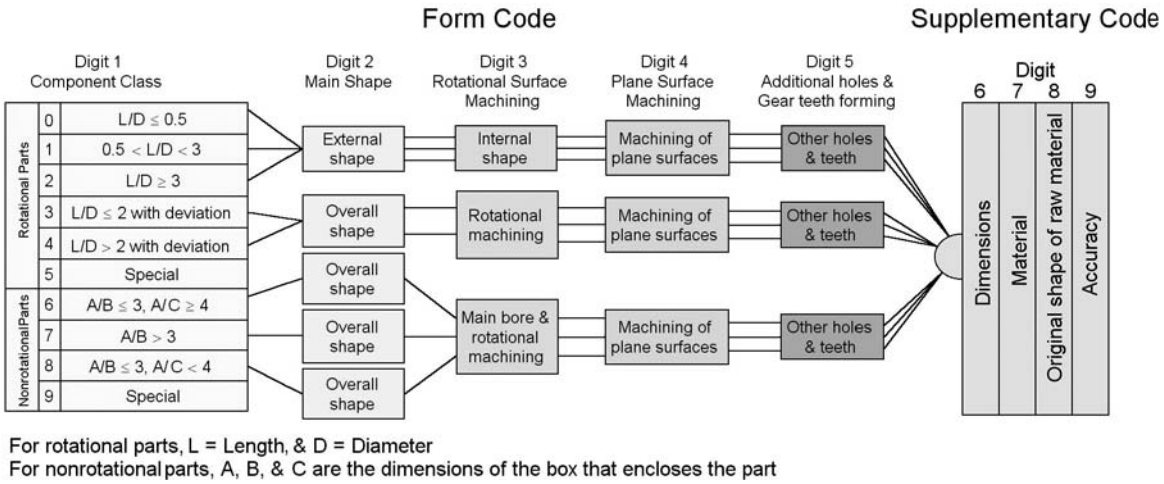


Figure 6-9.
The basic structure of the Opitz code.

Under digit two, main shape, a code of zero represents a smooth external shape. A code of eight indicates the part is threaded similarly to a screw. The combination of codes for each digit then gives a complete description of the part. The special codes following identify the specific design attributes of the part. These attributes include its dimensions and material. Using GT codes, it is far easier to locate one part fitting the current needs at hand. The engineering department can then avoid designing a brand new part. As a rule, GT codes are assigned to both purchased items and fabricated parts.

A simplified version of GT in a job-shop setting involves the sequencing of similar parts on a machine or series of machines. This job-shop facility can process a wide variety of parts since it is still a job shop. The parts are processed in families (using the GT code), however, to realize some of the benefits of GT.

A more sophisticated approach to GT entails the creation of manufacturing cells. A manufacturing cell is a collection of machine tools and material-handling equipment grouped together to process one or several part families. Transfer of the piece from one process step to another within the cell and possibly on to a different cell can be automated. Essentially, a manufacturing cell is a hybrid production system meeting the needs of a specific firm. The development and application of manufacturing cells are dependent on the type of manufacturing operations performed, the life cycle of products fabricated, the product mix, and projected customer demand. Cells are a blend of job shops producing a large variety of parts and flow shops dedicated to the mass production of one product. **Figure 6-10** portrays one view of the differences between manufacturing parts in a job shop using a conventional layout and a cell shop subscribing to GT principles. A fully operational flexible manufacturing cell speeds up the manufacturing process faster, since parts are moved quickly and systematically from one workstation to the next. This allows the manufacturer to reduce inventories of partially finished parts, representing significant cost savings.

Radio Frequency Identification (RFID)

Radio frequency identification (RFID) is an automatic ID technology that uses tags or transponders to identify objects, collect data, and most importantly, enter the data into a computer system using a wireless network. Most RFID tags are attached to a product, an animal, or a person and have two parts. These parts are an integrated circuit for storing and processing information and an antenna to receive and send signals to the wireless network. There are also simpler RFID tags without integrated circuits that can be printed directly on the product.

Most early use of RFID was in supply-chain management. One of the early adopters of this technology was Walmart. As the largest retailer in the United States, Walmart uses RFID to read product information from tags as products are moved from Walmart's distribution centers into their stores. Walmart uses passive RFID tags. These tags do not emit a wireless signal. Instead, a special reader reads the tags. The use of RFID tags allows Walmart to replace its stock faster and reduce excess inventory. In the last few years, other companies including Audi, Sony, Dole Food, and Boeing have followed Walmart's lead and set up RFID systems to track products. At its Auburn, Washington aircraft plant, Boeing uses RFID tags to manage incoming parts for its planes. Today, using RFID tags, the supplies are automatically scanned when they enter the building. Boeing's computer system is notified. This notification dramatically reduces labor costs for both Boeing and its suppliers.

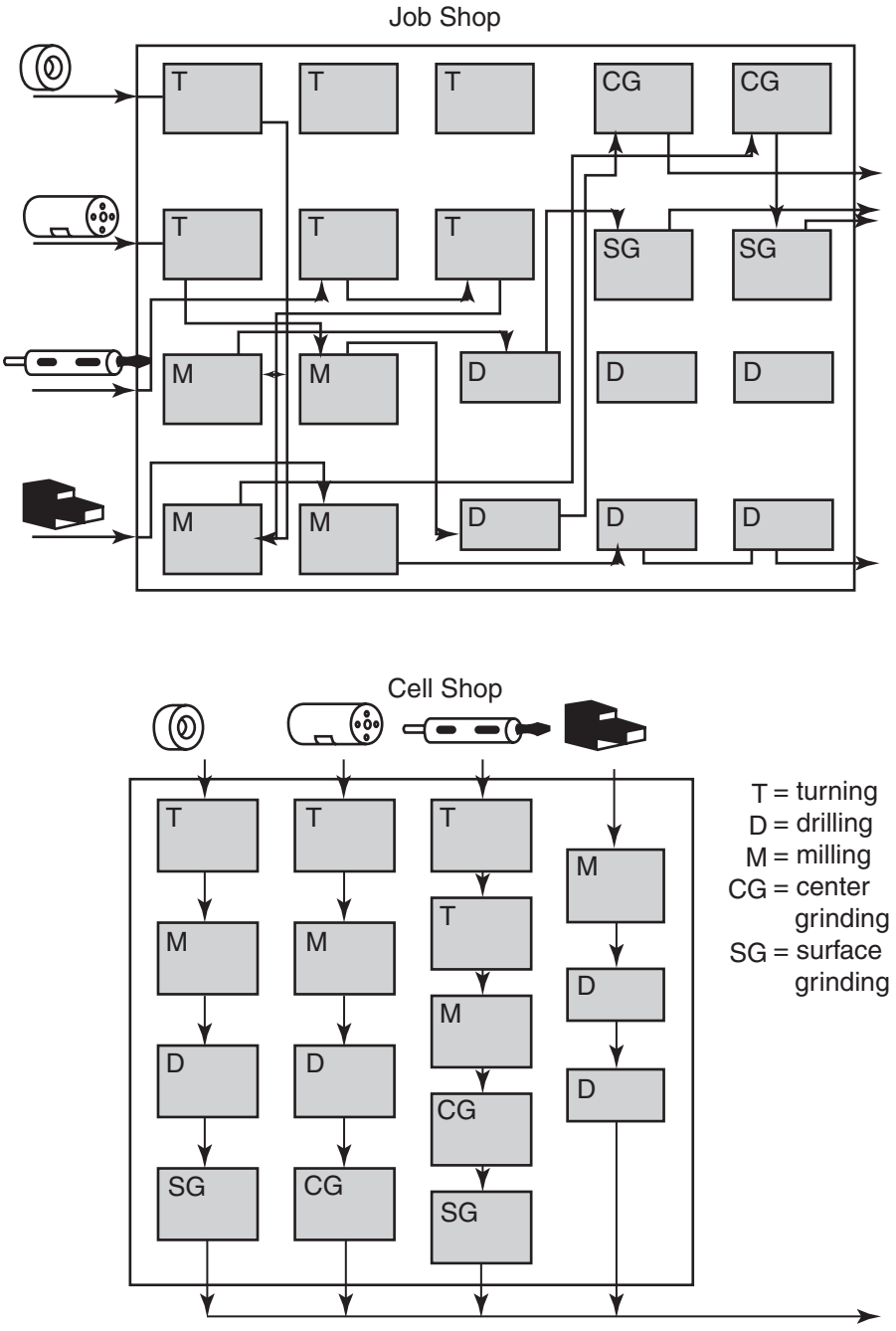


Figure 6-10.
The movement of parts through a traditional job shop, compared to the movement through a GT-oriented cell shop.

Since its adoption in supply-chain management, RFID has been used in a wide range of applications. The port of Oakland, California uses RFID to track delivery trucks entering its international terminal. RFID is also used in wireless-tool pass systems on the nation's highways. One of the biggest users is the U.S. DOD. The DOD began using RFID to track cargo and vehicles during the 1991 Persian Gulf War. Today, the DOD requires all suppliers, excluding those of bulk goods, to include RFID tags on their DOD supplies when they are delivered. Currently, all new passports the U.S. government issues contain an RFID chip with the passport holder's name, nationality, gender, date of birth, place of birth, and digitized photo. The chip also contains the passport number, issue date, expiration date, and type of passport.

RFID tags are not restricted to products and supplies. In the last two decades, millions of household pets have been implanted with RFID tags. The USDA has a new voluntary initiative. This initiative is the National Animal Identification System (NAIS). The NAIS identifies individual animals through imbedded RFID tags. The Department of Agriculture plans on using this animal-tracking feature to trace an animal-related disease back to its source within 24 hours, thereby reducing any further health threat to the U.S. public. Xmark® software's RFID system for tracking and monitoring patients is used both for infants and in nursing homes for elderly patients. In hospital nurseries after birth, both the mother and the child are given wearable RFID tags. If a baby is removed from the newborn ward, an alarm is triggered. This alarm alerts hospital security. Xmark software's Roam Alert® system for nursing homes allows wandering residents to be monitored. When the tagged resident approaches a monitored exit, the tag emits a special signal. Not all the uses are for medical purposes, however. The Baja Beach Club in Barcelona, Spain, described in the Dateline section, offers regular customers the option of implanting RFID tags under their skin, in order to provide quicker entry and payment for drinks.

As the prices of RFID tags continue to drop, more companies will use them to manage their inventory and supply chains. The use of these tags in animals and people is more fraught with controversy. Although an implanted RFID can quicken entry into nightclubs and secured facilities, activists point to the possibility of RFID tags being used to monitor citizens. When tags are imbedded in expensive products such as clothing or electronics, will these tags continue to monitor these products after the consumer brings them home? At this point, it is too soon to tell.

Total Quality Management (TQM)

Along with the strategic implementation of manufacturing technologies, the management of productivity and quality has emerged as a major business strategy in numerous organizations. There appear to be several forces driving this ongoing trend. The first force is related to an intensive amount of global competition in all industrial sectors. There has been an increasing demand for better-quality goods and services at either the existing price or a significantly lower one.

A second force stems from the fact that production costs have gone up considerably over the past several years. To offset this situation, manufacturers are investigating new ways to improve the productivity of labor, as well as to apply a variety of innovative manufacturing technologies. Third, the level of consumer education has intensified,

leading to a more acute awareness of quality. Public acceptance of manufactured goods is based on strict conformance to specifications. People commonly expect the products they purchase to be 100% defect free. They quickly lose confidence in a manufacturer when these expectations are not satisfied.

A widely accepted generic definition of *quality* is "fitness for use." The manufacturer views fitness for use from the perspective of its own ability to process and produce finished goods with less rework, less scrap, minimal downtime, and high output. Customers view fitness for use whenever they consider things such as product durability, availability of spare parts, identity, and comfort. Two main aspects of quality are the quality of design and the quality of conformance.

The quality of design involves the features obtained through changes in or manipulation of design parameters. Differences (not always improvements) in quality can be achieved by changing elements, such as the size of the item, the materials used in the product, the equipment used in production, and the tolerances during manufacturing. The quality of conformance is a measure of the extent to which the product conforms to the specifications and tolerances the design requires. Many factors influence this measurement, encompassing training, employee motivation levels, the complexity of the production process, and the quality assurance system being used.

Consumers evaluate a product's fitness for use through a review of certain quality characteristics. Depending on the item, any number of features might be critically considered. If the buyer expects the product to last for a certain length of time, quality elements such as its warranty, serviceability, reliability, and maintainability are important. Ergonomic features, including comfort, size, and ease of use, fall into another category. Finally, one should not overlook the sensory-oriented qualities, such as the product's color, taste, fragrance, beauty, and appearance. If you have ever been involved with the selection and purchase of a new automobile, you should remember these things well. Nothing quite compares to the new-car smell!

There are several quality-management functions that must be executed at different levels of the manufacturing process. The corresponding control activities and the types of data collected at each level tend to vary considerably. Quality planning is a function parallel to process planning. For each workpiece handled, the measurement parameters, tolerances, and test sequences must be determined. It is also necessary to establish sampling plans, process-capability studies, and the amount and type of quality data to be accumulated and stored. The company's quality expert normally completes this planning operation with or without the use of a computerized data storage-and-retrieval system.

As previously described, quality is the sum of all attributes and characteristics of a product or service contributing to the usefulness of the product or service or its ability to perform certain functions. Quality management is, therefore, a regulatory process through which performance is first measured and then compared with preset standards. If necessary, corrective action is taken. The backbone of an organization's quality-management system is the internal, national, and international standards it aspires to guarantee. These standards are essentially akin to a contractual agreement between the manufacturer and the customer. Adherence to publicly accepted standards is the aim of a quality assurance system. In recent years, many organizations have adopted the International Organization for Standardization (ISO) 9000 standards as the basic foundation for their total quality management (TQM) system.

An efficient quality-management system can be described as a complex adaptive control loop. All critical properties and product-performance standards are identified and checked throughout the factory:

1. At receiving.
2. At the location where the parts originate in the manufacturing process.
3. At subassembly stations.
4. During the final acceptance test of the finished product.

Within the system, when the cause of any defect and its place of occurrence are known, measures for the defect's correction or elimination are initiated. Requisite corrective actions might take place at the factory-floor level or might extend back into product design. An important aspect of quality management is reaction time. This is the length of time (seconds, minutes, hours, or days) between the instant the defect is recognized and the instant it is corrected. Coordinated efforts between plant managers and shop personnel, combined with advanced computerization, will eventually lead to shorter reaction times and more efficient quality assurance programs. JIT production goes hand in hand with good quality. Poor quality requires buffers of inventory ready for use when bad or unacceptable parts are found during assembly. As stated earlier, one goal of lean production and JIT is to operate with greatly reduced inventory.

A new technique Motorola pioneered has been added to the TQM movement—Six Sigma. Six Sigma refers to the amount of variation existing in a product. The average product at a company usually has a variation of four sigma. This equates to more than 6000 defects per million. In the late 1980s, Motorola started a campaign to reduce defects in its products. The company used a quality system review to assess the effectiveness of all the major business units in Motorola. Motorola developed the Six Sigma concept to improve its processes and increase product and process quality. Six Sigma is equivalent to products that are 99.9997% acceptable or, in other words, have only 3.4 defects per million opportunities. In 1988, Motorola was the winner of the first Malcolm Baldrige National Quality Award.

The Six Sigma concept has spread to hundreds of organizations since its establishment by Motorola. GE estimated that its profits in the late 1990s increased by $6 million because of its use of Six Sigma. AlliedSignal recorded more than $800 million in savings. Six Sigma has spread beyond the manufacturing world and is used by organizations in many areas. These areas include banks, health-care providers, and schools. This concept represents a higher level of commitment by an organization because it requires a paradigm shift in thinking about quality. Six Sigma focuses on selecting projects carefully targeted to improve selected business operations. The goal is to eliminate defects before they occur in an organization. Six Sigma is often implemented in conjunction with lean manufacturing.

Statistical Process Control (SPC)

While quality assurance has traditionally been accomplished through product control (such as inspection), the focus of process control is on individual operations and the roles they perform in manufacturing. Process-control strategies are prevention oriented, as opposed to inspection driven. The ultimate goal of process control is to have each operation functioning within its normal capability limits. This type of control is often referred to as ***statistical process control (SPC).***

STATISTICAL PROCESS CONTROL (SPC)

An approach to quality assurance differing from the traditional policy of product control via inspection. SPC is prevention oriented, versus inspection driven. This approach involves statistical analysis and increased personnel responsibility to ensure all equipment and processes are operating within acceptable limits. SPC implementation focuses initially on two or three critical parameters in each process that must be controlled.

As a theory, SPC is over 60 years old. SPC is based on work Walter Shewhart did during the 1930s at Bell Telephone Laboratories. SPC principles were widely adopted only about 30 years ago. Since that time, however, they have become a pervasive feature of manufacturing plants, as well as more commonly used in other industries.

Process control involves both statistical analysis and increased personnel responsibility for making sure equipment and processes are operating within acceptable limits. This control provides a unifying and validating factor for the overall quality program. Process control provides management with critical feedback regarding the condition of the plant's manufacturing equipment and machinery and can pave the path toward excellence in timely machine tool replacement. Managers who are committed to their quality assurance programs are beginning to realize the "run-it-til-it-drops" strategy for machine replacement is not the way to stay ahead in the international manufacturing race.

The decision to implement process control should focus initially on the ID of two or three critical parameters or characteristics in each process that must be controlled in order for the process to adequately fulfill its function. Next, the operating ranges of these critical parameters must be specified. After this step, it is possible to go back and evaluate how each process can be improved to tighten the acceptable operating ranges and enhance overall product consistency. Managers can systematically utilize this input to plan and rationalize future capital improvements.

Process control is fundamentally different from traditional product-inspection systems. The basic philosophy that seems to permeate an inspection-based system is first you make the product. You then check it to see how good it is. In many cases, if you make enough of the product, you ship it out the door unless it is totally disastrous. This type of attitude and approach to manufacturing lies at the heart of the problems many American firms have had trying to maintain quality. As an alternative, the basic premise of process control is that the manufacturer knows enough about the operation to keep the system up and running and how to keep it within certain limits. Also, under a process-control system, the quality monitoring is delegated to the worker on the production floor. In this system, the worker knows how to continually monitor her process to ensure quality. The worker measures the critical parameters at her station, in order to assure that all products are built with an acceptable quality standard.

The process-control system demands quality by design. CE, discussed previously in this chapter, has been effectively used to increase the quality of the product through the design process. Design for defect reduction can be an effective way to quantify and minimize the probability of product defects. This requires an analysis of the defects that will most seriously affect customer satisfaction and an examination of the manufacturing processes to define which ones might cause defects. Those manufacturing operations unable to stay within tolerances should be corrected or not be allowed to keep running.

Quality Function Deployment (QFD)

As stated earlier, today's lean and agile manufacturers are already thinking about quality outcomes during the product design-and-development stage. A technique known as ***quality function deployment (QFD)*** has emerged in recent years. QFD is a systematic way for the manufacturing firm to identify customer requirements and convert them into design and manufacturing needs. Essentially, it is a management planning tool that can be used in any phase of production. QFD helps all concerned personnel identify the critical design parameters. These parameters are then optimized through quality engineering to minimize variation during production. To ensure customer expectations are met in an economical fashion, adequate resources are focused on any areas that can cause failure.

The main feature of QFD is its focus on meeting customer needs. This focus is called the *Voice of the Customer.* The House of Quality is the most recognized tool used in QFD. A multifunctional team takes the customer requirements obtained from market research and benchmarking and converts these requirements into a new product design, using the House of Quality. After the customers' needs are translated into technical and design requirements, the team looks at the relationship between these two categories. Say, for example, we are designing a new pencil. Two customer requirements might be that the pencil is easy to sharpen and that it is hard and lasts a long time. After translating these two customer needs into technical requirements, the team might determine that these two needs conflict. If a pencil is harder, the material used has to be stronger. This would make the pencil harder to sharpen. This type of information goes in the top of the House of Quality, in the technical correlation matrix. **Figure 6-11** shows a sample House of Quality. Most companies adapt this form, however, to serve their specific needs. A key to all implementations is the focus on the customer.

International Organization for Standardization (ISO) 9000 and Standards-Based Manufacturing

Another significant change has been the rise of the quality-standards movement. ISO 9000 is the most popular quality standard in the world. Thousands of organizations have adopted it. This standard is actually a set of standards. The most recent standard, ISO 9001: 2000, applies to manufacturing, service firms, and public agencies. ISO 9001: 2000 is a series of three interrelated standards.

A company first develops a quality system meeting the standards. There are eight sections to ISO 9001: 2000. The first three sections provide background. Section 4—Quality Management System—requires a company to establish and document its quality system. The focus is on continuous improvement, both of the product and of internal processes in the company. Section 5 focuses on the responsibilities of management and requires the company to satisfy its customers, establish a quality policy, and perform management reviews. Resource Management is Section 6. The standards state that, without adequate resources, a quality plan will not be successful. Section 7 relates to product design and development. Section 8 focuses on measurement, analysis, and improvement.

Once the quality system has been developed, the company carries out an internal audit to make sure the quality program is working. The last step is to have a visit from an external evaluator. The evaluators audit the company's quality system. If the auditor approves the new system, the company receives an official certificate that the company is ISO 9000 registered.

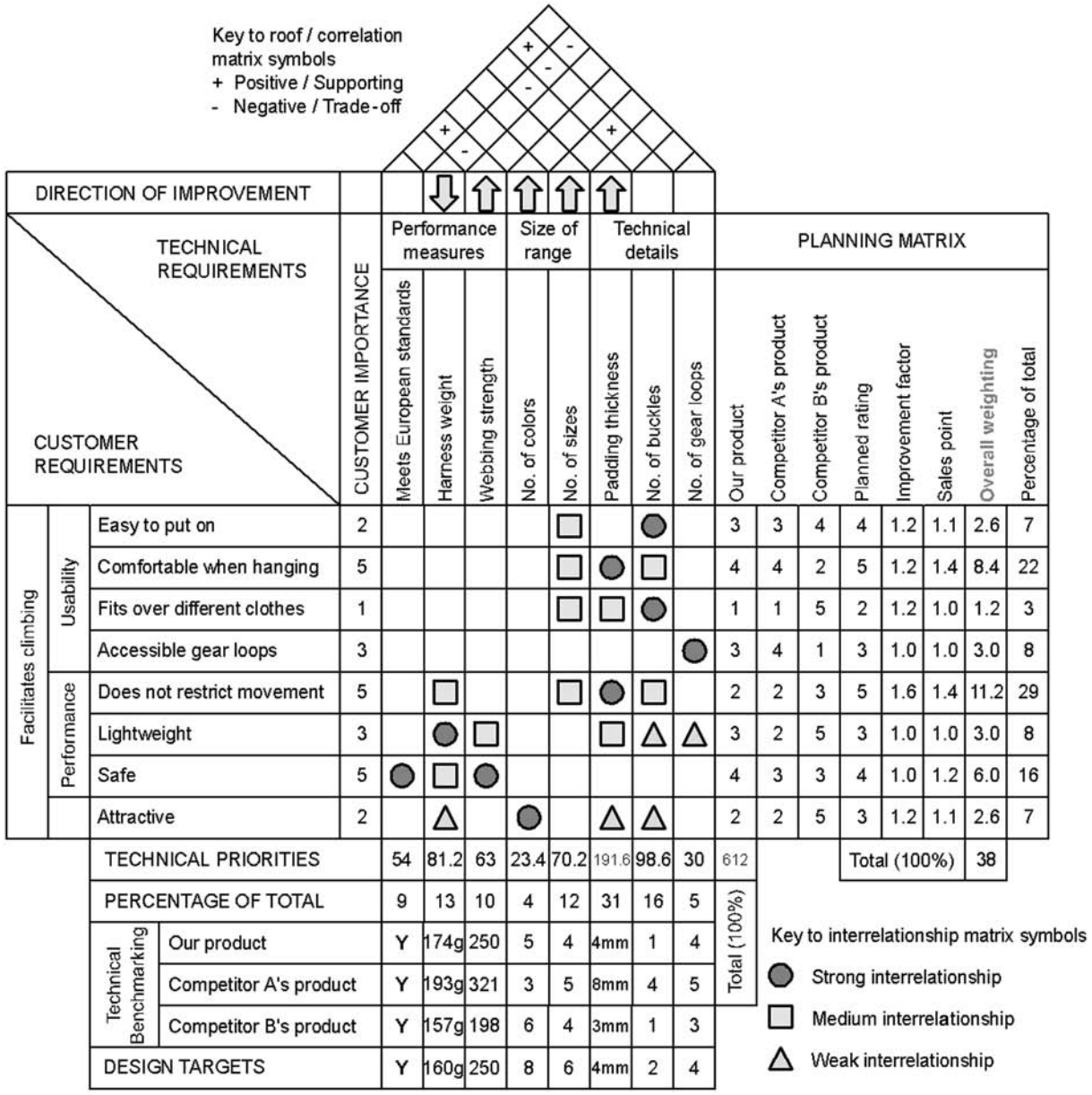


Figure 6-11.
The House of Quality is the most recognized tool in QFD. (Dr. A. J. Lowe MEng PhD)

Since ISO 9000 certification indicates that a company meets international quality standards, companies are using their achievement of ISO certification as a marketing strategy. Even small companies are jumping on the ISO 9000 bandwagon.

See **Figure 6-12.** Also, for some companies, ISO 9000 certification is now required to get contracts, particularly in Europe. The European Community (EC) pushes ISO certification in Europe. In certain industries, the EC requires ISO 9000 certification because



Figure 6-12.
ALOM Technologies, a small manufacturer and distribution center in Milpitas, California, proudly shows it has received ISO 9002 certification. ALOM helps high-tech and e-commerce companies get their products manufactured and distributed to customers. ISO 9002 is the ISO standard for companies participating only in production, installation, and servicing.

the products have stringent requirements for safety and reliability. Even if a small company does not sell directly in Europe, ISO certification can still be useful because the small company might sell to other companies that sell in Europe. Also, as a large company achieves ISO 9000 certification, often it pushes down this requirement to its suppliers.

With the globalization of business, ISO certification creates a standard companies can rely on as they buy goods and services from across the world. Not surprisingly, the number of ISO 9000–certified companies is growing each year. In 2006, the number of ISO 9000 certificates worldwide totaled nearly 900,000. ISO certification will remain a large part of the manufacturing world in the future.

Environmental Sustainability as a Business Practice

Over the past 10 years, a fundamental change has occurred in the philosophy of American businesses. Prior to 2000, there were few businesses that followed green practices in their businesses. Traditional thinking was that green practices would automatically increase company costs and negatively impact a company's bottom line. Consumer concerns about global warming and other environmental issues have forced companies, however, to take a hard look at developing processes that protect the environment. In many communities, companies are banding together to promote best practices in reducing energy and waste. One such consortium, based in San Jose, California, is Sustainable Silicon Valley (SSV). SSV is a collaboration of businesses, governments, and nongovernmental organizations that are identifying and addressing environmental and resource pressures in the Silicon Valley. Most of the high-tech companies from Silicon Valley are partners in SSV. These partners include Adobe Systems, Advanced Micro Devices, Applied Materials, Cisco, eBay, Hewlett-Packard, and Sun Microsystems. Each of these companies has pledged to reduce its CO_2 emissions and to report its emissions annually. Cisco was

able to reduce its greenhouse-gas emissions by 11%, while at the same time, increasing its revenue by over 20%. Since 2001, Adobe Systems has improved energy efficiency at its headquarters in San Jose by implementing several green building techniques. Adobe was able to reduce its irrigation-water use by 76%, by installing drought-tolerant landscaping, and its internal-water use by 22%, by installing waterless urinals.

Sun Microsystems applies environmental principles both in the design of its product (computer servers) and in its own business practices. Sun's UltraSPARC® server processors are the most energy efficient on the market. Sun encourages its employees to work from home, in flexible offices, and at satellite locations. Today, over 50% of Sun employees no longer work from their offices. This saves both carbon emissions and real estate costs.

Environmental sustainability, however, is not limited to companies based in California. A large multinational company, GE, invested $200 million over four years to increase production of energy-efficient lighting in response to consumer demand. Alcan, one of the globe's leading suppliers of bauxite, alumina, and aluminum, has a comprehensive environmental strategy for all its business areas. One of its plants, the Alcan Packaging plant in Dublin, Ireland, drastically reduced its waste from 2770 tons, in 1996, to 400 tons, in 2005. Furniture-maker Herman Miller is 63% toward its commitment to achieve zero emissions in its manufacturing by 2020. Both Herman Miller and Nike were ranked as two of the most sustainable companies worldwide. Nike has focused on integrating more environmentally friendly materials into its products, as well as controlling the waste it produces. Today, over 50% of all cotton garments Nike produces contain at least 5% organic cotton. Environmentally preferred rubber is used in over 50% of all Nike footwear. Nike also created the Nike Reuse-A-Shoe program. This program recycles discarded shoes into material that is used to cover sports surfaces, such as basketball courts and tracks. Since the program began in 1993, Nike has processed more than 18 million pairs of shoes.

Under the old model of manufacturing, companies designed new products under a "cradle-to-grave" approach. After a product ended its useful life, it was discarded. Today, most companies are taking a different direction and using a "cradle-to-cradle" approach to product design and manufacturing. This approach strives to make the entire product design and manufacturing waste free. In this way, a company takes responsibility for the disposal of its products and builds this disposal into the design. This philosophy transforms existing disciplines and practices into those promoting sustainability, encourages technologically and economically viable products, and emphasizes the protection of the earth.

Advances in Automation

It is hard to believe, but the robot is well into its middle age. In 2002, the robot turned 40! According to Joseph Engleberger, who is often referred to as the *father of robotics,* Unimation installed the first industrial robot in the early 1960s on a production line at General Motors. Since that time, more than 900,000 robotic units have been set to work in factories around the world. Robots are being used for a variety of operations. They are familiar entities in chemical-processing plants, automobile assembly lines, and electronics-manufacturing facilities. The most popular applications worldwide include arc welding, spot welding, spray painting, parts and tool handling, and assembly. Robots are commonly used to replace human labor in repetitive and potentially dangerous operations.

They can work in hazardous conditions. In these conditions, high temperatures, toxic chemicals, or radioactive substances are present. Robotics has also moved into warehousing, shipping, and receiving functions. Robots are installed in some offices and used in several service industries. These industries include hotels, hospitals, restaurants, and landscaping.

Industrial robots are a critical component of factory automation. Alongside peripheral technologies such as CAD, numerical control, and automatic ID, these ever-improving factory-floor helpers come in all shapes and sizes. Very few of them bear any resemblance to the humanlike androids pictured in science fiction movies. Most of them can be described as computer mechanisms, to which limbs, tools, and other appendages have been attached. Although somewhat less exotic, a more technical term for a present-day robot is an *automatically controlled programmable manipulator.* The most commonly accepted definition still in use today for an *industrial robot* is "a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable motions for the performance of tasks."[2] Robots operate with several degrees of freedom and can be either fixed in place or mobile. The key word in this definition is *reprogrammable.* The reprogrammable robotic feature differentiates industrial robots from other forms of so-called *hard automation.* These forms do not allow for easy changes. Research efforts in the fields of AI and expert systems will continually expand the capabilities of these steel-collar employees.

Regardless of their size or functions, industrial robots have three main parts. See **Figure 6-13.** The main body of the robot is called the *manipulator.* The body's base can be fastened to the floor, modified to move on tracks, or hung from an overhead support. The power mechanism moving the arm of

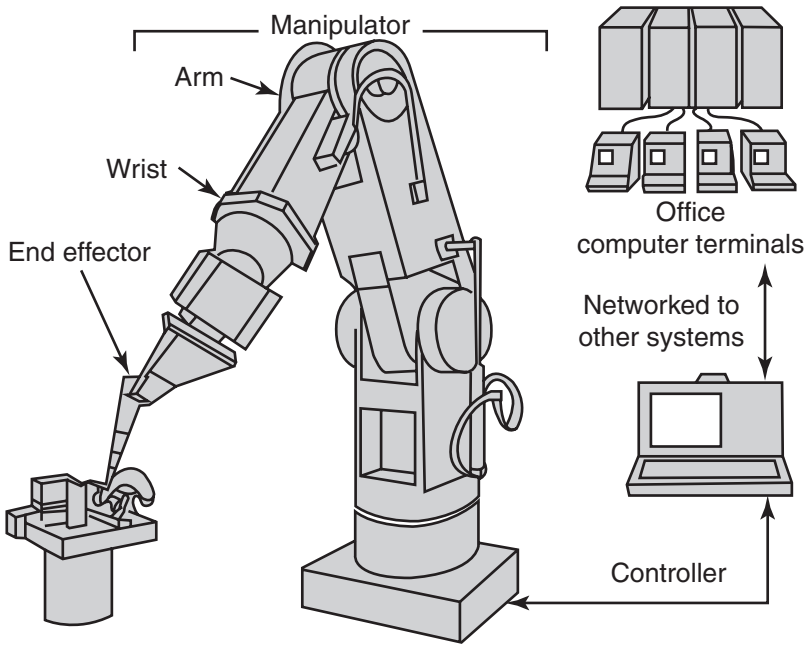


Figure 6-13.
The three main systems of an industrial robot are the controller, the manipulator, and the end effector.

[2]Robot Institute of America. 1981. *Worldwide survey and directory on industrial robots.* Dearborn, MI. 1.

the robot is contingent on its size. Hydraulic power is used for heavier arms. Electric or pneumatic power is used on lighter units. Electrical robots can return to a given position repetitively and do it quicker and more accurately than hydraulic or pneumatic robots can. On the other hand, these smaller units have a limited load capacity. The number of joints, or degrees of freedom of the arm, determines the robot's dexterity, as well as its cost. For example, it takes six degrees of freedom to emulate human-arm motion (two degrees of freedom at the shoulder, one at the elbow, and three at the wrist).

The second essential part of the robot is an end effector. This is the gripper, the welding gun, or another tool allowing the arm to execute assigned tasks. Grippers are normally custom-made. They vary a great deal from one application to another. A gripper designed to pick up a book looks quite different from one used to grasp an egg. The grasping of an item by a robot emulates human-finger motions. Some grippers can lift several heavy objects at one time. Other mechanisms can grasp a fragile component without damaging it. Examples of grippers include vacuum cups, hooks, electromagnets, clamps, scoops, or fingerlike devices.

The third essential part of a robot, the controller, is the program and computer used to activate the robot, guide it, and direct its movements. One very common way to program the unit is to lead it through the desired sequence of operations. A human operator moves the robotic arm physically or with switches on a control panel. The controller records the path. This is an effective programming method for tasks such as recording the curved motions needed to produce an even coat of spray paint or to pick up parts from one location and move them to another. On the other hand, the path is difficult to edit or revise without completely rerecording or reprogramming the task.

Off-line programming is when an operator writes a new program at a terminal. Off-line programs can be written without interrupting production. They can be used to issue a different set of instructions to the robot that the situation at hand dictates (for example, if no part is available for treatment, stay on hold and wait for the next cycle). In the mid-1990s, it became possible to program industrial robots with Windows operating system–type technology on a PC in an office with interactive video. In recent years, computers have not only made robots smarter. They have also made it possible to control, program, and monitor these machines from remote sites anywhere.

Robot manufacturers classify robots with respect to their abilities. A point-to-point robot uses mechanical stops or limit switches to go from one predefined point to another. This type of robot is less expensive and generally used for simple maneuvers. A controlled-path robot continuously follows a preselected geometric path. A servo-controlled robot uses software to control its movements. This robot can sense points on a path and feed the information back so the controller can take alternative actions. Due to the greater flexibility and the controllability of the sequence of motions in servo-controlled robots, most contemporary industrial robots are servo controlled.

Applications in Industry and Elsewhere

Whether robots are simple or sophisticated, the decision to implement robotics into manufacturing and production operations should be based on a comprehensive analysis of the entire operation. Until the mid-1980s, the robotics industry grew fast, as companies invested heavily in robots to automate their factories and replace blue-collar employees. Industrial managers discovered industrial

robots were not a panacea, or solution, for all manufacturing jobs. Not everything can be automated. In some cases, robots can be a major disappointment. As assemblers, they might dumbly attempt to jam a nut into an opening, even if it does not fit. As surface finishers, they might actually paint themselves on the paint line. It is essential to recognize robots for their realistic potential:

- ❏ Robots are not mechanical people.
- ❏ Robots do not replace human labor. They do, however, enhance it.
- ❏ Robots are tools within an integrated manufacturing system.

The U.S. robotics industry has only recently recovered from the downswings of the 1980s. There is only one U.S. company, Adept, still producing industrial robots. Most of the other companies went out of business, were consolidated, or were sold to European and Japanese companies.

Robots work as an integral component of a production system. Environmental conditions such as heat, humidity, static electricity, and dust determine the surroundings and should, therefore, influence the selection of the robot. The range of motions and speed at which robots are required to operate determine the capabilities demanded of the robot. If robots are used to perform material-handling tasks, sensors are necessary to make them aware of the work environment at any given moment. Improvements are being made to robotic devices on a regular basis. These changes usually involve speed, precision, and remote control.

What is the functionality of today's industrial robots? Many early robots were used (and still are) for monotonous or dangerous jobs and for loading and unloading heavy parts. More sophisticated robots are capable of a variety of value-added jobs, including assembling electronics, sanding missile wings, and moving parts from one machine tool to another. In some cases, robots almost appear to be replacing machine tools. To summarize the most common industrial operations assigned to robotized devices in factories worldwide, the list minimally contains these tasks: materials handling, assembling, spraying, cutting, deburring, and inspecting. The need for sensing devices is most acute when robots are used in inspection processes. This area might involve some form of monitoring, detection, analysis, or calibration. Robots are used to gauge and measure tolerances on manufactured parts, as well as used with ultrasound to detect leaks in assemblies.

As "senses" are added to industrial robots, these robots become evermore valuable to manufacturing enterprises. The cost of technologies such as sight, touch, and voice is decreasing. Equipped with camera eyes or optical scanners, robots are able to select, inspect, assemble, and place parts or products on machines, trolleys, and warehouse shelves. Look away from the factory floor for just a moment. See **Figure 6-14.** In the near future, household robots might provide companionship and assistance for the elderly or for people with physical disabilities. Using electronics, servomechanisms, controllers, sensors, communication equipment, active and passive beacons, and receivers for the GPS will enable household robots to navigate living spaces in an effortless manner. Consumers might soon purchase these robots for their capacities to give ambulatory aid, fetch and carry, cook, clean, monitor vital signs, entertain, and even get in touch with relatives in case of emergency.

As discussed in the chapter on space exploration (Chapter 4), robotic explorers have already gone to Mars to collect critical data. In the medical field, robots hold the promise of increased accessibility to medical care for people living some distance away from specialists. The promise of medicine at



Figure 6-14.
Advanced Step in Innovative MObility (ASIMO) first appeared in the United States on February 14, 2002. On this date, it rang the opening bell at the New York Stock Exchange. (American Honda)

a distance—telemedicine—allows a person to receive specialized care from a surgeon, using a robot. For example, people requiring medical assistance might find robotic devices have the capacity to save their lives, even when human surgeons are miles away. With the use of robots, it might be possible to perform complicated surgery at remote sites or even on the battlefield! See **Figure 6-15.**

Implications for Workers and Their Job Environments

Robots and other automation have been successfully integrated into the American manufacturing and production scene without the catastrophic consequences some projected in the early 1980s. It was theorized that robots would migrate through factories and displace people. This problem never became a reality. The role of robotics in reducing the percentage of the workforce employed in manufacturing has not been as dramatic as initially projected. Industrial robots, similar to other forms of technology, are tools allowing people to become more productive and skillful. Industrial robots have not replaced shifts of workers. "Lights-out" factories are not expected to become a reality in the near future.

Employees might express concern about job security when confronted with a discussion on automation. The extent to which automation



Figure 6-15.
A surgical team operating at a console in New York sent instructions to a set of robotic arms that removed the gallbladder of a patient across the Atlantic in Strasbourg, France. "Operation Lindbergh" was a world first in telesurgery. (IRCAD)

is successfully implemented is a reflection on the amount of cooperation and communication among management, supervisors, employees, and the design-engineering staff. In industries where automation is being implemented, employees must be open-minded in their reactions to changes in their work environment.

An industrial organization's future success is linked directly to the organization's ability to manage and support a manufacturing system focusing on producing a high-quality product at a competitive price. Labor costs continue to rise. Robot-equipment prices drop. Secondhand robots are a viable option. In instances when it is strategically and financially determined that a corporation's needs can best be served through the use of industrial robots, the decision to invest in the appropriate equipment is a wise one. The primary consideration for robotics implementation must take into account product characteristics plus the manufacturing processes required. As previously stated, not everything can be successfully automated through the use of robots. A number of companies have found they can be more competitive if they use a softer, perhaps even more traditional, mix of human labor and machine technology.

Summary

The executive suites of manufacturing firms in the United States look to be happier places than they were two decades ago. Managers in industries as diverse as construction equipment, motorcycles, electronic pagers, automobiles, and PCs have analyzed and adopted a striking array of integrated automated process technologies. By studying each step in the manufacturing process and cyclical fluctuations in workloads, companies have found ways to reduce variation, eliminate bottlenecks, improve quality, and speed up the time to market. Many of the strategies being applauded fall under the CIM umbrella. Under this umbrella, a company-specific blend of computers, machining centers or cells, industrial robots, and human labor is fundamental to success.

The CE design environment has enabled manufacturing and production enterprises to discover the advantages of getting it right the first time. The benefits of simultaneous product design, development, and manufacture are hard to dispute. The growing ability of competitive firms to gain a larger share of their markets has, to a great extent, been accomplished through their implementations of lean-manufacturing techniques. There is a trend toward increased customization of products. For a manufacturing company, this puts increased pressure on being able to respond to market demand in a quick and efficient manner. On the road to becoming leaner and meaner, JIT philosophies have flourished among manufacturers across the nation.

A whole new collection of intelligent materials that can anticipate breakdowns and repair themselves is on the horizon. Industrial robots are being renovated. Industrial organizations are being more cautious about investments in large-scale FMSs. The future of manufacturing will be structured within a process-manufacturing paradigm that will undeniably include RP, customized production, and delivery to consumers just in time.

Discussion Questions

1. Develop an argument to either defend or refute the following statement: "CIM is not a specific technology."
2. Explain some of the benefits manufacturing firms have realized as a result of implementing CE strategies. Use a specific industry to illustrate your response.
3. How does the JIT management philosophy differ from traditional manufacturing philosophies that manufacturing firms practice in this country? What potential problems might be associated with its adoption in, for example, a shoe-manufacturing plant in Syracuse, New York?
4. Briefly describe what the term *lean manufacturing* means. Select one industry. Give examples of how it can make itself leaner and subsequently more competitive.
5. Provide a description of a personal-service robot that sets this type of robot apart from an industrial robot. What uses might you project for personal robots in the near future?
6. Consider a simple product you use every day. How would you redesign this product to utilize a "cradle-to-cradle" philosophy?
7. In a creative way, identify all the similarities one might find between an agile manufacturing enterprise and a seasoned jazz band.

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Ordnanceman Airman Clayton Hill checks an AIM-9X Sidewinder air-to-air missile loaded on the wingtip of an F/A-18E Super Hornet. Raytheon used Six Sigma principles in its design process for the U.S. Navy's AIM-9X Sidewinder missile. This resulted in a $1.2 billion reduction in life cycle costs and a 20% reduction in production costs. (U.S. Navy photo by Photographer's Mate Airman Ashley Gayton)

Chapter 7

Technology Transfer

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DATELINE

Matamoros, Mexico

Mexico's nearly 50-year-old Border Industrialization Program is seemingly responsible for serious social and environmental problems. The cost of living in border towns forces hundreds of thousands of employees working in foreign-owned factories to live in shantytowns that lack electricity and water. Many young female workers earn less than a dollar an hour, for up to 10 hours a day, six days a week.

Besides overburdening a weak sewer system, owners and managers of these small factories, or maquiladoras, readily admit to moving their operations to Mexico because their hazardous processes are more severely regulated in the United States (especially in operations such as metalworking, tanning, and dyeing). The Mexican government does not have strict regulations. Therefore, many employees are subjected to hazardous working conditions.…

Introduction

The international technology-transfer network is a topic that has received much critical analysis since the end of World War II. At that time, the United States began to export a significantly greater number of manufactured goods to war-torn European nations. On the home front, the U.S. government continued to increase its domestic expenditures on military programs and aerospace R&D projects.

Technology transfer is the process by which technology developed for one purpose is employed either in a different application or by a new user. To cite one specific historical example, the transfer of U.S. technology helped to speed up Europe's recovery process following the end of World War II. By the mid-1950s, increased European competition emerged in the U.S. export markets. Similarly, significant technological developments occurred in the U.S. commercial sector as a result of sizable government R&D spending. This served to reduce the technical and market risks that individual industries would have otherwise confronted. As a result, the 1950s witnessed the introduction of numerically controlled machine tools, integrated circuits, commercial aircraft, and communications satellites.

TECHNOLOGY TRANSFER

The development of a technology product or process in one setting, which is then transferred for use in another setting.

A more comprehensive explanation of the technology-transfer concept evolves throughout a complex and somewhat controversial network of activities. The uncritical transfer of technology to reluctant recipients marks this transfer continuum at one end. The opposing end of the same continuum is replete with covert activities akin to high-tech espionage. This chapter discusses a variety of topics and events relevant to the paradoxical nature of the contemporary U.S. technology-transfer engine. As you read through the various sections, keep in mind the following inquiries:

- What are the key patterns, motives, and channels associated with technology-transfer activities?

- ❑ Should the United States continue to address the "technology gap" perceived to exist between the creators of technology and the recipients or purchasers of technology?
- ❑ To what extent is the increasingly competitive aspect of entrepreneurial science impacting the traditional roles played within institutions of higher education?
- ❑ What strategies and guidelines can be employed to determine the extent to which a specific technology can or should be transferred to another nation?
- ❑ How rapidly do industrial innovations spread from one country to another? Which factors determine the relative ease with which the recipients can begin producing these innovations on their own?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

appropriate technology (AT)
demand lag
entrepreneurial science
foreign direct investment
imitation lag
licensing
maquiladora
most favored nation (MFN)
reverse engineering
technology transfer
technology transfer channel
turnkey plant

The International Technology-Transfer Profile

The technology-transfer process encompasses a diverse range of activities. There are, however, a few generic elements that can be used to examine a majority of the activities in a comparative manner. The first key element involves the transfer item itself. What is being transferred (for example, a product, a process, or information)? Second, who is the technology supplier (who possesses ownership rights to the transfer item)? Third, who is the technology recipient (an individual, a manufacturing firm, or the residents of an entire geographic region)? Of central concern is the recipient's capability to effectively adopt and implement the technology once it has been transferred. In some cases, less-developed nations have particularly poor capacities to assimilate new technology. A fourth element for comparison is the type of ***technology transfer channel***. How will the transfer item be delivered from the technology supplier or developer to the recipient? Typical transfer channels include foreign direct investment, licensing, and the direct purchase of manufactured goods. Finally, the technology-transfer process can be studied through an analysis of the rate of diffusion of the technology. The concepts of imitation lag and demand lag provide two perspectives for this examination and are discussed later in this chapter.

TECHNOLOGY TRANSFER CHANNEL

The formal or informal route through which technological artifacts travel from the supplier to the end user, within the international network of technology exchange and transfer.

Transfer Channels

The flow of technological innovations and information through the contemporary international network is a continuous process occurring through many avenues. See **Figure 7-1.** The nature of the technology being transferred; the commercial considerations, as well as the economic incentives, associated with the transaction; and the expectations the recipients of the technology express directly influence the mode of transfer that can be effectively employed.

Commercial transactions between and among American and foreign firms seem to form both the foundation and the overarching protocol for the international flow of technology. The underlying motive in a majority of these exchanges is not solely technology transfer. These interchanges are usually associated with the potential for a significant return on investment or the desire to gain market access for future investment opportunities. A human-interest dimension, regarding the degree to which the recipients will benefit equally or at all from the new technology, might never even be considered.

Several principal channels through which technology is formally transferred from one country to another include foreign direct investments, turnkey plants, licensing, entrepreneurial science, and manufactured exports. Numerous informal transfers occur via student exchange programs, professional meetings, technical seminars, cooperative scientific ventures, dissemination of technical and scientific publications, and the review of on-line resources. These lists are certainly not exhaustive, but an examination of these types of transnational channels will enhance your understanding of the complexity of the exchange procedures and legislation related to technological products and knowledge.

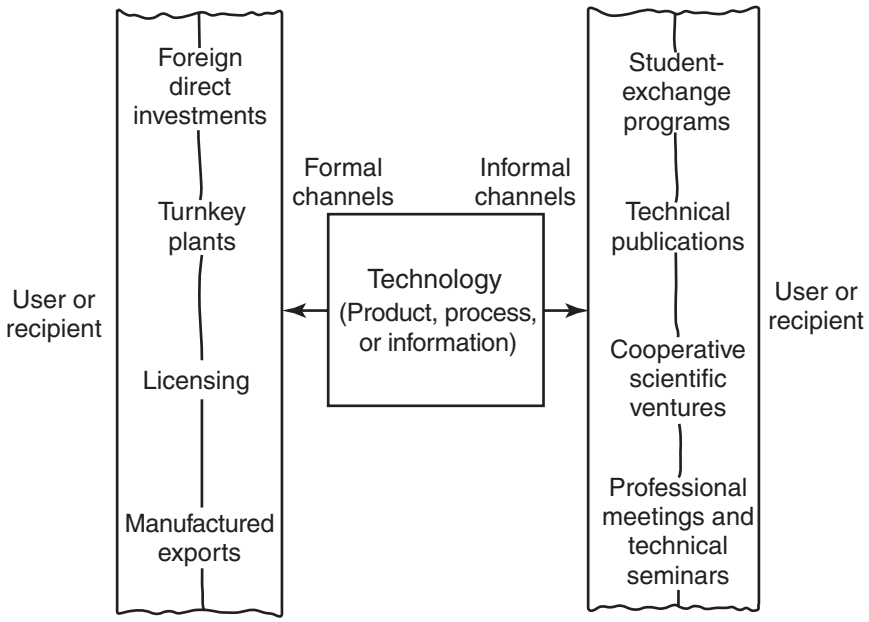


Figure 7-1.
International technology-transfer activities typically occur through these channels.

Formal Channels

Foreign direct investments represent a primary channel for the transfer of technology. These are generally made with commercial considerations in mind. A manufacturing firm's decision to establish overseas subsidiaries is often related to its desire to reduce current distribution costs, avoid hefty import duties, or manufacture with lower labor costs. Nevertheless, the firm's transition from a national corporation to a multinational corporation provides an environment highly conducive to technology transfer. In this type of endeavor, the technology supplier is the parent firm claiming either full or partial ownership of the foreign subsidiary. It is typical for the recipient country to provide material and labor resources, while the parent firm assumes responsibility for the capital, technology, management, and marketing skills.

The economic incentive alone should provide motivation for the parent firm to do everything possible to ensure the transfer proceeds efficiently. If the transfer is successful and an effective working relationship develops between the provider and recipient, technology transfer occurs in a variety of ways. Most commonly, the technology suppliers train the resident operatives and managers, communicate with engineers and technicians in order to translate critical information, and might ultimately encourage the local supporting firms to upgrade their existing technology.

In a growing number of instances, the recipient nations in these transactions are expressing a desire for greater control over the local enterprises of multinational corporations. This has produced a trend toward joint ventures, in which the subsidiary is partially owned by the parent firm and partially owned by public or private interests within the host country. Both parties contribute capital to the project, and the management, control, and profits are shared in proportion to each party's equity in the enterprise.

Turnkey plants provide another example of a channel for technology transfer. In this type of operation, the technology provider constructs a fully operational production plant for the recipient nation. The term *turnkey* refers to the notion that, once the facility is completed, the recipient simply needs to "turn a key" to initiate the production process. Since the parent firm retains no equity interest in the plant after its completion, turnkey operations are more accurately described as a contractual sale between the party with the technical and managerial expertise and the party that has requested this technological assistance.

Varying levels of technical knowledge and skill are transferred via this form of exchange. In some cases, the receiver can write a clause into the contract to have the supplier thoroughly train its local technicians and managers to be able to operate the facility on their own. In these instances, the technology provider leaves the site on the completion of the construction or training project.

If on the other hand, the recipient nation feels it lacks the capacity to execute the skills needed to effectively operate the new technology, the seller might be asked to stay and provide assistance even after the plant is finished. This type of request generally requires a formal management contract or technical-service agreement. This type of contractual agreement, combined with the turnkey operation itself, becomes an extremely effective mechanism for bilateral technology transfer. Specifically, a high level of personal interaction between the two countries over an extended period of time is necessary. Visitors to the foreign nation ultimately acquire new language skills and gain greater sensitivity and awareness of cultural differences. Further, they might

learn new techniques and methods by teaching others how to safely manage and operate the facility. In sum, a considerable amount of on-site technical information and experience eventually becomes a mutual acquisition.

Licensing is one of the primary mechanisms unaffiliated firms employ for transferring technology among themselves. The license is an agreement specifying the conditions under which the recipient can employ the supplier's technology. In other words, the license agreement is technology specific, and it can cover a patented process, a trade secret, a manufacturing permit, a trademark, or the sales and distribution rights for a particular product. A prelicensing discussion might actually precede the establishment of the exact terms of the agreement. Ultimately, the agreement is arrived at through bargaining between the owner of the technology and the purchaser. In most cases, the licensor either receives a lump-sum payment at the time of transfer or later receives a predetermined percentage of resultant sales in the form of royalty payments—sometimes both.

Licensing agreements often specify restrictions on the use of the technology item being transferred in order to protect the owner's competitive position, as well as its current markets. For example, the licensee might be prohibited from reexporting the resulting products or services it develops through the use of the newly acquired technology. This technology-transfer mechanism is most useful in situations in which the recipient nation has a high capacity to absorb the technology being transferred. Licensing another entity's technology can be quite beneficial for several reasons: it provides access to current technologies at minimum cost; it reduces the duplication of effort and can save a significant amount on the costs of in-house R&D efforts; and it might help to raise the recipient's level of technical competence, if it is supported with an orientation training program.

Entrepreneurial science is essentially subsumed within the licensing channel just described, but its impact deserves individual attention. Financially motivated, highly skilled scientists who work in the laboratories of entrepreneurial universities are engaged in numerous commercial agreements throughout the world, in which knowledge is transferred into intellectual property. At leading research academic institutions, faculty members and their graduate students are increasingly learning to assess the commercial, as well as intellectual, potential of their cutting edge research. Essentially, universities have begun in earnest to combine teaching and research with technology transfer and are subsequently playing a pivotal role in the economy of our country.

Interestingly, entrepreneurial science represents a convergence between basic and applied research, culminating with commercial opportunities linked to the "pure" science. As you learned in Chapter 1, the line between scientific research and technological applications has nearly disappeared. While opportunities for commercial utilization of scientific research might have been available to research scientists prior to the late 1970s, however, disciplinary norms did not encourage the scientists to violate the respected boundaries between science and business. In 1980, the Bayh Dole Act permitted U.S. universities to take advantage of opportunities to gain income from licensing their intellectual-property rights (most commonly held in the form of patents). This legislation made receipt of federal funds conditional on universities making an effort to put research results to good use in society.

While the entrepreneurial spirit in science sounds promising for young and aspiring scientists, some perceive it as a threat to scientific inquiry since it has the tendency to squelch the free flow of ideas at scientific meetings. This reality became

quite apparent during the early years of the biotechnology industry, when the money madness created a competitive spirit, rather than a cooperative one, where all new genetic engineering research was involved. Nevertheless, when scientific knowledge is appropriated to generate income, the discipline of science is transformed. Critics of entrepreneurial universities debate value issues and question whether or not participation in licensing ventures detracts from the traditional educational and research missions of the universities. This debate is far from over, and this formal channel for the transfer of technology from university research labs to industrial firms to the general public is most definitely here to stay.

Export of manufactured goods represents another principal formal channel for international technology transfer. In terms of dollar volume, the sale of technology-intensive products represents the dominant mode of technology transfer today. The mere existence of a new gadget in the recipient nation might result in the transfer of technology, in the form of increased knowledge, skill, or convenience.

In many instances, the core technological data and know-how is difficult (if not impossible) to extract from the products that have been imported. Subsequently, this channel for transfer might not be perceived as the most efficient choice. On the other hand, numerous recipient nations have demonstrated very astute reverse-engineering capabilities over the past few decades. This introduces a unique twist into the transfer network, as the purchasing agent carefully disassembles, examines, and eventually copies the imported technological device. The resultant reengineered product might not meet or exceed the quality of the original, but these imitators often compete well in the open market.

Informal Channels

Noncommercial avenues also make a significant contribution to the international flow of technology. For example, governmental agreements among the United States and other countries are set up on a regular basis to exchange technical information or to conduct cooperative R&D projects. These types of endeavors usually involve extensive contact among government representatives, tours of industrial plants, and the establishment of domestic training and educational programs. The information exchange is purported to be mutually beneficial to all participants involved. A few contemporary areas of concern that have initiated or stimulated these types of agreements include environmental protection (especially global warming), the impact of AIDS on Earth's population, global energy-resource management, national defense policies (especially regarding terrorism), and space station design and construction.

Scientific and technical publications provide another outlet for the transfer and exchange of information. One of the principal norms of science is to report and disseminate its research findings. Subsequently, journal literature becomes a repository of most scientific knowledge. Technological knowledge might be more difficult to acquire through this channel, since it is often proprietary in nature. The review of printed scientific and technical journals has a serious drawback as a means of transferring technology. The information might very well be obsolete by the time it is finally published! In today's networked world, abundant information, facts, and figures can be found on-line, but currency and accuracy are not guaranteed.

Technical seminars, conferences, and trade shows help to compensate for the delays inherent to the printed publishing circuit. See **Figure 7-2.** International meetings provide a convenient forum for the development of



Figure 7-2.
Manufacturers on the trade-show floor at the International Consumer Electronics Show (CES), held in Las Vegas in 2009, exhibit their newest technological products. The CES is a huge technology-related, weeklong trade show where many previews of products are introduced and new products are announced. (Consumer Electronics Association [CEA])

new contacts and often stimulate a dynamic interchange of opinions regarding contemporary technological projects still on the drawing board. Manufacturers who invest huge sums in acquiring a prime location on the trade-show floor usually exhibit their most sophisticated and up-to-date technological wares. Valuable technical information can usually be attained through an informal conversation with one of the booth's representatives.

Technology transfer continues to occur through many different types of channels. Those discussed here represent a few of the principal exchange systems utilized in the current international network. Each of these transfer modes has distinct advantages and disadvantages for both the technology provider and the technology recipient. The next section examines several of these concerns, as they relate to the role of the United States in technology transfer as an operative device to close technology gaps where they might exist in the world.

Closing the Technology Gap

The heading for this section might strike you as being rather presumptuous—it suggests there is indeed a social phenomenon labeled a *technology gap* and further implies that countries such as the United States are somehow capable of closing it. This heading presses one to visualize a global scenario in which some nations are leading the world in technological pursuits, while the rest of the world's countries are sluggishly lagging behind. This "gap" concept portrays a world order that can easily be assembled into suitable categories, such as the "technoleaders" and the "technofollowers."

Based on your intuitive understanding of technology and the technology-transfer concept, it is appropriate to develop an interpretation for this elusive technology-gap idea. Very few people would dispute there is a general, across-the-board technological difference among the United States and several developing nations across the African continent. The gap between the United States and the UK, another so-called "advanced" country, or even an emerging "Third World" power, however, is not so clear-cut.[1]

In fact, it has become quite apparent that international technological leadership constantly fluctuates among any number of key players. Present technology leads can be quickly lost or ceded, and they might or might not ever be regained. During the early 1980s, the United States reigned as a leading producer of high-tech products, but its margin of leadership narrowed by the decade's end, as Japan aggressively enhanced its stature in high-tech fields. The U.S. share of global shipments of high-tech manufactured goods declined in the 1980s, while Japan's market share increased nearly 10% in the same period. During the 1990s, U.S. high-tech industries regained some of the market share they had lost during the previous decade. By the early 2000s, the United States had again become a leading producer of high-tech products, responsible for just over 40% of the world's production.

Before we proceed any further into the dialogue, it might be useful to set some parameters to the term *high technology*. The Organization for Economic Cooperation and Development (OECD) presently identifies five industries as high technology, based on their high R&D intensities: aerospace, computers

[1]"Third World": Contemporary writers continue to use the term *Third World* to refer to those countries that have yet to achieve a level of technological expertise comparable to their industrialized neighbors. The authors put this term in quotation marks in Chapter 7 because they believe it is difficult to identify which nations conversely belong to the "First" or "Second" Worlds. We encourage readers to understand "Third World" to mean less-developed nations, newly industrialized countries, emerging participants in the international technology-transfer arena, or even just simply countries in transition.

and office machinery, communication equipment, pharmaceuticals, and scientific instruments. High technology industries drive economic growth around the world. They are associated with innovation, are linked with high value-added production and success in foreign markets, and perform industrial and science-based R&D that has positive spillover effects (for example, new products and processes might be generated, leading to gains in productivity).

As we stated previously, the U.S. high-tech industries faltered, losing market share during the 1980s, and the Asian global market share in high-tech industrial ventures gained steadily. Interestingly, high technology manufacturing in Asia grew dramatically over the past quarter century—led first by Japan in the 1980s, and then by South Korea, Taiwan, and China in the 1990s. Data from the early years of the twenty-first century reveal that China's high technology industries have surpassed those in Taiwan and South Korea. Value that the EU's high technology manufacturing sector added was at its high point in the early 1980s, but it has decreased since that time. Further to the west, the U.S. world market share remained relatively flat through the mid-1990s and moved up sharply toward the close of that decade. See **Figure 7-3.**

In each of the aforementioned industries making up the high-tech cluster, the United States maintained strong, if not leading, market positions for most of the last two decades of the twentieth century. Competitive pressures emanating from countries around the globe contributed to the decline in the U.S. aerospace and communications-equipment industries during the 1980s. Since then, the communication-equipment developers have rebounded, but the aerospace industry continues to struggle. See **Figure 7-4.**

Another perspective on the technology-transfer network has to do with overall balance of trade. Near the end of the 1990s, U.S. trade in technology products accounted for a larger share of U.S. exports than U.S. imports. The United States also remained a net exporter of technological know-how sold as intellectual property. Royalties and fees received from interested foreign firms have averaged three times the amounts U.S. firms paid out to foreign-based companies—for access to new technology. Japan is the largest consumer of U.S. technology sold as manufacturing know-how, and South Korea is a distant second. You should recognize this technology transfer channel as the one labeled *licensing* earlier in this chapter.

The U.S. Bureau of the Census uses a classification system for exports and imports of products that, in one way or another,

Share of Global High Technology Value Added, by Country or Region: 1980–2003

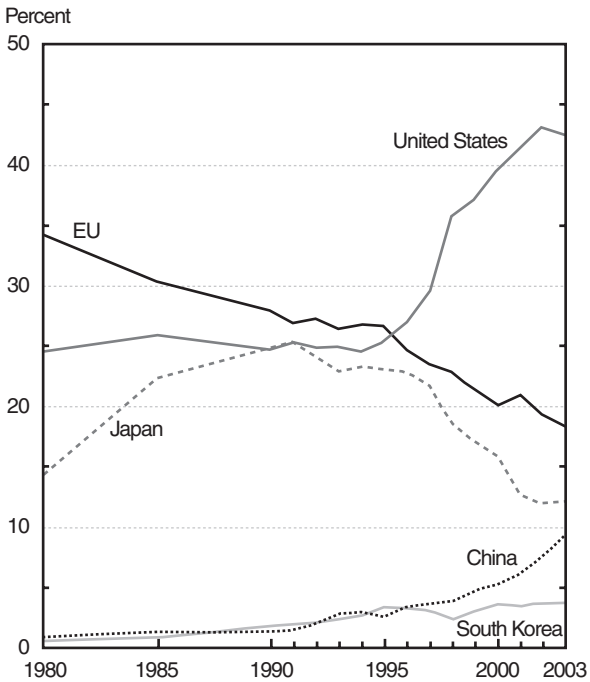


Figure 7-3.
Each country's share of global high-tech output. (Adapted from *Science & Engineering Indicators—2006*)

U.S. Share of Global Value Added, by High Technology Industry: 1985–2003

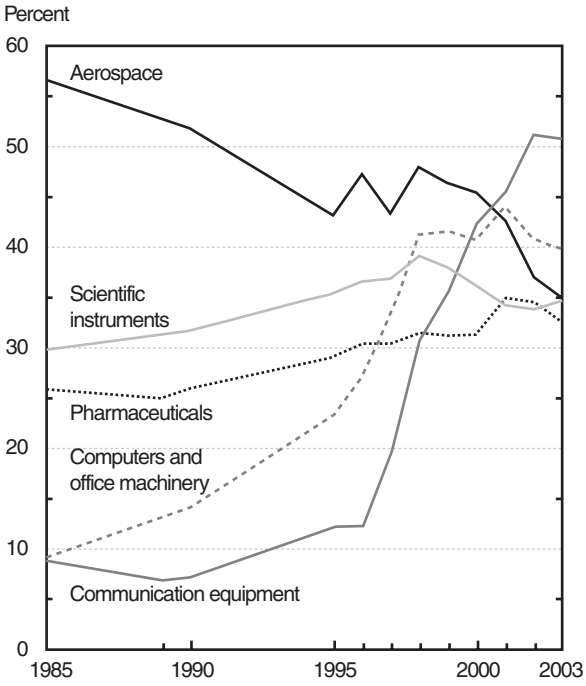


Figure 7-4.
U.S. global output share, by high-tech industry. (Adapted from *Science & Engineering Indicators—2006*)

embody new or leading edge technologies. This system allows international trade to be examined in 10 major technology areas, including biotechnology, life science technologies, optoelectronics (such as optical scanners, optical disk players, and laser printers), information and communications, electronics, flexible manufacturing, advanced materials, aerospace, weapons, and nuclear technology. Using this classification system, with the inclusion of computer software as an 11th category, the three largest foreign markets for U.S. manufactured technology products can be determined. See **Figure 7-5.** Japan and Canada are among the top three technology recipients across a majority of the product categories, with the Netherlands and China making themselves known as well. On the flip side of the transfer scene, the leading foreign suppliers of technology products to the United States can also be determined. See **Figure 7-6.** Imported technologies from leading economies in Asia and Europe enhance the productivity of U.S. firms and workers and offer U.S. consumers more choices.

Until this point in the chapter, the topic of international technology transfer has been discussed from the perspective of a willing technology developer and an anxious technology recipient. By virtue of its leadership position in the realm of technology-intensive products, the United States is either revered or coveted for its capacity to reduce technology gaps where they are evident. Does the United States truly have the technical prowess to share its science and technology (S & T) with those nations who indicate a need or desire for it and, subsequently, create a new world order?

Creating a New World Order

Sociologists, anthropologists, and government leaders have addressed the issue of international development for several decades. One interpretation of international development suggests a driving force to improve the standard of living and quality of life for people in countries where food supply, nutrition, shelter, and education are inadequate and human beings are unable to live up to their full potentials. The gross national product (GNP) per person is the most commonly referenced statistic used to measure development, but it does not always include these other quality-of-life factors in its calculations and inferences. International development refers, then, to a combination of improving the quality of life, meeting basic needs, and increasing per capita GNP.

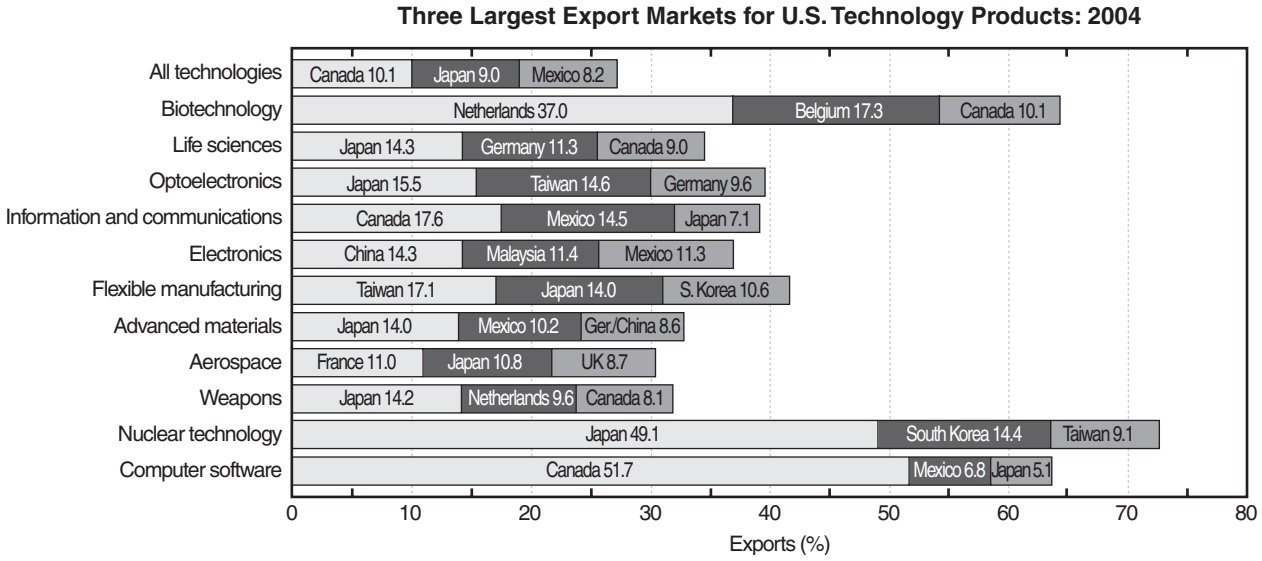


Figure 7-5.
The three largest export markets for each category of U.S. technology products. (Adapted from *Science & Engineering Indicators—2006*)

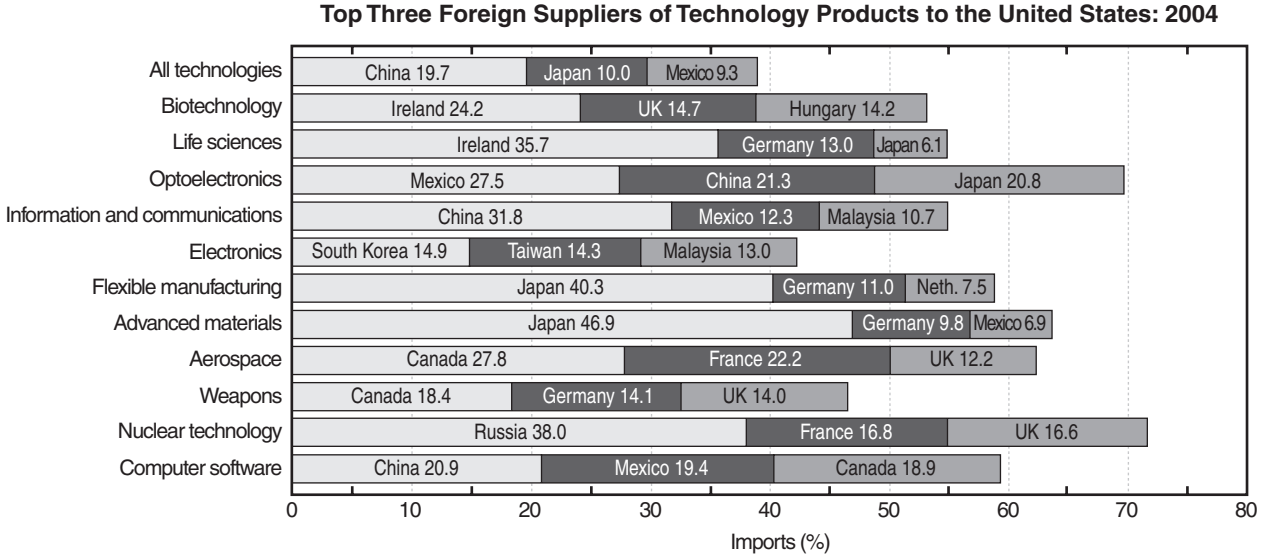


Figure 7-6.
The top three foreign suppliers of each category of technology products to the United States. (Adapted from *Science & Engineering Indicators—2006*)

With these parameters, or boundaries, in mind, what role can the transfer of technological products and knowledge play in the overall international development scheme? Should a primary objective for U.S. technology-transfer activities be to equalize the levels of technological development on a global scale? Stated differently, should a humanitarian connotation be ascribed, or attributed, to a schedule of transfer activities seeming to be heavily commercial, as well as competitive, in nature?

A brief review of the U.S. government policies since the Truman administration (the mid-1940s to the early 1950s) indicates that a general interest in international development has been maintained. The motivations have been mixed, however, and the framework for involvement has changed over the years. A thread of humanitarian concern has endured. The element of competition with the former Soviet Union for international influence in defense lasted several decades and has not completely disappeared, even with the breakup of the Union of Soviet Socialist Republics (USSR). The importance of "Third World" resources to the United States and the awareness of the potential for export markets in those countries emerged, as the quest for technological leadership continued under the guise of development or foreign assistance. Meeting basic needs and human rights became prominent components of U.S. foreign policy in the "Third World" during the late 1970s. More recently, the principal policy objectives of the United States seem to focus on combating terrorism, providing medical assistance, strengthening the private sector, and supporting U.S. national-security interests. Regardless of the administrative tenets espoused over the years, technology transfer has retained a consuming presence throughout.

Economists have consistently highlighted the importance of technology in stimulating a nation's economic growth. Sometimes the creators of the technology benefit. In other cases, the new end users of the technology benefit. In any event, since technology has speeded economic growth and development in industrialized nations, should it not be expected to assist in the development of less-industrialized countries?

Transferability and Appropriateness

Two important aspects of technology transfer to be studied are the nature of the transfer item itself and the recipient's capacity to adopt the technology once it has been transferred. An attempt to study how certain transfer items are assimilated and modified to suit local circumstances raises the issues of transferability and appropriateness. Should, for example, aircraft, microwave ovens, fiber optics, computers, or satellite dishes be transferred to India, the former Soviet Union, China, and countless African nations? Are these technology-intensive items useful to or even desired by the citizens of these countries?

AT emerged as a discipline in which the objective was to develop a form of technology that meets local needs, uses local resources, involves the local residents in the decision-making process, and does not adversely affect the environment. AT is discussed in greater detail in Chapter 8. ***Appropriate technology (AT)*** is defined here, however, as "a technology that fits the cultural or social situation for which it is intended, without causing more problems than it solves." E. F. Schumacher popularized the term in the UK during the early 1970s. The term should not be interpreted to describe secondhand or second-rate technology that has become obsolete and is no longer useful.

It seems reasonable to assume that no one is in favor of "inappropriate technology." Some capital and technology-intensive products have proven to be unworkable (inappropriate) in certain geographic areas, where the level of technological sophistication was not conducive to their implementation. In other words, the introduction of the new technology directly caused more problems than it solved.

Consider the situation in Mexico, as described earlier in the *Dateline* segment of this chapter. In the mid-1960s, the Mexican government spearheaded the Border Industrialization Program to lure foreign manufacturing business from the United States into Mexico's border states. By the early 2000s, there were more than 3000 plants in operation, mostly along the border, employing more than 1 million Mexican citizens. The plants, known as ***maquiladoras***, extend along the 2000-mile U.S.-Mexican border from Tijuana in the west to Matamoros on the Gulf of Mexico. Their owners include the likes of IBM, General Motors, Motorola, Eastman Kodak, and Zenith. The manufacturing jobs have been transferred to Mexico (and other "Third World" nations as well) with high social and environmental costs. Mexico's lax monitoring of industrial practices allows haphazard dumping of toxic wastes. Working conditions in these plants are typically inferior to those required by law in the United States. Maquiladora employees produce electronic equipment, clothing, plastics, furniture, and auto parts, and 90% of these goods are shipped north, back to the United States. The typical maquiladora worker is a woman in her prime reproductive years, between the ages of 16 and 28. Sanitation is poor, production quotas are high, and noise levels are often unbearable.

Another unfortunate transfer situation, spurred by the rush to develop an energy reserve in Alaska during the 1970s, involved the introduction of modern technology in the form of snowmobiles and televisions in small Alaskan communities. Technology artifacts uprooted the efficiency of a traditional hunting and fishing lifestyle. Grocery stores eventually supplanted subsistence hunting. Most homes not only became electrified, but they had cable television installed as well. Without the emphasis on hunting and fishing that once existed in these communities, *boredom*, *idleness*, and *low self-esteem* became the operative terms to describe the situation in many Alaskan communities.

An additional case of technology transfer's role in international development involved an agricultural project that procured its initial funding from the Rockefeller Foundation. U.S. scientists went to work with local scientists in Mexico and the Philippines to develop new varieties of wheat and rice that could outproduce existing local strains. What became known as the "Green Revolution" was considered to be a great success toward the abatement of famine and starvation.

Conversely, this transfer of agricultural technology hurt the small farmers who cannot afford the fertilizer and water the new varieties require. There is also an increased risk of crop failure through monoculture diseases introduced via the transfer activities. While it is true that recipient nations have been able to increase their crop yields, the problem of starvation still exists.

In recent years, the construction of paved highways in the densely populated regions of rural China and India has enabled these nations to modernize. Unfortunately, these new travel routes have disrupted traditional economic and social networks. Fatalities have occurred, as local residents misjudge the speed of vehicles and attempt to cross the highways on foot.

These illustrations are not meant to be representative of all technology-transfer activities occurring among the United States and developing countries or societies in transition. There have been, and are currently, many successful projects executed through hundreds of international organizations. Three of these groups include the following:

- **International Monetary Fund (IMF).** Headquartered in Washington DC, the IMF was established to promote international monetary cooperation, exchange rate stability, and orderly exchange arrangements; foster economic growth; and provide temporary financial assistance to countries, enabling them to avoid hefty penalty adjustments to their balances owed to lenders. The purposes of the IMF have developed over the years to meet the needs of its 185 member countries in an evolving world economy. The IMF was established in 1945.
- **United Nations Conference on Trade and Development (UNCTAD).** Headquartered in Geneva, it works to ensure that domestic policies and international actions are mutually supportive in bringing about sustainable development. UNCTAD functions as a forum for intergovernmental deliberations. This conference undertakes research, policy analysis, and data collection. Established in 1964 as a permanent intergovernmental body, UNCTAD fosters technology transfer, encourages international patent dialogue, and provides technical assistance oriented toward the requirements of developing countries. UNCTAD's 193 members promote the integration of developing countries into the world economy.
- **OECD.** Headquartered in Paris, OECD has 30 members, including representatives of West European governments, Australia, Canada, Japan, Korea, Mexico, NZ, Scandinavian countries, Turkey, and the United States. These nations share a commitment to democratic government and the global market economy. This organization is a reputable and reliable source of comparable statistics and economic and social data. OECD is one of the world's largest publishers in the field of economics and public policy. In recent years, several countries have been extended invitations to become members. Some of these include Russia, Brazil, Israel, China, and India. OECD was founded in 1961.

Ostensibly, the technology-transfer recommendations, projections, and assistance these organizations provide for those parties seeking their help or advice are based on the importance of the transferability and appropriateness of the ingredients, with reference to the recipient nation's existing "technological mix."

Rates of Diffusion

Once a technological process or product is introduced to the public, the potential for its introduction into the international technology-transfer network is inevitably addressed. From the economist's perspective, the diffusion rate of this new technology quickly becomes a prime dimension for statistical analysis. The rate of diffusion of technology is typically examined from two vantage points. First, after the lead nation begins producing a new device, how long does it take for other countries to obtain the production capabilities to produce or reverse engineer the same product? This interval period can be called the ***imitation lag***. Second, after the technology is first introduced into the innovating country's domestic market, how long does it take for it to gain acceptance in foreign markets? This can be referred to as the ***demand lag***, or social readiness, for the technology.

The imitation-lag concept is most closely associated with an earlier discussion that focused on the decline during the 1980s in the U.S. share of the export market involving technology-intensive products. Some groups believe this apparent narrowing of the American technological lead is due in large part to the transfer of technology between U.S.-based multinational firms and their overseas subsidiaries. These transfers increase the likelihood that key technological information and know-how are assimilated into the minds and hands of those who run offshore, non-U.S. firms that will eventually use this information and know-how to their competitive advantages.

Besides the initial introduction of a new technology by the developing agent, there are also other factors seeming to influence the speed with which other countries are able to develop and produce a similar product on their own. The first of these factors involves domestic government expenditures on technology-based R&D activities. Organizations spending relatively large amounts on R&D projects are generally closer to the leading edge of the technological frontier and are more capable of efficient imitation activities.

Nations aspiring to be competent players in the venues of profitable technology-transfer agreements recognize the need to promote R&D in order to strengthen their internal technological infrastructures. One of the most widely used indicators of a country's commitment to growth in scientific advancement and technology development is the ratio of R&D spending to GDP. See **Figure 7-7.** The United States and Japan peaked at 2.7% and 2.8%, respectively, in the early 1990s and dropped for several years, before rising again near the close of the decade. Over the years, a good portion of the peaks and valleys in the U.S. R&D to GDP ratio can be attributed to changing

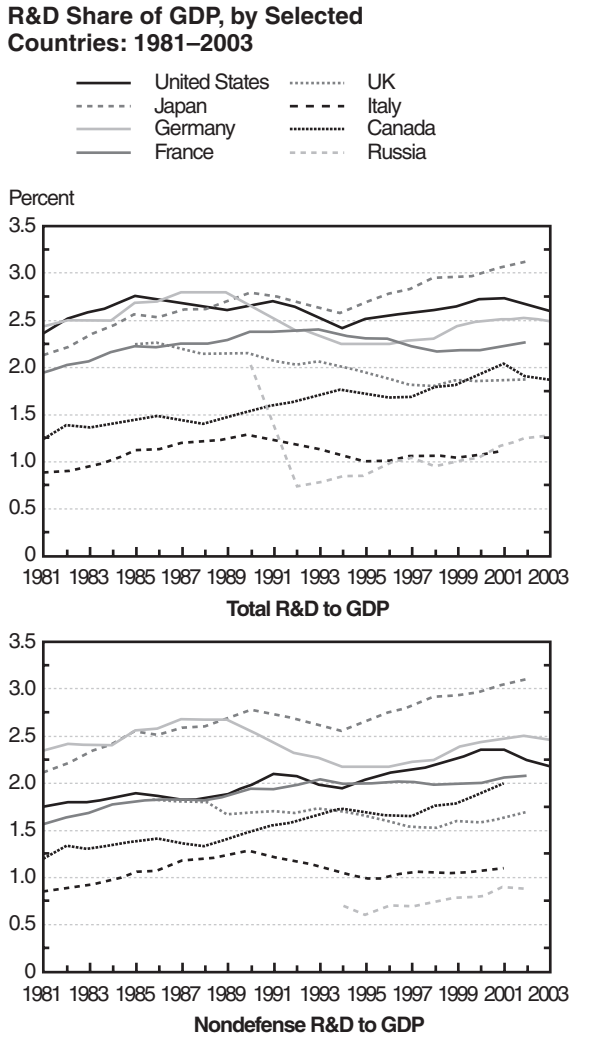


Figure 7-7.
R&D funding as a percentage of GDP, by country. (Adapted from *Science and Engineering Indicators—2006*)

priorities in our federal government's spending. The graphs in **Figure 7-7** provide evidence of this, regarding defense-related expenditures.

A second factor is related to the recipient nation's current level of concentration in the relevant industry. In other words, there might be a greater motivation for a country to venture into reverse-engineering strategies to imitate a product that could greatly

enhance its own productivity in a related discipline. For instance, a country such as Germany might have more interest in robotics technology than Spain, where the automobile-manufacturing industry is not as concentrated. If the recipient country's existing technology mix is ripe for the implementation and full utilization of this new technology, there is no question that the country will place greater emphasis on imitation strategies.

The predominant transoceanic export and licensing of American technology, coupled with stronger trends in R&D expenditures in other industrial nations, provide the basic ingredients for reduced imitation-lag periods and greater capacities for these countries to be more innovative, with reference to technological endeavors. International technology-transfer activities will become more complicated and interwoven as time passes. More importantly, however, the presence of a large technology gap between the technology creators and the technology purchasers is becoming less evident.

Shortly after the end of World War II, the United States developed legislation to prevent the transfer of sensitive technologies to potential adversary states. The United States believed then, as it still does today, that America's ability to maintain technological superiority in defense dictates U.S. national security. Examples of legislation include the Coordinating Committee for Multilateral Export Controls (COCOM) and the Export Control Act (ECA), both established in the late 1940s. The Export Administration Act (EAA) replaced the ECA in the late 1960s. The EAA was comprehensively rewritten in the late 1970s and later amended in the mid-1980s. The Defense Department developed and now maintains a Militarily Critical Technologies List (MCTL). Around the same time, the Defense Technology Security Administration (DTSA) was established to ensure that international transfers of defense-related technology are consistent with U.S. foreign policy and national-security objectives. The DTSA continues to control and limit transfers that could prove detrimental to U.S. security interests. This administration is responsible for annually reviewing thousands of requests and proposals aligned with the international transfer of defense-related technological goods and services. The next section of this chapter focuses on these and other contemporary technology-transfer issues through a discussion of the United States' evolutionary political and technical involvements with three separate nations, each of which aspires to acquire and maintain a global leadership position in technological enterprises.

Contemporary Transfer Scenarios

As the world confronts the prospect of establishing and working its way into a new international order, any generalizations made about technology-transfer activities or S & T policy for specific nations must remain tentative. The dawning of the 1990s unveiled dramatic events in Eastern Europe, German unification, the Persian Gulf War, and the demise of the Soviet Union. Near the middle of the 1990s, three nations (Mexico, the United States, and Canada) entered into the North American Free Trade Agreement (NAFTA). During the first decade of the twenty-first century, we survived the Y2K phenomenon; struggled with the reluctance of the United States to pursue the Kyoto Protocol (also referred to as the *Greenhouse Treaty*); led the formation of an international coalition to battle terrorism; and witnessed Brazil, Russia, India, and China (BRIC)'s combined GDPs surpass that of the EU.

Essentially, the international order is a legal system, or network, encompassing the principles, ideologies, units of measure, and mechanisms through which international relations are coordinated and common international problems are confronted. The nature of our international order, therefore, influences the web of technology-transfer activities and agreements. With the close of the cold war, an international order based on a few major powers imposing their views on other nations is no longer viable.

The countries we discuss in the following segments of this chapter are aggressive players on the world's economic stage. At the middle of the new millennium's first decade, comparative statistics reveal these countries' stories of economic transformation. See **Figure 7-8.** The technology-transfer projects of these countries with the United States and among themselves represent those that will shape tomorrow's social, industrial, and governmental institutions.

The course of establishing a new international order has been and will continue to be uneven. In our minds, the recipe for an emerging international order of coordinated global management should contain the Five Principles of Peaceful Coexistence developed more than half a century ago at the Bandung conference of Afro-Asian States (1955): sovereignty, equality, peace, justice, and noninterference in internal affairs of states. International acquisition of S & T to ensure subsistence and enhance quality of life will undoubtedly remain an issue of concern throughout these dynamic and ever-evolving early decades of the twenty-first century.

The People's Republic of China (PRC)

The People's Republic of China (PRC) has maintained a technology-transfer policy in close alignment with its foreign policy. While the PRC was on good terms with the Soviet Union in the 1950s, a substantial amount of Soviet technology was imported, mainly on a turnkey basis. During the early 1950s, China imported more than 150 turnkey plants, mostly in heavy industry, power generation, mining, refining, chemicals, and machine tools. More than 400 research units were established, primarily focused on ***reverse engineering*** Soviet technology. These units ultimately evolved into three groups: Chinese Academies of Science, State Planning Commission, and the State Science and Technology Commission. When Sino-Soviet ties were severed in the early 1960s, China relied more on Japan and Western Europe as sources of technology. The onset of Mao Zedong's

Economic Indicators for Selected Nations						
	India	**China**	**Russia**	**UK**	**United States**	**EU**
GDP ($, in Trillions)	3.7	8.1	1.5	1.9	12.4	12.2
Per Capita ($, in Thousands)	3.4	6.2	10.7	31	42	28
Growth Rate (Percent)	8.0	9.2	5.9	1.8	3.5	4.3
Population (in Millions)	1100	1300	143	60	300	457

Figure 7-8.
The economic growth rate of three nations in transition, as compared to three industrialized countries and regions. (Adapted from Ninian, A. 2006. India in the world. *Contemporary Review* 288 [1682]: 312.)

Cultural Revolution of the mid-1960s drastically constrained the entire nation's scientific and technological progress. The Chinese S & T research structure was neglected, which curtailed the careers of a generation of would-be scientists.

The late 1970s hailed the birth of widespread economic reform and an open-door policy. Both movements were construed to be mutually supportive of technology-transfer activities. Several aspects of the Deng Xiaoping–inspired open-door policy that expanded foreign trade included a reduction of centralized government planning and control; the establishment of special economic zones, regions, and cities with increased decision-making autonomy, related to foreign involvement; and approval of joint ventures, cooperative management strategies, wholly owned subsidiaries, and participatory ventures in natural-resources surveys.

The PRC's open-door policy significantly modified earlier approaches to technology transfer. Blueprints, technical documentation, Soviet technical advisers, and training programs accompanied the 1950s technology imported from the Soviet Union. Later agreements with Japan and the West did not involve peripheral technical support. The resultant arms-length turnkey-plant transfers resulted in excessive costs and a total lack of the transfer of competencies essential for technological literacy and mastery of the operations. There was an absence of adequate training for the successful absorption of acquired technology throughout the system.

China's modernization efforts throughout the 1980s focused on the infusion of foreign technology to develop export capabilities, versus sole dependency on substitution of imports. Technology-transfer activities have since emphasized disembodied technology, know-how, "know-why," a complementary mix of hardware and software, and the hiring of foreign consultants and technical-training support services. The PRC made great economic strides in the 1980s and 1990s. The PRC's GNP doubled, and China enjoyed a predominantly amiable relationship with the West. Reforms included the rapid growth of special economic zones, higher receptivity to foreign direct investment, and accession to the WTO. China's integration into the world's trading system has earned China its reputation as the manufacturing center of the world. Despite its optimism, this huge nation remains a developing country in transition with an immense population and a fledgling economic foundation.

Further, the appalling events of the late 1980s in Tiananmen Square forced the Chinese Communist party leaders to realize the impossibility of separating economic and political phenomena. The party's dream of being able to reap the harvest of increased production and technological efficiency by liberalizing the economy without slackening its control over the Chinese people was shattered. The Communist party's massacre of prodemocracy protesters seriously disrupted relations with the United States. A critical task of Chinese foreign policy for the 1990s was to create an international technology-transfer environment allowing countries with different social and cultural systems to coexist.

China's current administration is focused on restructuring the economic, educational, and legal systems to achieve future growth, based on increased innovative capacity. Recognizing that a large, low-wage workforce cannot be the foundation for global economic leadership, President Hu Jintao has stated repeatedly that China must give high priority to independent innovation in S & T. His aspirational vision is to move his nation from an imitation stage of manufacturing ("Made in China") to an innovative stage of design and production ("Made by China").

A document that forms the centerpiece of the PRC's strategic plan for aggressive shifts forward toward innovation is the *State Council's Medium and Long-term Program on Science and Technology Development—2006–2020*. This ambitious agenda gives priority to 16 key projects, ranging from core electronic components and wireless mobile communications to the development of large oil and gas fields and the launch of manned spaceflights. From the United States' vantage point, key impediments to fostering this level of innovation are the pervasive influence of the Communist Party in business and the grossly inadequate protection of intellectual property. Foreign firms that want to enter the Chinese market to sell or produce goods might tolerate the violation of contractual commitments (for example, the nonpayment of royalties by Chinese companies or blatant piracy of patented processes). They do this because they believe the large domestic market in the PRC will ultimately be very profitable.

The Chinese are not without complaints about U.S. trade and investment policies and practices. For nearly two decades through the 1990s, the PRC expressed dismay that it had to renew its ***most favored nation (MFN)*** status each year, instead of it being given in perpetuity, as it is for other developing nations. MFN status is now referred to as *permanent normal trade relations (PNTR)* and earns its recipient provision of concessional loans, support for World Bank funds, and a Generalized System of Preferences (GSP) treatment. The Chinese also object blatantly to certain U.S. export-control laws. The United States finally granted PNTR status to China in 2002, immediately following China's accession to the WTO.

We close this section with a brief look at an example of contemporary technological prowess and Chinese ability for self-reliance. The government initiated the gargantuan and very controversial Three Gorges Dam Project as a multiphased endeavor in the early 1990s, and the project is estimated to be completed very soon. See **Figure 7-9.** Government officials have promoted this infrastructure megaproject as an expression of state power, scientific proficiency, and technological modernity.

Phase I stretched throughout the 1990s and consisted of building cofferdams, within which the river bottom was excavated and the foundation of the dam was begun. A temporary ship lock was also constructed to allow shipping to continue throughout the project. Phase II, charted from 1998 to 2003, involved a good part of the dam itself, which is 600′ high and nearly 1.5 miles across. The final phase of the project is underway and forecasted to culminate near the end of the first decade of the twenty-first century. The dam across the Yangtze River is now complete, and additional powerhouse units are being built. The reservoir created behind the dam covers more than 400 square miles of land. Three Gorges Dam will soon be the world's largest hydroelectric dam, fitted with 26 generators rated at 700 megawatts each (equivalent to the output of approximately 15 of the world's nuclear power plants currently in operation)! Despite the projected benefits of the project, there are severe environmental and social side effects to this transfer of technology. These are discussed in Chapter 9.

Regardless, this example illustrates China's level of technological advancement and efforts to become a full partner in world trade and international technology transfer. Amazingly enough, Chairman Mao Zedong, as early as 1953, declared his staunch support of a Three Gorges Dam project for his country. In his mind, this structure would provide a forceful symbol of China's self-sufficiency and ability to develop resources without assistance from the West. In many ways, China remains a land of



Figure 7-9.
The Three Gorges Dam Project on China's Yangtze River. (gugganij)

distinctive contrasts, but it continues to make great strides toward technological modernization. The United States stays optimistic that China will make good progress in coordinating its technology policies and nurturing a compassionate human rights agenda.

India

The Republic of India is also a sprawling land of contrasts and seeming contradictions. Since becoming independent in the late 1940s, the Indian government's basic philosophy of development has been self-reliance. For decades, it pursued somewhat autarkic (nonreliance on imports or economic aid) policies, placing hurdles in the path of both foreign and domestic businesses. Although India is a nation in transition, whose economy is heavily dependent on agricultural performance (71% of the population depends on agriculture), it is not technologically unsophisticated. The country continues to graduate a high number of science and engineering doctoral graduates each year, many of whom are fluent in English. India's industrial base has grown steadily—in recent years, to a rate of 8% annually. See **Figure 7-8.**

A significant portion of this growth since the turn of the twenty-first century has been linked to India's rapid expansion of IT-enabled services. India has acquired an international reputation as the IT-enabled service center of the world—providing evidence that often the greatest form of technology transfer is in the form of human resources. Conversely, India's literacy rate is low, at 66%, and its communication and transportation networks do not even come close to meeting the needs of an industrialized nation. Unlike China, which removed many of its trade barriers in order to join the WTO, India remains a very closed economy, in comparison to its international S & T partners.

Technology-transfer relationships between India and industrialized nations, specifically the United States, are delicate and complicated. While cold war politics have largely conditioned U.S. foreign policy, India's policies have sought to maintain an independent position outside the cold war struggle. Over the years, India has befriended America's adversaries, including the Soviet Union, North Vietnam, and Cuba. India might be a democratic state with political values similar to the United States, but relations between the two have been less than congenial. During much of the four decades preceding 1990, the "world's largest democracy" was, by declaration, neither an ally to nor enemy of the "world's most powerful and technologically advanced democracy."

Throughout this cycle of conflict and cooperation, the Indian government developed a highly elaborate set of policies and practices for screening and regulating foreign direct investments. Many of these mechanisms presented a burdensome nightmare of bureaucracy to American firms interested in technology-transfer agreements with India. Through the 1980s, the Indian government emphasized its preference for technology-transfer investments in the form of sales or licensing of technology, as opposed to joint ventures. When foreign direct investments were approved, the technology supplier's ownership was generally limited to 40% of a company's equity. External investors were required to acquire equipment, components, and raw materials within the country. Imports to sustain the organization were seldom allowed, even when locally available substitutes cost more or were found to be of inferior quality.

Also, much to the frustration of American scientists and technologists, Indian patent laws have afforded significantly less protection than the intellectual-property laws of most industrialized countries do. Strict limitations on equity ownership discourage multinational firms from installing state-of-the-art equipment, for fear these firms will lose control of valuable proprietary information. The lack of patent protection and the government's efforts to immediately diffuse technology know-how to other firms after one local company has obtained it do not describe an optimal transfer scenario for technology owners who have already invested heavily in R&D.

One final feature of India's industrial policy prior to the 1990s involved insistence that Indian nationals are competent to provide all the people-intensive skills and services to run joint-venture facilities. The importance of organizational skills, managerial expertise, operating experience, marketing plans, and equipment maintenance is often overlooked. The "learn by doing" approach is consistent with the philosophy of self-reliance. Local users are subsequently cut off from valuable training, education, experience, and technical innovation that could be obtained from the foreign companies. This deficiency in the technology-transfer process might have contributed to the devastating pesticide-plant accident in Bhopal in the early 1980s. To some extent, those Union

Carbide workers had received job training based on rote memorization of steps, rather than a thorough understanding of the logic behind the technical procedures.

Subsequently, near the end of the 1980s, our two governments signed an agreement for the establishment of a U.S.-India Fund (USIF) to provide for joint activities such as workshops; exchanges of scientists and experts; and joint research programs in the fields of education, culture, and sciences. USIF was initially set up for 10 years. The fund's life was extended into an 11th year, however, providing funds for more than 300 joint scientific research projects.

A series of economic reforms was put into action in the early 1990s. Several of the reforms enhanced technology-transfer flow through various channels. For example, foreign investment and exchange regimes were liberalized, foreign firms are now allowed to own a majority share in subsidiaries, tariffs and other trade barriers have been reduced, and India's financial sector has seen some modernization. Foreign portfolio and direct-investment actions increased steadily through the 1990s, and some progress was made toward strengthening India's intellectual-property legislation. Despite this healthy progress, India's economic growth remained constrained by cumbersome bureaucratic procedures, high interest rates, and inadequate infrastructure.

In the late 1990s, the United States was India's largest bilateral trading partner. Principal among U.S. exports to India are aircraft and parts, advanced machinery, and fertilizers. From India, the United States imports textiles, ready-made garments, gems, jewelry, and chemicals. Moving further into the 2000s, sectors dominating foreign investments in India include software, electric and electronic products, chemicals, and pharmaceuticals—all of which demand highly skilled professional employees, which India is able to provide. GE and Microsoft are among the many multinationals that have established R&D labs in India, investing in the skills of Indian scientists and engineers and patenting new discoveries for commercial application.

India's technological advancements are progressing amidst a great deal of political turmoil. During the past decade, this nation has endured terrorist attacks, natural disasters, revolutionary social movements, religious strife, nuclear stand-offs with Pakistan, caste-based violence, and several parliamentary elections yielding different prime ministers. The current administration recognizes the need to promote S & T research in India's institutions of higher education to narrow India's technology gap with the rest of the world. In this regard, Prime Minister Singh's government recently established the National Knowledge Commission (NKC), which is working to accomplish the following:

- ❏ Build excellence in the educational system.
- ❏ Promote the creation of new knowledge in S & T laboratories.
- ❏ Improve the management of institutions engaged in intellectual-property rights.
- ❏ Promote knowledge applications in agriculture and industry.
- ❏ Make the government more effective, transparent, and accountable to its citizens.

In tandem with the NKC, India's Technology Information Forecasting and Assessment Council (TIFAC) observes global technological trends in order to formulate optimal S & T initiatives for the country. In short, India competes on par with global players in some technologies, lags behind in other sectors, and is in a position to surge ahead into global leadership by developing tools devoted to rural development. India recently signed a bilateral umbrella S & T agreement with the United States, giving the profile of our scientific cooperation a promising new dimension.

The Russian Federation[2]

Changing administrations and an unsettled political climate make an overview of U.S. technology-transfer activities with the Russian Federation region highly speculative. For more than four decades prior to the dissolution of the USSR, the controversial aspects of technology-transfer activities were most pervasive when the subject of selling technology to this nation was broached. Prior to the breakup of the Soviet Union, there were some 4000 federally subsidized research institutes located around the vast country—a number incidentally quite similar to the population of federally funded labs found in the United States. Under Soviet rule, an anxiety prevailed among scientists about sharing information in general. This, of course, was counter-productive to a vibrant technology-transfer process, even inside the country's borders. All inventions and scientific discoveries became Soviet state property once disclosed—at most, bringing the inventor a bonus of a couple hundred dollars.

For several decades, many of the U.S. policy statements concerning technology deliveries outside our borders had been predicated on a bipolar world order. Without question, U.S. government officials had great difficulty authorizing or even tolerating the sale of technology to communist countries. Administrations since World War II have seriously questioned decisions to even allow Soviet scientists access to American universities and research materials when these educational endeavors could ultimately be used against us.

The Soviet Union first began to import technology on a broad scale in the 1920s, but the United States largely curtailed its exports during the Depression. Exports increased substantially during World War II, when the United States was in alliance with the USSR against Germany and Japan. The beginning of the cold war in the 1940s virtually ended these arrangements. Import policies changed again after Krushchev was removed from office in the mid-1960s. Soviet dependence on Western technology artifacts continued to increase into the 1980s.

Toward the end of the 1980s, in return for hard currency and high technology, Soviet research institutes started to sell their S & T back to the West. Much of the discreet technology developed for the Soviet space station went up for sale, as did a broad array of other technologies that had, for decades, been considered militarily sensitive. Monsanto Corporation of St. Louis, Missouri formed a research collaboration with four Soviet laboratories, in order to secure licensing rights for a process by which diamond films are applied to polymers. Around 1990, the Soviet Association of Biotechnology signed an agreement with Genesis Technology Group of Cambridge, Massachusetts to develop medical products deemed marketable to pharmaceutical companies or midsized biotech firms. It was agreed that Soviet scientists would retain patents and receive royalties, but they would sell commercial rights in return for future R&D funds. Shortly after these and many other promising transfer agreements were finalized, the future of S & T in the former Soviet Union became highly uncertain.

Early in the 1990s, the new "managed democratic" Russian government saw it necessary to curtail funding to most research institutes. At the same time, however, these entities were granted both the right and incentive to solicit business from foreign firms, in order to generate their own operating incomes. The intellectual foundation underlying Russian innovation in S & T has fewer resources than when the state was involved in technology ownership, but collaboration is now more widely encouraged. Through the 1990s and into the twenty-first century, as

[2]After the December 1991 dissolution of the Soviet Union, the Russian Federation became the Soviet Union's largest successor state and inherited its permanent seat on the United Nations Security Council, as well as the bulk of its foreign assets and debt.

the country shifted to a more market-oriented economic structure, technology-transfer arrangements and collaborative opportunities increased.

The intellectual-property rights situation in Russia remains unsatisfactory and has been a significant obstacle to foreign investment in sectors such as pharmaceuticals. In this field, the cost of investing in the development of new drugs makes companies skeptical about risks regarding their intellectual-property rights. Large U.S. companies such as Monsanto and Uniroyal Chemical, which have entered into technology-transfer arrangements with firms in the Russian Federation, caution companies to thoroughly investigate potential partners before signing a joint-research contract. Otherwise, when the project is finished, it might turn out that the Russians who signed the licensing agreement (or other document) did not have the authority to do so on behalf of their institution. Ultimately, the U.S. company can end up with no rights to the intellectual property resulting from the research, or worse, it can be prosecuted for attempting to steal Russian property.

As we stated above, political relations between the United States and Russia are unsettled. Generally speaking, the two nations have enjoyed amicable relations for the past decade and a half. Two American presidencies have been proactive about fostering partnerships with the Russian Federation. More recently, however, President Vladimir Putin has based foreign policy not on global integration, but on Russia's own welfare, sovereignty, and place in the world. During his tenure, he has worked to improve education and health care, strengthen Russia's currency, invigorate domestic markets, nationalize critical industries, and reduce government corruption.

The Russian Federation has begun to utilize its competitive prowess in the areas of energy and defense technologies. Russian energy and defense supplies represent the core of strategic partnerships and technology-transfer agreements the Russian Federation is pursuing with India and China. Just after the turn of this century, the Russian Federation joined with China to build the Shanghai Cooperative Organization (SCO). One of the main goals of the SCO, as a permanent international intergovernmental agency, is to promote and sustain cooperation in politics, trade, S & T, education, energy, transportation, tourism, and environmental protection. Some observers believe that the SCO's agenda has undercut some of the United States' strategic arrangements in Central Asia.

Undeniably, the United States and Russia will continue to share common interests, with regard to international security and technological development. The United States has generally supported negotiations regarding Russia's accession to the WTO, but not without disagreements. Both countries have fostered cooperative programs to increase the physical security of nuclear materials and sensitive technologies. A key recommendation of a recent task force the Council on Foreign Relations sponsored encourages Moscow and Washington to craft an agreement that provides a legal basis for mutually beneficial civilian nuclear-energy projects, including international storage options for spent radioactive fuels. Above all, future administrations in both nations should articulate an attitude of scientific collaboration between themselves and with other foreign colleagues.

Summary

There are many types of technology-transfer agreements occurring on an international scale. Most of these involve some form of horizontal or vertical transfer of a new material or product, design specifications, or capacity for production from one organization or nation to another. Transfer agreements typically consist of a technology supplier and a technology recipient, who rely on a variety of channels for the linkage to take place. A few of the formal channels for transfer include foreign direct investment, turnkey plants, licensing, and the export of manufactured goods. An assortment of noncommercial and more informal transfer channels also permits the effective exchange of technological information and expertise among world nations.

A comprehensive assessment of the transferability and appropriateness of the technologies being considered should always precede transfer investments. International technology-transfer activities are most successful when multinational companies are skillful and able to cope with unfamiliar language and cultural clues, arbitrarily enforced legal protection, and bureaucratic red tape. Current technology-transfer interactions among the United States, the PRC, India, and the Russian Federation illustrate many of these principles. In a survey Price Waterhouse Coopers conducted in the middle of the first decade of the twenty-first century, 35% of multinational corporations reported they were likely to set up R&D centers in India, compared to 22% in China, and 12% in Russia. These three nations are dynamic economies in transition, and they accurately reveal the fact that numerous political complexities and technical complications, as well as a great many beneficial settlements and transactions, characterize the contemporary international technology-transfer network.

Discussion Questions

1. Provide a general definition of the term *technology transfer.* Give several contemporary examples to illustrate your explanation of this concept.
2. What are the key elements that can be used to conduct a comparative analysis of the diversified activities associated with international technology transfer?
3. What strategies and procedures are U.S. manufacturers of high-tech products using to prevent or deter the process of reverse engineering?
4. Explain the difference between foreign direct investment and licensing, as they are currently used to transfer technology from one country to another or from the public sector to the private sector. Provide contemporary examples of each transfer channel.
5. Speculate on the causal factors that might be responsible for intermittent declines in the U.S. global market share of high-tech exports.
6. Define the term *AT* and discuss several examples illustrating the presence or absence of AT in your current living arrangement or daily routine.
7. Select a foreign nation other than those discussed in this chapter and develop a profile of its current involvement with the United States, with reference to technology-transfer activities.

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Technology has many applications that benefit our environment. Here, a biological-science technician records water-depth measurements made with an electronic caliper during infiltration studies on no-till plots. (USDA Agricultural Research Service)

Chapter 8

Appropriate Technology (AT)

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DATELINE

Nigeria

The initiative to create a $100 laptop for the developing world has hit a few snags. In 2005, MIT professor Nicholas Negroponte announced an effort to create and market a $100 laptop that could be used in developing countries. Not all U.S. companies have agreed to join forces to build these laptops. Also, many foreign governments are not convinced that this laptop is the most critical need for developing countries. Recently, Nigeria's education minister questioned whether or not his country should buy these laptops. Dr. Igwe Aja-Nwachuku said, "What is the sense of introducing One Laptop per Child, when they don't have seats to sit down and learn, when they don't have uniforms to go to school in, where they don't have facilities?…"

Introduction

AT has been used to cover a wide range of technologies and lifestyles, including sustainable living, alternative fuels, and ethical technology transfers. A technology is considered appropriate if it solves a social problem without many adverse negative effects. In order to understand AT, first we need to understand the relationship of technology to society. Every new technology has consequences for society. Some of those consequences can be foreseen. Other consequences are unforeseen.

The development of the first Apple® computer led to more people using a computer and, therefore, to more people knowing how to use a computer. Since then, we have become so accustomed to newer computers that it is difficult to remember when they first exploded on the open market. An unintended consequence of the computer boom has been an increase in hazardous materials. As computers are discarded, they increase the amount of hazardous waste in local landfills. Today, we can ask the question of whether or not the computer itself is an AT.

Depending on how we define *appropriate*, our answers can be different. If we define appropriate as increasing one's production, while at the same time reducing dependence on natural resources (think, for example, of telecommuting), we might conclude the computer is an AT. On the other hand, if we define the appropriateness of a technology based on the waste it generates, we might conclude the computer is not an AT.

A technology is appropriate when its intended positive consequences outweigh its unintended negative consequences. *Appropriateness*, however, is not a simple term. The decision of whether or not a technology is appropriate can be made only after one investigates a technology, understands the environment or context of that technology, and knows the reason for or purpose of that technology. The situation

described in the *Dateline* section of this chapter shows a problematic use of computer technology in the developing world. Most people in the United States assume computers are required for schoolchildren, in order for these children to succeed in the world. The organization behind the One Laptop per Child Project claims that the laptops will provide tremendous educational benefits to children. In Nigeria, however, schools have more fundamental problems. Is it appropriate for the government of Nigeria to spend millions of dollars on computers, when they could spend the money improving their school buildings? It is unclear whether or not the $100 laptop is an AT for Nigeria or other developing countries.

Often we do not consider the issue of appropriateness when we choose to use a particular technology. In this regard, we are very similar to the engineers who design these technologies. A new car or toaster is often designed to meet certain technical and marketing constraints. Experts in various fields develop these constraints. As a product goes through the design and development cycle, often the potential users' needs get lost. Consequently, when the product is on the market, it might fit the needs for only a particular subgroup in society. The traditional automobile industry is a perfect example of this type of thinking. For most of the twentieth century, almost all automobile designers were men. They designed their vehicles with male drivers in mind. In the United States, however, women either influence or make at least 80% of all new-car purchases. The U.S. automobile-manufacturing companies were confronted with the issue of appropriateness—were the male-designed cars they built appropriate for their female customers?

One solution addressing the issue of appropriateness is to let the potential users guide the product design and development. In the 1990s, Ford Motor Company did this by assembling a team of 30 women engineers to redesign the Windstar® van. The team came up with several changes that made the Windstar van more appropriate for women drivers, including a larger gas tank to reduce the need for refueling; a thinner steering wheel; and "sleeping baby" lights that provide indirect, soft lighting inside the vehicle. Although this is an American example, the issues it raises can be applied to other technologies. The end user will not necessarily use a product the way the product was designed to be used. Also, a designer can only hypothesize about whether or not a technology will be appropriate. Without the input of the various constituent groups, a new technology might not be successful or appropriate.

The focus of this chapter is to discuss the issues and emerging technologies falling under the umbrella of ATs in the United States, as well as overseas. Some of the questions we address include the following:

- How is smart growth changing the land-use patterns across the country?
- How can renewable energy sources best be integrated into our existing energy system?
- What is the environmental impact of green buildings?
- What are the different techniques and technologies used in sustainable agriculture?
- How does a company implement ISO 14000? How do these standards affect the way a company is managed?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

agroecology
biomass
environmental management
ethnobotany
green building
integrated pest management (IPM)
International Organization for Standardization (ISO)14000
new urbanism
nongovernmental organization (NGO)
renewable energy
smart growth
sustainable agriculture
technology equity

What Is Appropriate Technology (AT)?

There are three ways of evaluating appropriateness: technical, cultural, and economic. A decision about whether or not a technology is technically appropriate can be made after considering the technical knowledge and background of the people who will be using this technology. A decision about cultural appropriateness should analyze the technology's relationship to the critical systems in the society, including family, religion, labor, and education. A decision about economic appropriateness is made after looking at a technology's effect on income levels and distribution in a society and disparity among different socioeconomic groups.

This decision about appropriateness is dependent on the country and situation. AT is used in discussing technology transfers, as well as the use of technology in an individual country. In the case of AT in the United States, a general perception is that a technology is appropriate if it has little to no adverse effect on the environment, social structure, and culture of the United States. Some examples of AT used in the United States are renewable energy sources, sustainable agriculture, and recycled materials used in the construction of new buildings.

Appropriateness is also used in relation to technology transfers. Here, the decision about whether a technology is appropriate or not can differ depending on where the technology is being transferred. What one country might consider acceptable, another might not. In many cases in the past, technology has been transferred from a developed country to a developing country without much thought or consideration as to whether or not it is appropriate. Each country has its own constraints that interact with the technology being transferred. As an example, in general, solar energy is an AT because it reduces our dependence on fossil fuels. It is not, however, appropriate to transfer solar technologies to a country with very little sunlight. Does the country receiving the technology agree that the technology is useful for them? The issue of appropriateness is particularly important when there is a disagreement between the developed country and the developing country as to the appropriateness of a technology.

The issue of AT is inherently linked to technology transfer. As discussed in the previous chapter, technology transfer is the transfer of a technology from one group to another group, most often from one country to another country. As technologies are being transferred or a decision is being made as to whether or not they should be transferred, an assessment of the appropriateness should be completed. Various factors for this assessment include the following[1]:

[1]Everts, Saskia. 1998. *Gender and technology. Empowering women, engendering development.* New York: Zed, 34.

- ❏ What is the need?
- ❏ Is there an adequate business environment in place for this technology?
- ❏ What is the best technical option for the transfer? (Some issues include the requirements for operating the technology, repair facilities for the technology, and scope of the technology.)
- ❏ What are the possible unintended negative effects of the technology?
- ❏ What are the broader cultural, political, and social effects of the technology?

Many activists argue that the local people in a country understand their individual needs better than people in a country far away. Unfortunately, since many technologies are transferred from one government or industry to another, the needs or desires of potential local users might not be heard and are often overlooked.

The U.S. government has a mixed record in supporting research into AT. After the 1973–1974 oil embargo, people in the United States were increasingly sensitized to energy conservation. In the late 1970s, the United States created a National Center for Appropriate Technology (NCAT), which focused on investigating technologies and processes appropriate for low-income communities. NCAT was funded as a federal agency until the early 1980s, when Ronald Reagan became president. During the pro-business 1980s, AT was put on the back burner, at least with respect to government funding. NCAT found new life, however, as a contractor with the U.S. DOE. This center was hired to evaluate the 2200 final reports from small grants the DOE funded and build a database of technical information related to the transfer of technology from the government to civilian applications. Near the end of the 1980s, the USDA established and funded a new national AT center, called the *Appropriate Technology Transfer for Rural Areas (ATTRA)*. ATTRA, which NCAT manages, addresses the issue of AT in three areas: sustainable farming, alternative crops and livestock, and innovative marketing.

In the following sections, we discuss several examples of AT in the United States. In the United States, the issue of AT is usually linked to a philosophy trying to balance growth with a concern for the environment. Often, these environmentally sensitive technologies are referred to as *green technologies*. Whatever we might call them, they are evaluated in a different way than traditional technologies being developed for the marketplace are.

Renewable Energy

Since the 1980s, energy consumption in the United States and worldwide has been increasing. In just five years (2000 to 2005), world energy consumption increased by 15%. The United States, China, Russia, Japan, and India were the world's five largest consumers of energy in 2005. These five countries account for over half of world energy consumption. At the same time, the remaining inventory of traditional energy sources (petroleum, natural gas, and coal) is decreasing, making ***renewable energy*** more desirable.

RENEWABLE ENERGY

Sources of energy that are always available because, in reality, they cannot run out and they can be replenished.

Renewable sources of energy, by definition, cannot run out. Some energy writers say these sources are eternal. Generally speaking, renewable sources do not blow up, melt down, or pollute the environment. After the

first oil crunch of the early 1970s, optimistic forecasters claimed alternative energy sources could eventually meet all the world's energy needs. Due to the fact that all renewable energy sources have at least two inherent shortcomings, that optimism has faded somewhat over the past few years.

These sources of energy are diffuse and intermittent. One example of the diffuseness feature is that a 1000-megawatt solar farm might occupy about 5000 acres of land, while a nuclear power station with the same generating capacity requires only around 150 acres. Since renewable energy is intermittent, it is also unreliable. Although the wind often blows strongest when most power is needed (late afternoon and evening), it cannot be counted on to do so each day. Likewise, the Sun might not always shine when you expect it to—consider the last time you were forced to cancel an outing! For these reasons, any renewable supply must be attached to an efficient means of storing energy for the lean times. Storage systems are becoming more efficient, but they commonly waste up to 20% of the accumulated energy. Despite these limitations, renewable energy is making a visible contribution to electricity grids in various parts of the world.

Renewable-energy industries produce energy resources such as sunlight, wind, water current, and organic waste. Eternal forces in nature continually replenish each of these resources. Contemporary renewable-energy technologies include solar thermal energy, biomass energy, geothermal energy, solar photovoltaics (PVs), wind energy, small hydroelectric energy, and ocean energy. The first three on this list generate heat energy, while the remaining techniques directly generate electric power. By the middle of the first decade of the twenty-first century, renewable energy accounted for 7% of the total energy consumption in the United States. In Germany, however, over 14% of the total energy consumption is from renewable energy, making Germany a world leader in this area. Two types dominate renewable energy sources: biomass and hydropower. These and other forms or sources of renewable energy are discussed briefly in the following sections.

Biomass

The most common renewable source of energy is organic plant matter. Many developing countries depend on wood and agricultural waste for energy. See **Figure 8-1.** Wood provides almost half of India's energy consumption and nearly 90% of the total energy consumption in several small countries in Africa. India is increasing its use of ***biomass*** to light Indian villages that are not close to the national electric grid. The use of biomass is not limited, however, to developing countries. In Europe, biomass constitutes about 60% of the renewable energy sources. Sweden has increased its use of biomass dramatically in the last 10 years and presently uses fast-growing willow trees and other organics to supply 14% of its total energy supply.

In many areas of the developing world, trees are being used faster than they are being replaced. Also, when dung is burned for energy, farmers deprive their fields of essential nutrients. As a result, they reduce the amount of crops grown and fed to cattle to produce more waste matter. One solution might be found in biogas. Digesters can use the dung to make methane gas and also yield a residue that is good fertilizer. China is already making use of millions of digesters across its expansive landmass. In China, over 18 million households use biogas technologies for energy. There are over 3000 biogas plants that treat animal wastes and convert them to biogas.

Plants might have a modest future in replacing the oil used as a fuel for vehicular



Figure 8-1.
Central Vermont Public Service (CVPS) Cow Power™ program manager Dave Dunn, left, discusses generator performance with farm owners Amanda and Mark St. Pierre. (Central Vermont Public Service Cow Power)

transportation. Brazil presently commands an impressive program of ethanol production from its sugarcane crops. In other parts of the globe, vehicles are running experimentally on coconut oil, in the Philippines, and gopher weed, in Arizona. NASA scientists found that sewage-fed water hyacinths can be converted into biogas. The Japanese are experimenting with microorganisms that eat rice waste to produce hydrogen, which could ideally be used in conjunction with fuel cells.

An emerging application for biowaste is in the production of biofuels for transportation. The U.S. government is investing a lot of money into research on ethanol and other biofuels. The problem is, even with the high price of petroleum, the cost of commercially produced ethanol from corn is not competitive with traditional gasoline. Also, at this time, it takes more energy to create ethanol from corn than the ethanol produces. Researchers are now turning to biowaste and other plants to create ethanol. The U.S. DOE is studying switchgrass, a grass native to North America,

as a feasible source of ethanol. In 2006, it conducted a three-month trial of switchgrass at a coal plant in Iowa. During the trial, the DOE burned 15,000 tons of biomass and generated more than 19 million kilowatts of electricity. Compared to coal, the switchgrass produced significantly fewer sulfur and carbon dioxide emissions.

Hydropower

Hydropower has been used for literally thousands of years, beginning with waterwheels used in mills and for irrigation. Modern large hydropower plants are very expensive to build. They have lower operation costs, however, than thermal or nuclear plants do. A problem with widespread use of hydropower is that it is not distributed equally around the world. China leads the world in the production of hydropower. See **Figure 8-2.** In the United States, about 7% of the total electricity is generated from hydropower. Although this number is high, it has dropped since the 1940s, when 40% of the electricity in the United States was hydropower.

There are different types of hydroelectric plants. The Tazimina Hydroelectric Project, located around 175 miles southwest of Anchorage, Alaska, is an example of a diversion hydropower plant, in which the water is channeled through a canal. This way, since there is no dam, there is less disruption of the natural environment. Disruption of the environment is the major reason there are fewer hydropower plants

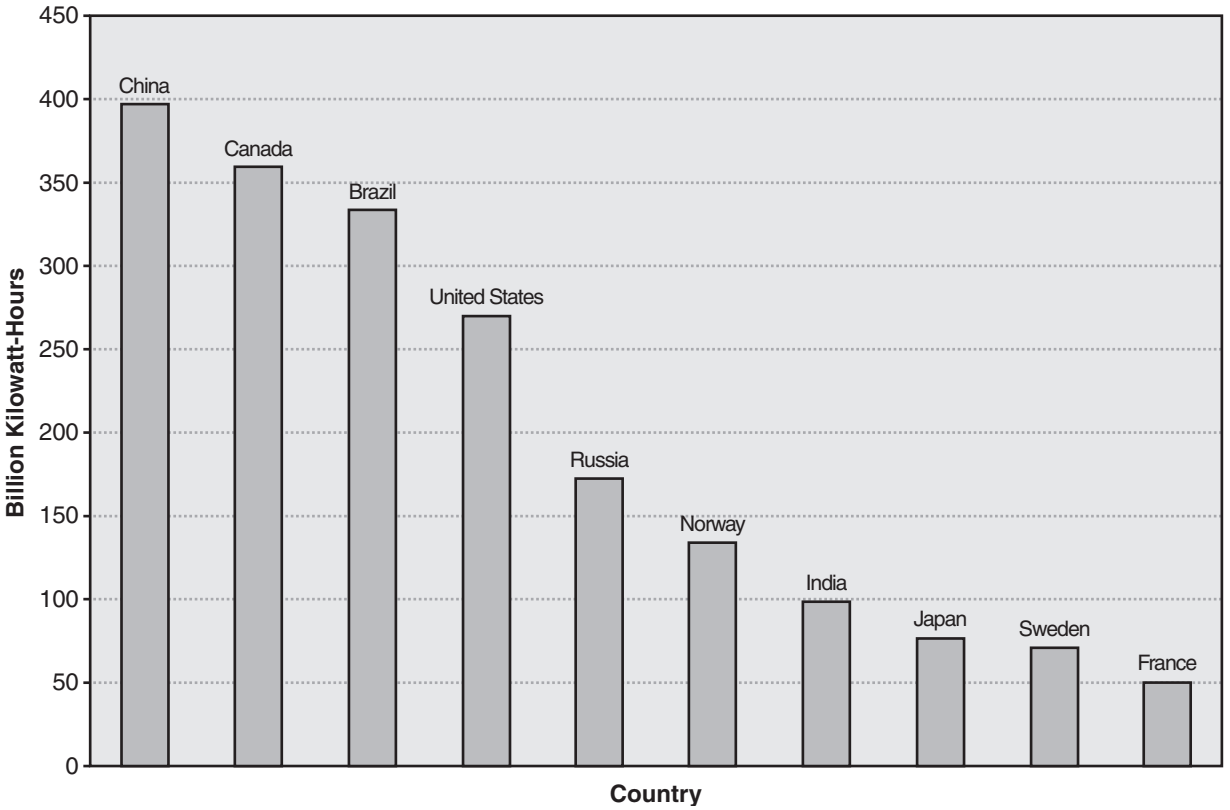


Figure 8-2.
The top hydroelectric-generating countries. (Energy Information Administration, U.S. Department of Energy)

being built today. Since hydropower plants require water to be channeled away from its natural flow, by design, they disrupt the environment. Hydropower has caused several changes in the environment: reduction in both the amount and variety of fish in rivers; increase in sediment; decrease in water quality because of decayed material in flooded areas; and human-health problems, such as malaria. Engineers have been revising hydropower-plant designs to try to mitigate these problems. Many new plants include fish ladders, allowing fish to bypass the power generation, but even this solution is not appropriate to all countries.

Geothermal energy

This form of energy is not strictly renewable or eternal because Earth's rocks will eventually cool. Residents of Italy also argue that, contrary to some publications, it is not a new form of energy. The Italians have been running a power station fueled by hydrothermal power (steam plus hot water) intermittently since the early 1910s. The planet's relatively small number of high-quality reserves of subsurface steam and hot water limits the potential of this form of energy. For those countries where active geysers have been found, geothermal power generation is quite effective. Worldwide, the United States produces the most energy from geothermal sources, followed closely by the Philippines. In the Philippines, geothermal steam generates 12% of the electricity. The percentage of geothermal energy is high (at least 10%–20% of the total) in several other countries: Costa Rica, El Salvador, Kenya, and Nicaragua.

There is a great deal of heat trapped inside Earth, just waiting to be vented, but larger-scale uses of geothermal power are still at least a decade or more in the future. Central America, parts of Southeast Asia, and the western United States have the greatest potential for major reliance on geothermal energy. Promising sites also exist in parts of southern Europe and East Africa. Taking full advantage of this resource will necessitate new technologies to tap into deeper geothermal reservoirs and make use of lower-temperature geothermal waters.

Wind

Experts in the field of alternative energy feel wind energy is the most favorable of the renewable resources. Windmills mechanically turn turbines without an intermediate stage of heating water. In the early 1980s, more than 8000 wind machines were installed in California. One of the largest wind farms is presently found in the rolling, windswept hills of the Altamont Pass, east of San Francisco. Wind farms are clusters of machines, generally located in mountain passes, connected to utility lines.

Technical problems have suppressed attempts to reap economies of scale by building larger windmills capable of generating more than one megawatt of power. Capital costs have remained prohibitive. More reliable and less expensive wind machines are being designed and built. One wind project, consisting of 500 turbines, will be located in New South Wales, Australia. When this wind plant is finished, it will generate enough electricity for 400,000 homes and supply over 4% of the electricity needs in New South Wales, Australia's most populous state. This large-scale project might stimulate the adoption of this technology in parts of the world where wind conditions are less than ideal. Despite technical problems, world wind-generating capacity increased over 1100% from 1995 to 2005. This trend does not look likely to stop. See **Figure 8-3.** Germany leads the world in the use of wind power, with Spain, the United States, India, and Denmark following.

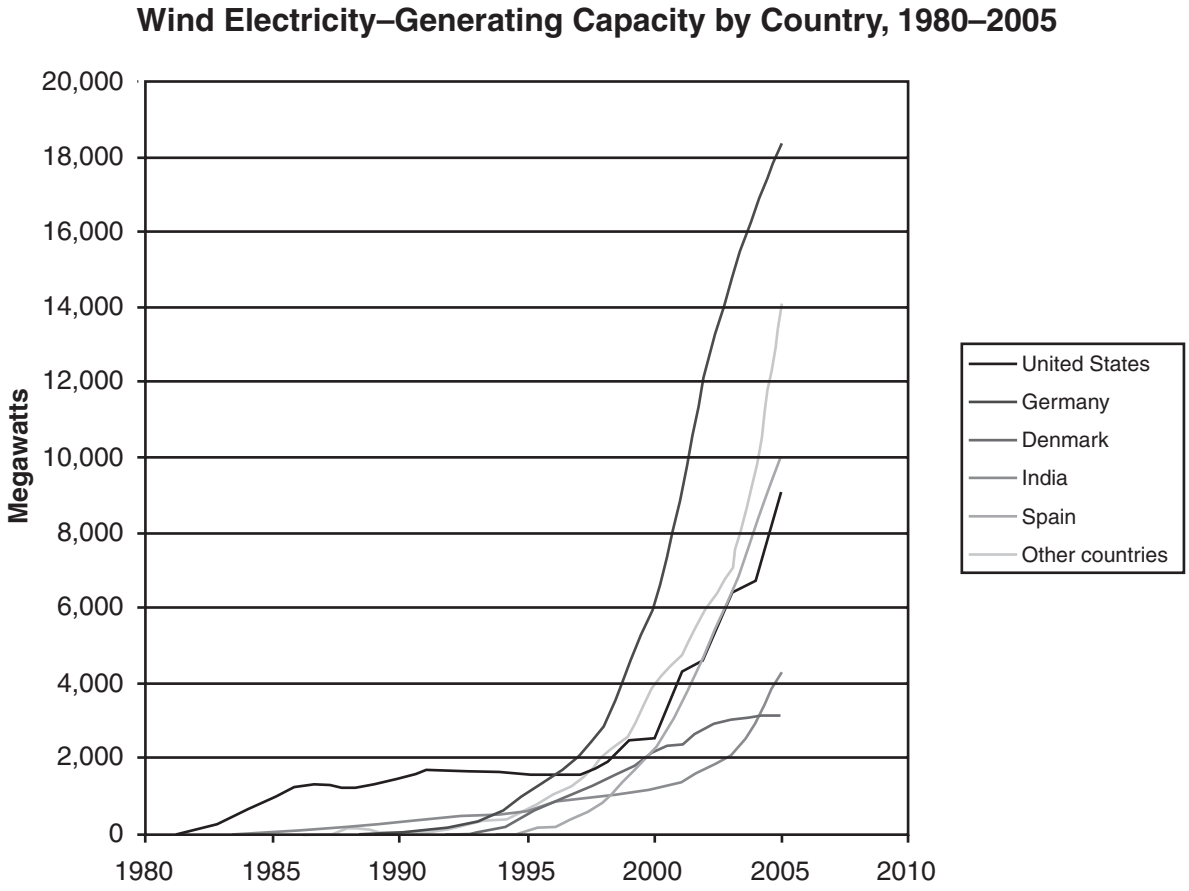


Figure 8-3.
Wind-generating capacity has increased dramatically, over 1100%, since 1995. (Worldwatch, GWEC, AWEA)

The ocean

Three methods for extracting energy from the sea have been reviewed seriously: wave power, ocean thermal-energy conversion, and tidal power. The first aims to harness the motion of the waves using a variety of devices. The second seeks to exploit the temperature differences between the warm surface layer and the colder deep waters of the world's oceans. Both can generate sizable amounts of electricity, but neither one has yet been demonstrated much beyond the experimental stage.

The third method is known as *tidal power*. This method is similar to hydroelectric power, in the sense that geography severely restricts it. Tidal power requires long, tapering bays that drive the tide into a large bore as it moves along the channel. The incoming tide can then be trapped behind a barrier of some sort and ultimately used to drive turbines on its way out again. There are not very many sites around the world having these specific geographic features. The Rance tidal power plant, placed on-line in 1966, was the world's first electrical generating plant powered by tidal energy. Another tidal plant is located at the Bay of Fundy in Nova Scotia, Canada, which has some of the highest tides in the world. These types of tidal power plants, however, usually require barrages, obstructions

diverting the flow of the water, to be built across a bay. This type of construction has a significant impact on the ocean's ecosystems. Therefore, power companies are testing tidal-power technologies that have less environmental impacts.

One of these new tidal technologies involves submerged turbine engines that capture energy from a river's currents. Tidal turbines work similarly to windmills, but they use the water's current, rather than air, to operate. One of the first test sites was in the East River in New York City. Since 2006, a turbine has generated 35 kilowatts of power to the city. Tidal turbines are applicable to a wider range of locations than barrage tidal constructions are, since they are less costly.

Solar energy

Solar energy harnesses the Sun's energy for our energy needs. Solar power is produced primarily through PV cells or solar thermal-energy technologies. Solar thermal energy converts solar energy into heat. This differs from PV cells, which convert solar energy directly into electricity. Solar thermal applications make up the largest category of solar-energy technology. There are three types of solar thermal collectors. Low-temperature collectors are usually flat solar plates used to heat swimming pools. In the United States, over 75% of solar collectors are low temperature. Medium-temperature collectors are used to create hot water for residential and business use. High-temperature collectors concentrate sunlight using mirrors or lenses and are generally used in power plants to produce electricity.

Photovoltaic (PV) cells

Semiconductors have the unique property of being able to turn sunlight directly into electric current. This application is surfacing in a variety of items, such as solar-powered calculators, refrigerators, and satellites. According to some energy forecasters, solar cells installed on rooftops might allow for a much greater decentralization of electricity than other technologies. Grid-connected solar PV cells are the fastest-growing power-generating technology, although solar PV cells provide less than 1% of the world's energy. Much of this increase can be traced to two countries: Germany and Japan. A law adopted in Germany in 2000 requires German utility companies to buy solar electricity from solar producers at marked-up rates. There has been a dramatic increase in the number of solar-energy systems in Germany because of this. In one year alone—2006—100,000 solar-energy systems were installed. Now, half of the world's solar electricity is produced in Germany. The Japanese government also encourages the installation of solar panels for residences. Beginning in 1994, Japan subsidized the cost of new solar installations to encourage owners to install them on their roofs. The strategy worked so well that Japan eliminated the subsidy for solar power in 2005, although demand and solar installations still remain strong.

Germany also leads the world in grid-connected solar PV plants. Of the 20 biggest PV plants, 15 are in Germany. Located in an agricultural field in Bavaria, 1 of these plants generates 12 million watts of power each year, enough to supply all the electrical needs of thousands of customers. Solar plants are also installed in Portugal and Spain.

Thermal solar power

Southern California Energy (SCE), one of the world's leading innovators of alternative-energy methods, has used solar energy as part of its production for over 20 years. With the support of a multimillion-dollar grant from the U.S. DOE, SCE constructed the country's first commercial-scale solar

electric facility in the Mojave Desert. Known officially as *Solar One*, this facility was the largest central-receiver solar plant in the world. In the Mojave Desert, direct sunlight often produces temperatures of 160°F at Earth's surface. Using Solar One's parabolic mirrors, water was converted to steam and used to power a steam turbine. A consortium of the U.S. DOE and a number of electric utilities, led by SCE, revamped Solar One in the mid-1990s and changed it to a more advanced solar technology—molten salt. See **Figure 8-4.** At Solar Two, solar energy is collected through a field of individually guided mirrors, called *heliostats*. The sunlight heats salt to 1050°F, which turns the salt into a liquid (or molten) salt. The liquid and hot salt are then piped away, stored, and used to power a steam turbine.



Figure 8-4.
Most of Solar Two's heliostats are large, segmented glass mirrors mounted on frames tracking the Sun throughout the day, continuously directing solar energy onto the central receiver. Solar Two has more than 1800 heliostats. Taken together, they make up the plant's largest single component. By collecting solar energy during daylight hours and storing it in hot molten salt, this solar technology gives utilities an alternative method for meeting peak loads when demand for electricity is high. For example, during summer afternoons, when air conditioning use is heaviest, the stored energy can be used to generate electricity and supply additional power to the utility grid. (Energy Technology Visuals Collection)

Both Solar One and Solar Two were designed as temporary facilities to test the viability of large-scale solar generation. Solar One produced power only when the Sun was shining. A sharp-edged cloud, large enough to block the Sun for just five minutes, automatically tripped the turbine. System restart took more than an hour. Solar Two solved this problem and proved that solar energy can be produced on a commercial scale. The molten-salt technology allowed the energy to be collected during the sunny days and stored until there was demand. Although both Solar One and Solar Two are no longer active, a third plant is being built in Spain using this technology. Solar *Tres* ("Three") will be three times larger than Solar Two and designed with a salt storage tank that gives the plant the ability to generate electricity 24 hours a day.

Regardless, the largest solar plant in the world today, with over 1 million mirrors and covering more than 1600 acres, is still located in the Mojave Desert in California. The installation, consisting of nine solar plants, uses parabolic mirrors and natural gas to generate electricity. This solar plant, with a capacity of 354 megawatts, can produce enough electricity for over 200,000 households.

It is unlikely the solar technologies described here or the other alternative-energy technologies mentioned will ever totally replace the world's conventional energy options. The most important point to recognize is that they most definitely belong in our international energy mix as we continue with our quest toward the creation of a sustainable society. We must maintain our momentum toward the further development and advancement of all potential energy resources, in order to make the imminent transition to an oil-independent civilization with the least amount of trauma.

Changing our energy-production structure is not easy. This change is a long-term process. The process will require commitments from business, government, and individuals. Since most scientists believe that conventional energy resources, including coal and gas, could last another 50 to 100 years, it is difficult to create a sense of urgency about renewable energy sources. Also, using renewable energy, as already discussed, does not mean there is no environmental damage. The perfect, nonpolluting, widely available energy source has yet to be found. For the near future at least, biomass and wind power have the most potential for use on a broad scale.

Smart Growth

Prior to World War II, most Americans lived either in rural communities or in cities. After the war, there was an explosion of a different type of land use—suburbs. As GIs from World War II got married and had children, they wanted to buy their own houses. These homes were usually single-family houses built on converted agricultural land. Of key importance, these new suburbs were located far from the centers of the older cities. Suburbanization, in turn, led to commuting. Commuting led to more use of personal cars for work and travel. This trend of development is the opposite of smart growth.

What do we mean by smart growth? ***Smart growth*** is development accommodating the needs of a community without sacrificing the environment. This growth aims to balance development and environmental protection by creating new developments centered more in the towns and cities; include alternative transit options (trains, bike paths, and safe walkways); and have mixed-use development. Mixed-use development moves away from the post–World War II ideal of single home–only suburbs to a

model including housing, commercial, and retail space in the same development. An example of a recent mixed-use development is the Paseo Colorado complex in Pasadena, California. The new complex was built in the center of town and includes a two-level shopping center with four stories of apartments above the shopping areas.

In 2001, the EPA concluded a comprehensive study of smart-growth development.[2] This report found that smart developments can increase air and water quality; preserve open space; and clean up older, blighted areas of the city. All these benefits increase a community's quality of life. Air quality is increased because people spend less time commuting in their cars, thereby reducing air pollution. A 2005 Seattle study found that residents of smart-growth neighborhoods traveled 26 fewer vehicle miles each day than residents of traditional neighborhoods. Water quality is increased in smart-growth developments because there are fewer paved surfaces. Paved surfaces increase polluted runoff. The EPA found that a one-acre parking lot has 16 times more polluted runoff after a rain than a same-sized meadow does. In many cities, there are abandoned or underused industrial facilities. These complexes are called *brown fields*. There are almost one-half million brown-field sites in the United States today. If a city redevelops a brown field, it can remove a contaminated site and provide new housing or workplaces in a convenient location.

Chattanooga, Tennessee has become a model of smart growth. This city had one of the worst environmental records in the country when it started. The U.S. Department of Health, Education, and Welfare named Chattanooga as the most polluted city in the country in 1969. After this dubious honor, the city decided to take a dramatic approach to redevelopment. Chattanooga decided to reclaim its downtown and use this process to provide more jobs, better housing, and a better environment for its people. In just 20 years, the city had a dramatic turnaround. Chattanooga's air met federal standards. Chattanooga had transformed its decaying waterfront into a park. To reduce the amount of air pollution, Chattanooga now has a free electric-bus service that shuttles visitors and residents from parking lots located on the outskirts of town.

Chattanooga's overall plan directly addresses brown-field development. The city's largest project aims to transform a former industrial district into an ecoindustrial park. This environmentally friendly center is designed to be a zero-emissions zone, where all waste is converted into fuel.

There are direct and indirect effects of development on the environment. See **Figure 8-5.** Any development modifies the land and changes the existing ecosystem. Development can also directly affect the water quality because buildings, roads, and other structures change the natural flow of water in an area. In the Washington DC area, for example, over 200,000 acres of open space were lost to development, just in the 1980s. The indirect effects are not normally considered. New residential and commercial

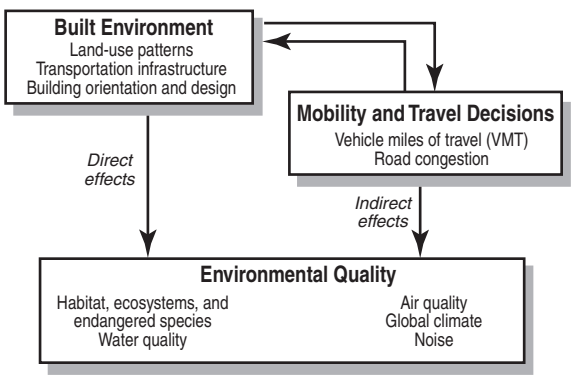


Figure 8-5.
The direct and indirect effects of the built environment. (Environmental Protection Agency)

[2]EPA. 2008. Environmental benefits of smart growth. http://www.epa.gov/smartgrowth/topics/eb.htm.

buildings change the employment opportunities for a community. If a company decides to move from its downtown headquarters to a new office park located in the suburbs, this move affects both the workers and the community. Also, since many suburbs have little to no public transportation, suburbs indirectly increase the amount of solitary driving in a community, thereby increasing the amount of air pollution.

Smart growth means less land can accommodate new development. This development is sometimes called *compact development*. There are three common techniques to achieve compact development: in-fill development, brown-fields redevelopment, and cluster development. In-fill development is development attempting to add additional housing or business facilities inside an existing development. This way, a city can fill unused space in a particular area. Cluster development allows for the same number of dwellings to be built as a "regular" development does. The individual lot size for each house is reduced, however. Room is left for open spaces in the development.

Many cities are encouraging in-fill development to meet the demands of a growing population. San Jose, California, located at the center of Silicon Valley, has been grappling with a booming population for over three decades. Before the digital revolution, San Jose was best known as the *Valley of Heart's Delight* because of the many orchards and walnut trees covering the valley. Almost all this agricultural land has been sold and developed to become either housing or industrial workplaces. Along with the fruit orchards, San Jose was also home to many fruit canneries. Over 17 packing plants have been demolished to make way for new development. One of these former Del Monte canneries, Plant 51, is the site of a brown-field development to convert the cannery into lofts. Most of the historic features of the building remain, but the inside of the plant was converted to provide living spaces. See **Figure 8-6.**



Figure 8-6.
Del Monte's Plant 51 was one of the many fruit-packing plants formerly operating in Santa Clara County, California, when the area was better known as the *Valley of Heart's Delight.* Now, Santa Clara Valley is better known as *Silicon Valley.* Today, Del Monte Plant 51 in San Jose, California is being renovated and converted into downtown lofts.

The changing attitudes toward home ownership among people in the United States help the reconversion of industrial plants into living spaces. As the U.S. population ages, there is more demand from the so-called *empty nesters* for housing located near restaurants, cultural venues, and shopping. Along with this group, are many young, childless professionals who also are looking

for convenient and maintenance-free living environments. This movement of middle-class people into town living is sometimes called new urbanism. Despite the advantages this in-fill development offers, most of these new living units are developed for the middle and upper classes of society. The Plant 51 apartments and lofts will range from $300,000 to $1 million each—prices well out of range for all but the wealthy.

The smartest U.S. city, in terms of development, is Portland, Oregon. In the mid-1990s, Portland's regional government, Portland Metro, established a 50-year plan for growth in the region called *Region 2040*. Portland has dealt with development differently than most other cities in the United States have. Instead of expanding outward, Portland established an Urban Growth Boundary (UGB) in the late 1970s. Outside this boundary, there was green space. When the UGB was established, it seemed to allow enough space for future growth. The city's growth, however, has occurred more dramatically than expected. Instead of expanding the UGB, Portland decided to embark on a smart-growth strategy to accommodate its future needs. Zoning will consist of changes to encourage mixed development. Suburban centers will change from single-story to multistory buildings. Portland, through its Metro Council, works with surrounding counties to identify potential future urban areas and rural areas that should be preserved.

In addition to zoning changes, Portland will expand its light-rail network to reduce the amount of driving its citizens do. Portland is not the only city that has plans to increase public transportation. There is a resurgence of trolleys, light-rail lines, and other commuter-train lines across the United States. After decades of dependence on automobiles, cities are discovering the benefits of public transit. Light-rail transit has seen the biggest boom in the last two decades, with nearly two dozen light-rail systems installed since 1981, including light-rail in San Diego (1981), San Jose (1987), Baltimore (1992), St. Louis (1993), Memphis (streetcar, 1993), Denver (1994), Dallas (1996), Salt Lake City (1999), Tampa (streetcar, 2002), Houston (2004), and Phoenix (2008). Los Angeles, arguably the most car-crazy city in the United States, now has a booming subway system that continues to expand.

Smart growth requires us to reconsider the American ideal of a single-family dwelling located in the suburbs. In order for the United States to reduce both urban sprawl and air pollution, there needs to be more effort on reusing the existing developed land and providing alternative public transportation. Without this type of creative planning, the reality remains longer commutes and increased pollution.

Green Buildings

When we think of pollution sources, we might think of automobiles or factories with smokestacks, but few of us think of our own homes as sources of pollution. Surprisingly, buildings are a major source of air pollution in the United States. According to the U.S. DOE, buildings emit 52% of all sulfur dioxide, 19% of all nitrous oxide, 38% of carbon dioxide, and 5% of particulate emissions. Considering the number of homes and businesses in the United States—over 80 million residential and 5 million commercial buildings at last count—this problem is considerable. Tearing down all polluting buildings is not feasible, but building new ones with green features should reduce the amount of air pollution. By 2015, the DOE estimates that another 15 million buildings will be constructed in the United States. If just some of these new buildings include green features, this would favorably impact the environment.

There are many different techniques used in the construction of ***green buildings***. These techniques include energy efficiency, renewable energy, water conservation, and waste minimization. We discuss some of these techniques in the following sections.

GREEN BUILDING

A building constructed in a way that minimizes waste and includes recycled, renewable, and reused resources to the maximum extent possible.

Designing energy-efficient buildings

Energy efficiency is the most important factor in green construction. Since buildings last for decades, even centuries, reducing the energy needs of a building can bring long-lasting savings in both energy and money. Unfortunately, many of these energy-saving techniques increase the construction costs.

Green buildings are designed to use higher levels of insulation than conventional buildings. Also, it is important to make buildings as airtight as possible. All houses leak to a certain extent—green houses will lose less of their energy to the environment. This trend toward making houses more airtight can lead to increased air pollution inside the structure, however—an unintended negative consequence of green building technologies.

Another way to make houses more energy efficient is by using renewable energy sources. Solar energy, because it is the energy source with the least environmental problems, is particularly suited to meet the energy demands of green houses. Studies of housing patterns in the United States indicate that 70% of new homes can be designed to use solar technologies. To increase the number of houses and businesses using solar energy, the DOE is sponsoring numerous R&D activities. One such program is the Million Solar Roofs (MSR) Initiative, which has the goal of installing solar-energy systems on 1 million rooftops by 2010. If this goal is achieved, the reductions in carbon dioxide emissions will equal the exhaust from 850,000 cars. Another DOE program is the Building Technologies Program. The goal of this program is to improve the energy efficiency of buildings through innovative new technologies, new engineering building practices, and the application of renewable technologies. The Building Technologies Program promotes a systems-engineering approach to home building that results in new houses that use 30% to 70% less energy than conventionally built houses. New homes can also be qualified to be Energy Star homes by meeting the guidelines for energy efficiency the EPA sets. Energy Star homes are at least 15% more energy efficient than traditional homes. These homes use many of the following energy-efficient design features: effective insulation; high-performance windows with protective coatings and improved frames that help keep heat out during summer and in during winter; tight construction that seals holes and cracks and reduces drafts; efficient heating and cooling systems; and Energy Star–qualified products including compact fluorescent bulbs, ventilation fans, and appliances, such as refrigerators, dishwashers, and washing machines. One of the Energy Star developers is Bosgraaf Homes in Michigan. Since 1999, Bosgraaf has built over 1000 Energy Star–certified homes. Bosgraaf includes environmentally friendly attic and wall insulation made from recycled material; energy-efficient air conditioners, furnaces, and water heaters; low-emissivity, insulating glass windows with coatings that block 83% of harmful UV rays and 96% of the Sun's infrared heat; drip-free faucets; programmable thermostats; and Energy Star

appliances. Homeowners in Bosgraaf homes can save more than $500 per year on their energy bills in an Energy Star home.

The DOE is also studying ways to design zero-energy homes. Zero-energy homes generate more energy than they use and are not connected to the local power companies. The DOE built a prototype zero-energy home in Lakeland, Florida and a traditional home nearby—both homes had the same 2425–square foot floor plan. This department compared the energy consumption of these two houses. The zero-energy home used 72% less power from air conditioning than the conventional home did. Air conditioning is a severe power drain in the hot and muggy climate of Florida. The builders achieved energy savings through several innovative techniques. Instead of a flat roof, the zero-energy house has a 3'-wide overhang. This overhang increases the amount of shade. The builders also used reflective white tiles on the roof and installed solar-control windows, admitting light to the house, but limiting infrared and UV light, which cause heating. The appliances and lighting in the zero-energy house are all high efficiency. This also reduced the amount of heat they produced. Overall, the zero-energy house used less energy, while maintaining cooler indoor temperatures.

Solar energy is not the only renewable resource being considered. In certain parts of the country, geothermal energy is also being used to provide power, particularly heat. Although most geothermal reservoirs are located on the West Coast, in Alaska, and in Hawaii, a builder was able to use geothermal energy in a house in Salem, Michigan. The geothermal system in the Kujawski House provides heating, cooling, and hot water for $50 a month. Even in the midst of Michigan's cold winters, the heating bill did not exceed $65 a month. Demographics limit both solar and geothermal energy, but designing a house with energy-efficient appliances is a step that can be applied throughout the United States in building new houses and renovating older ones.

The U.S. Green Building Council began its Leadership in Energy and Environmental Design (LEED) Green Building Rating System to provide builders with standards to support and certify successful green building design, construction, and operations, for both residential and commercial buildings. Both new and refurbished building projects get scores in six areas: sustainable site development, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation and design process. Once the points in each area are added up, builders can win one of four awards: certified, silver, gold, or platinum. Genzyme Center, the corporate headquarters for Genzyme Corporation, a biotechnology company in Cambridge, Massachusetts, earned the highest LEED rating of platinum. In addition to the reduced energy costs (42% less energy and 34% less water usage) of the buildings, the employees recorded less sick time and reported higher productivity levels than employees at other Genzyme facilities. See **Figure 8-7.**

Reducing material use in construction

Smaller is better for the environment. In terms of construction, using less material is always preferable, from an environmental point of view. The trend today, however, is for houses to get larger. This trend inevitably causes more pollution and energy use, but size is not the only constraint. The energy loss from a building is related to its surface area. Small, green designs reduce the outside surface area of a building, in order to reduce energy losses.



Figure 8-7.
The new California Academy of Sciences building in San Francisco practices what it preaches when it comes to environmental issues. (Charmagne Leung)

There are changes inside the house that can also reduce material use. Building America, a partnership promoting green buildings, changed the framing in a new house. This partnership set the studs for the walls 24″ apart, instead of the standard 16″. This allowed the builders to put in thicker insulation and use less wood in the house's construction. Since an average wood-framed house uses the equivalent of over one acre of wood during its construction, any wood savings mean less adverse environmental impacts.

Using low-impact materials during construction

Many construction and building materials contain toxins. Several types of carpeting, for example, emit gases as they age. Also, carpets catch all the pollutants and toxins that come into our houses on our shoes. Research has found, particularly in tightly sealed houses, that the occupant's exposure to dangerous chemicals and pesticides is much higher inside the house than outside the house. For those living in tightly sealed houses, the air inside is generally much dirtier than the air outside.

Builders are beginning to use recycled or renewable materials during construction. Several houses in Arizona have used straw bales, rather than wood, to construct the frame for the house. The bales are covered with a thick layer of stucco on the inside and out. Since straw is an abundant by-product of agriculture (generally produced when growing cereal grains), this technique is a good example of the use of a renewable material in construction. A side effect of straw-bale construction is that the thick walls increase the energy efficiency of the home. This effect lasts over time. Another renewable construction material is rammed earth. This technique uses compacted soil in conjunction with stabilizers for wall construction.

Using recycled materials can also reduce environmental impacts. Although these materials might be difficult to find at your local hardware store, recycled alternatives exist for roofs, sidings, floorings, and carpets, to name a few. Reusing parts of older buildings and renovating them to serve new uses also reduce the environmental impacts. See **Figure 8-8.**



Figure 8-8.
Majestic Slate™ tiles are a premium recycled roofing product manufactured by EcoStar, a division of Carlisle Syntec. (Bruce Beaton)

Another technique in reducing material use is modularization. Instead of building a house entirely on-site, the house or industrial building is built using a modular approach. This type of construction is significantly faster than conventional construction. There is less waste. Although most people think of mobile homes as modular construction, the reality is much different and more permanent. Today, one can build a multistory building from modules constructed in a factory. After the building is finished, it will be indistinguishable from conventional buildings. In Great Britain, the modular-built McDonald's restaurant in Peterborough was open for business just 48 hours after construction began. In home construction, a group of Boston developers are working with the DOE to design a house using modular design. The developers' first two energy-efficient homes were 20% less expensive to build than traditional houses.

Green building faces some obstacles, particularly with building codes designed for traditional construction. Green buildings are sometimes more difficult to maintain because they use unusual materials. The long-range impact of this type of construction is not certain. This construction might remain a small portion of the construction business, or it might take an even greater share in the future. Much of this depends on the tax benefits states and the federal government grant, as well as the individual motivations of the builders and homebuyers.

Improving the efficiency of existing buildings

There have been many changes in building design to improve the efficiency of existing buildings. Unfortunately, most companies do not have the luxury of designing new energy-efficient buildings. Instead, they must improve the efficiency of the older buildings they occupy. Many corporations, as part of their global citizenship, are voluntarily reducing their energy use and greenhouse-gas emissions. Companies and the state government in California have taken a leadership role in this area in the United States. Through the Green Building Initiative, California has committed to reduce energy consumption in state buildings by 20% by 2015. For major renovation projects, a company uses building commissioning, a systematic method that ensures that a building's systems, including heating, ventilation, air conditioning, lighting, water, and safety systems, are designed to operate optimally. If owners want to review an existing building, they usually focus on energy-using equipment, such as mechanical equipment, lighting, and related controls, and try to optimize existing system performance. The commissioning of Soda Hall, a computer-science building on the University of California (UC) Berkeley campus, illustrates the benefits of this process. When built in 1994, Soda Hall was designed to operate 24 hours a day, seven days a week, because the designers expected students to use the building at all hours to complete their programming work. With the advent of more powerful computers and the Internet, however, many students work from home, rather than in a laboratory. The building's airflow was designed at too high a level to meet the current demands of the building. After the commissioning study, the campus implemented the recommendation that had the highest energy savings and the fastest payback periods. The campus reduced the airflow and implemented improvements in the water systems, resulting in energy-cost savings of $110,000 per year.

Other organizations focus on reducing their carbon footprints. The carbon footprint is the total amount of greenhouse-gas emissions caused directly or indirectly through the production and delivery of products and services. SSV is a coalition of the San Francisco Bay Area's private and public organizations committed to reducing the carbon footprint of Silicon Valley. Overall, SSV members have recorded reductions in carbon dioxide emissions totaling 517,000 tons over 16 years. The reduction in emissions is equivalent to taking 100,000 cars off the road for one year. Most of the individual companies in SSV have made significant strides in this area. Lockheed Martin Space Systems Company reduced its carbon dioxide emissions by 21% since 2000. Adobe Systems reduced its electricity use by 35% and its natural gas use by 41% since 2001. Adobe's three headquarter buildings in downtown San Jose, California were all LEED certified at the platinum level. To achieve this certification, Adobe conducted improvement projects in lighting, equipment retrofits, water and waste management, and recycling. Overall, Adobe completed 64 projects and spent $1.4 million on energy conservation. The benefits of these programs allowed Adobe to receive over $350,000 in rebates from local and state agencies and to reduce the operating costs of the three buildings by $1.2 million.

Alternative-Energy Vehicles

Alternative-energy vehicles (in the form of electric cars) have been around as long as gas-powered ones. In the early 1900s, there were more electric cars on the road than gas-powered cars. At the time, it was very difficult to start a gasoline engine. Most

gasoline-powered cars had a crank in the front of the car to get them started. Gasoline also was very expensive. Electric cars were much easier to start and also much quieter. After the price of gasoline dropped and the electric starter was invented, gasoline cars increased in popularity. Although Henry Ford was not the first to manufacture gasoline-powered cars on an assembly line, his company was the most efficient. The Model T vehicle was introduced in 1908. By 1927, 15 million Model T vehicles had been built. In 1912, the gasoline-powered car had certain advantages over the electric car. This car could travel further distances. The gasoline-powered car was cheaper.

Electric cars disappeared until the 1960s. Dependency on foreign oil and a desire to reduce emission from gasoline-powered engines led to a small resurgence of electric cars. The development of electric cars was very slow until several political events in the 1990s. Of particular importance to the resurgence of electric cars are the U.S. 1990 Clean Air Act Amendment, the U.S. 1992 Energy Policy Act, and regulations the California Air Resources Board (CARB) issued. The Clean Air Act required the EPA to issue rules to reduce pollution from car exhaust. The air-quality standards in California are stricter than the U.S. standards. Originally, in 1990, the CARB mandated 2% of all vehicles sold in California in 1998 (approximately 20,000 vehicles) to have zero emissions. These rules were relaxed, however, after strong lobbying from the major automobile companies. Under California's rules, 10% of vehicles sold from 2003 to 2008 were supposed to be electric or zero-emissions vehicles. California, however, realizing the difficulty car companies had in making this goal, allowed automobile manufacturers to sell hybrid-fuel vehicles to satisfy part of the requirement.

In 2004, CARB created new rules for vehicle emissions in California. When fully implemented in 2013–2016, the CARB standards will result in a 30% reduction in greenhouse-gas emissions, as compared to emissions in 2002. Since 2004, 11 other states have adopted California's Motor Vehicle Gas Emissions Standards.

As emissions standards across the United States tighten, there is pressure on automobile companies to design cars and trucks with better gas mileage and alternative fuel vehicles (AFVs). There are several different technologies being pursued today that power these alternative-energy vehicles. In this section, we discuss three different types of vehicles: modern electric vehicles (EVs), hybrid electric vehicles (HEVs), and AFVs.

Electric vehicles (EVs)

One of the first modern EVs was the EV1® vehicle, produced by General Motors in 1997. EVs are cars that run on electricity that has been stored in internal batteries. These vehicles are zero-emissions vehicles because they have no tailpipe exhaust and are usually plugged in at night to recharge their batteries. There is a wide range of EVs available today. Some EVs are similar in design to electric golf carts and are designed for neighborhood driving. Others are designed to replace conventional cars and can be used for longer trips. A downside to EVs is their range. Today, most EVs can go around only 100 miles before they must be recharged. The most popular EV today is the GEM, produced by Global Electric Motorcars, a subsidiary of Chrysler. The GEM is designed as a low-speed vehicle and is legal to drive on streets in the United States on roads marked 35 mph or less. There are other EVs in production, including a high-end sports car produced by Tesla, although most of the major U.S. car companies are now focusing on hybrid-fuel vehicles.

Hybrid electric vehicles (HEVs)

HEVs combine the emissions savings from an EV with a small gasoline-powered engine. A HEV combines an energy storage system, usually made up of batteries, with a gasoline-powered engine and a vehicle-propulsion system. At very low speeds, the car runs typically on its electric motor. At higher speeds, it shifts to both the gasoline motor and the electric motor and recharges its batteries. The Toyota Prius® vehicle, released in Japan in 1997 and worldwide in 2001, was the first mass-produced hybrid vehicle. The Prius vehicle is a parallel hybrid, meaning it can run on gasoline or battery power. The computer system managing the Prius vehicle shuts off the engine when the car is stopped, driving down long hills, or reversing. This decreases fuel consumption. The Hybrid Synergy Drive used in the Prius vehicle's computer program maximizes the efficiency of this car as the vehicle is driven. Since the success of the Prius vehicle, almost every major automobile company has introduced a hybrid version of at least one of their cars. The market growth of hybrids has been outstanding. Hybrids now are over 2% of new-vehicle sales in the United States.

Alternative fuel vehicles (AFVs)

An AFV is a vehicle than does not use gasoline or petroleum-based diesel. There are many different fuels being tested today, including biologically produced diesel (biodiesel), ethanol, hydrogen, methanol, natural gas, and propane. AFVs produce fewer greenhouse-gas emissions than gasoline or traditional diesel vehicles do. Today, passenger cars are available that use compressed natural gas, ethanol, and biodiesel. Honda has developed a fuel cell car, the FCX Clarity, which runs on electricity powered by hydrogen. This car's only emissions are water vapor and heat, making it a zero-emissions vehicle. Right now, the car will be available only in Southern California because there are limited service and refueling locations available. An electric motor powers the FCX Clarity, similar to an EV, but this car has a significantly longer range. The FCX Clarity can travel over 250 miles before refueling. See **Figure 8-9.**

Sustainable Agriculture

Sustainable agriculture is not a set series of practices. Rather, it is a philosophical and practical approach to farming and agriculture. Sustainability is built on three broad goals: farm profitability, improvement of the environment, and increased quality of life for farmers and their communities. Sustainable agriculture is future oriented. The principle is that we should meet our food needs for the present, without limiting the ability of future generations to meet their food needs. Sustainable agriculture is an approach to land management and agriculture.

Agriculture, as a field, has changed dramatically since World War II. Major changes that have impacted agriculture include mechanization, increased use of chemicals and fertilizers, crop specialization, and government policies favoring maximizing production. Agricultural productivity increased throughout the twentieth century. Output in U.S. agriculture rose an average of 1.7% each year from the late 1940s to the middle of the first decade of the twenty-first century. At the same time, the cost of food has dropped. Although productivity is up, productivity will need to increase more to meet the needs of the future world population, which is estimated to reach 10 to 11 billion people by 2040. Also, soil continues to erode. Supplies of groundwater are being depleted. In some parts of the United States—California, for instance—there is a limit to the water supply for farmers. Sustainable farming in California includes the use of drought-resistant crops and the improvement of water conservation.

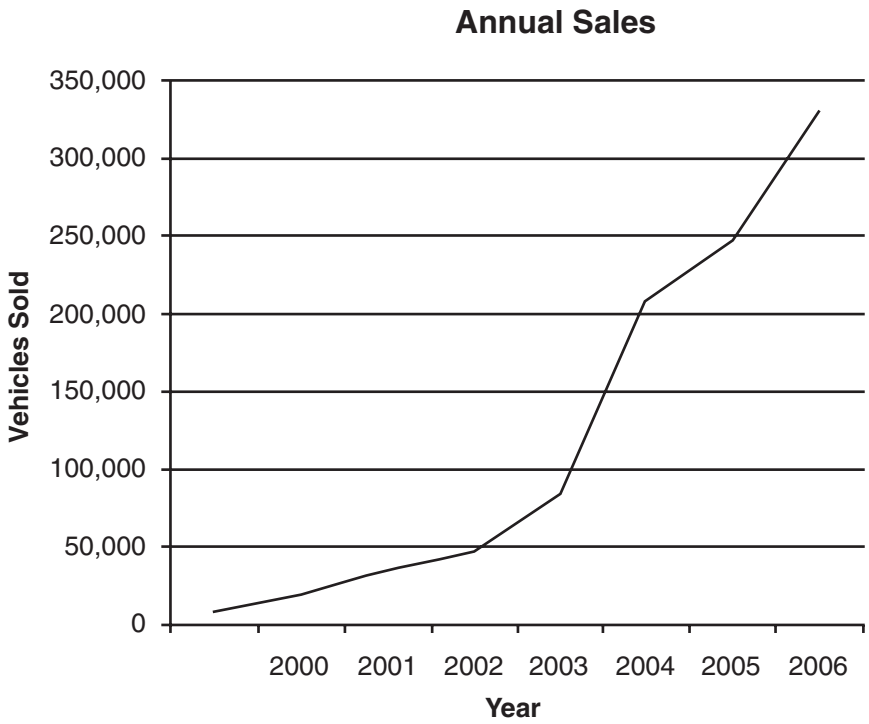


Figure 8-9.
U.S. sales of hybrid vehicles are increasing as more hybrid cars are available to the U.S. public. (Adapted from the Electric Drive Transportation Association)

There are four dominant practices used in sustainable agriculture: integrated pest management (IPM), conservation tillage, enhanced nutrient management, and precision agriculture. Each of these four techniques is used to a varying extent in the United States. IPM has been used for over 30 years, while conservation tillage has a lower adoption rate among farmers.

Integrated pest management (IPM) is a system for managing pests (including insects, diseases, and weeds) to keep them at levels at which they cause minimal damage to crops. This system differs from conventional pest management in that IPM attempts to use ecologically sound, nonpesticide methods to reduce and manage pests. IPM does not attempt to eliminate all pests. Rather, it manages them to keep pests at an acceptable level. Although some farmers use pesticides in IPM, the goal is to use pesticides targeting a specific pest, instead of generic pesticides that commonly kill a range of pests. IPM farmers also rely on biological controls, such as using other insects that feed on the unwanted pest. For some agricultural products (particularly in the fruit industry), IPM use is already high. Researchers predict that IPM use in the United States will increase significantly in the next few decades.

There are many different conservation-tillage techniques, but overall, *conservation tillage* refers to any plowing system leaving at least 30% of the soil surface covered with residue from the year's plantings. This is done so there is enough soil coverage to decrease soil erosion. Government policies

have, in part, driven this technique toward sustainability. The 1990 Farm Bill required farmers to develop strategies to stop erosion on their cropland. This law motivated more farmers to adopt nonconventional tilling of the land, to prepare the land for new crops. Many farmers adopted a no-till method, which leaves the organic waste from last year's crop on the field. See **Figure 8-10.** Conservation tillage also reduces the amount of fuel a farmer has to use on the field, thereby reducing both air pollution and costs the farmer incurs.

Enhanced nutrient management includes testing of the soil before using any fertilizer. The goal of nutrient management is to minimize unused nutrients. Farmers do this by conducting soil analyses. After the soil is analyzed, the farmers can apply the fertilizers at the point when they are needed. Crop rotation, when crops on a particular field are changed each year, is another technique used for nutrient management. This rotation can reduce the need for fertilizer because certain crops (alfalfa and legumes) replace nitrogen into the soil.



Figure 8-10.
Rows of soybean plants emerge from a field covered with old cornstalks from the previous harvest. These soybeans were planted in narrower (15") rows because, as they mature, their big leaves will quickly shade the ground, making it harder for the Sun to warm weed seeds that might lie between the rows. This natural canopy from the growing soybean plants can help farmers reduce the need for herbicides. (University of Missouri)

Precision agriculture is the newest and most technology-intensive technique in sustainable agriculture. This agriculture uses ITs, including the GPS and remote sensing, to achieve optimal farming outputs. This technique is based on the belief that, if a farmer matches the pesticide and fertilizer use to smaller areas in the field, there is less waste and less materials that can damage the environment. To collect data at specific locations in the field, a farmer can use the GPS to collect a wide range of data about the field conditions. GPS farming systems can create maps of a field, thereby allowing the farmer to change his planting to fit the soil conditions. Using a handheld GPS, a farmer can see features such as weed spots, plant-variety areas, and hazards. Another technology farmers use involves the use of probes. Probes can be placed in the field at various points and can continuously monitor the characteristics of the soil, including its moisture level and nutrients. A farmer then knows exactly how much water or fertilizer to place on this portion of the field.

This agriculture further extends the computer explosion onto our contemporary farms. Precision agriculture provides the farmer with detailed information about the conditions in the field so the farmer can make more informed choices. Although precision agriculture has been available since the early 1990s, few farmers use this technology. The information being gathered is voluminous and complex and has to be interpreted by the farmer. Also, not all aspects of precision farming are readily adapted. Most precision-agriculture farmers use a GPS guidance system. Few are using telemetry to send information from the field

to the home office. Until more farmers can see that precision agriculture gives them a good return on their investment, the use of these information-rich technologies will remain small.

In addition to the 1990 Farm Bill, there are many other laws affecting farmers in their work. Currently, U.S. policies on crop support systems encourage large farms producing a single type of product. This crop support system works against the principles of sustainable agriculture. If U.S. agricultural policies could be changed to encourage diversified production, sustainable agriculture would become more prevalent.

Economy versus Ecology

Economy versus ecology—unfortunately, this is often the way the relationship between these two is portrayed. In the United States, even the regulations promoting sustainability seem to take an antagonistic approach to businesses and the economy. The most critical environmental initiatives—the Clean Water Act, the National Environmental Protection Act, and the Endangered Species Act—are top-down regulatory approaches. The advantage of regulations is that they force changes to occur at a faster rate than these changes would occur in a free market environment. The automobile industry in the United States was changed because of the regulations related to air quality and safety, despite the resistance of the auto manufacturers. The unintended, but positive, results of these changes were enormous innovations in automobiles, including air bags, seat belts, new and lighter metals and composite materials, and catalytic converters.

Sustainability cannot be regulated, as it is an approach to the use and development of technology. Sustainable technologies generally are those minimizing ecological damage, however. Companies are realizing that protecting the environment can help sell a product. Recycled paper is one example of a sustainable product. Today, the EPA requires federal agencies and contractors to use paper containing a minimum of 30% postconsumer content for uncoated paper and 10% for coated papers.

Along with the press toward sustainability in the world, there has been an extensive amount of education on the effects of technology on the environment. All children in U.S. elementary schools learn the environmental three *R*s—reduce, reuse, and recycle. Reuse is the least used of the environmental *ABC*s in the United States today. Interestingly enough, reuse in previous generations was much higher. Before the 1970s, soda bottles were made of glass. Most of them were reusable. After you drank the soda, the bottles were returned to the store. The storeowner returned them to the bottler. The bottler sterilized the bottles and refilled them with soft drinks. This type of process was used for many other liquid household products and is still used in parts of the United States and in some European countries for milk.

The Energy Star program is a good example of the reduce principle. Computers following the Energy Star guidelines must operate on low power when not being used. They must enter a standby mode when not in use. The Energy Star feature on computers can reduce their consumption of electricity by 50%–75%. The marketplace is demanding greener products. Supermarket aisles are filled with products promoting their environmental friendliness—from compact fluorescent lightbulbs to phosphate-free detergent and toilet paper manufactured with recycled paper.

Several companies have created new programs related to sustainability. The New England Power Company opened a new

coal-ash recycling plant and is selling the recycled ash as a cement substitute. The recycled ash makes the concrete stronger and less expensive to produce. Dow Chemical has a program called *Waste Reduction Always Pays (WRAP)*, which in addition to cutting Dow's emissions in half, has resulted in annual savings of $10 million.

The amount of recycling has burgeoned in the United States. See **Figure 8-11.** The number of tons recycled increased from 34 million tons in 1990 to 82 million tons in 2006. This equates to over 30% of the nation's waste. See **Figure 8-12.** Recycling, however, considers only the end result in the product life cycle. New efforts are addressing the issue of sustainability at the design stage. Computers are some of the most powerful tools in our society. They also produce a tremendous amount of waste. In 2005, more than 2 million tons of used electronic products were discarded in the United States. Fewer than 17% were recycled. If more computers were recycled, there would be a positive effect on the waste stream. In the United States, there are different regulations for the disposal of computers and other electronic products in several states. In 2003, California enacted the Electronic Waster Recycling Act, which requires a recycling fee to be paid at the time of purchase of certain electronic products, including computer monitors, laptop computers, LCD and plasma televisions, and portable DVD players. Outdated or unusable electronic equipment is considered to be hazardous waste and should be recycled by an organization equipped to handle it.

The EU has taken another approach. A new directive, which took effect in 2005, requires electronics manufacturers to take physical or financial responsibility for their products when the products are at the end of their useful lives. The motivation for this directive is to make the producers of electrical and electronic equipment responsible for the pollution. Since the manufacturers are responsible for the disposal of their devices, they are more likely to design and manufacture their products so these products have longer lives and are easier to recycle or reuse. Under this directive, each country in the EU

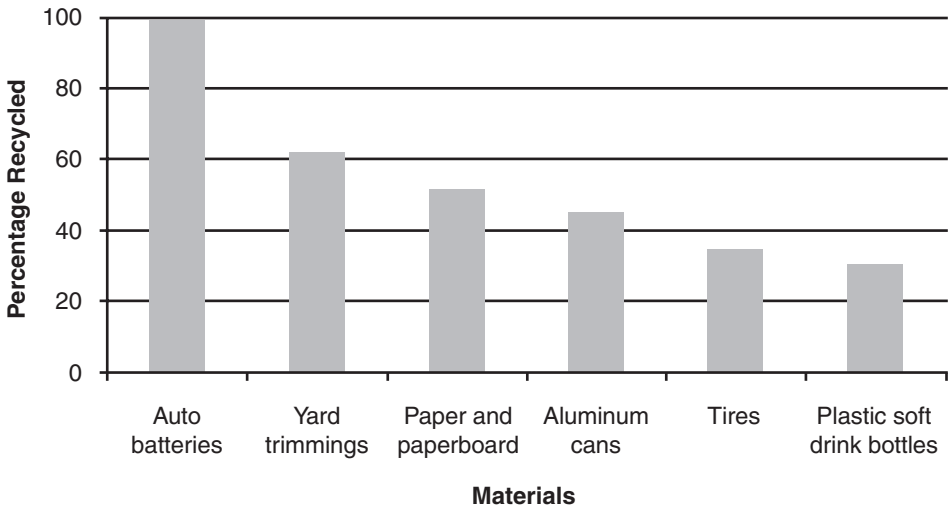


Figure 8-11.
Recycling rates in the United States vary depending on the materials recycled. The recycling rate for automobile batteries was almost 100% in 2006 because of government regulations. (Adapted from the EPA)

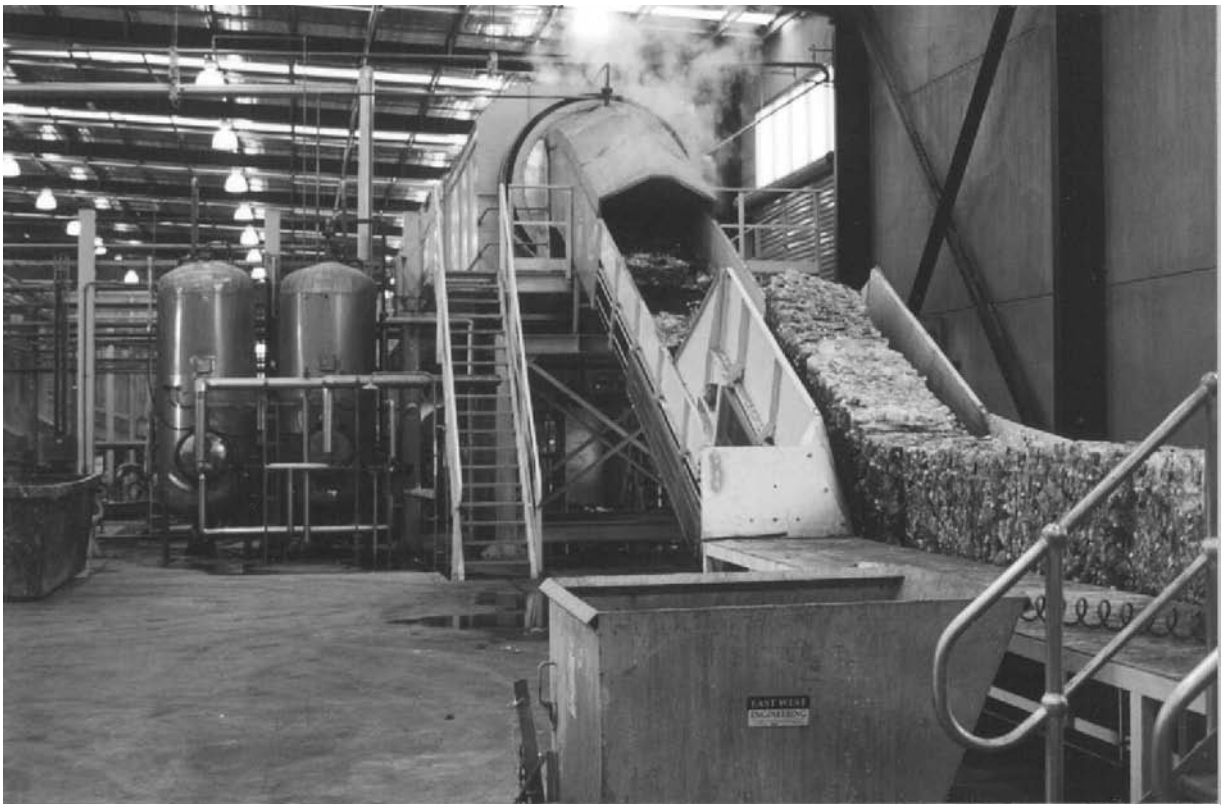


Figure 8-12.
Coca-Cola Amatil Beverage Packaging makes its polyethylene terephthalate (PET) soft drink bottles with 25% recycled content. (Charlie Woolford/Coca-Cola Amatil Beverage Packaging)

has to recycle at least 4 kg of e-waste per capita each year. The long-term effects of this law on multinational computer companies are hard to foresee, but some Europeans believe this law will place them at a disadvantage competitively.

The issue of sustainability and the implications of sustainable technologies for business will continue to be debated. Although there is increased awareness in the United States about protecting the environment, we have a tendency to consider our resources as without limit. Implementing the sustainable principles and behaviors into our lifestyles, as well as the design of new technologies, requires a shift in the attitudes of the American people. As with other issues we face, the tendency is to avoid uncomfortable issues until they become pressing. At the same time, the longer we wait to address sustainability, the more remediation will be necessary. Every new technology has consequences for society. Some of those consequences can be foreseen. Others are unforeseen. Considering the issue of sustainability in the deliberations about technology forces us to consider these consequences in a broader perspective.

International Sustainability Efforts

A sustainable society, over the long-term, uses resources at the same rate as or a lower rate than these resources are replenished. The production of waste materials in a sustainable society also does not exceed the rate at which the environment reabsorbs these wastes. There are three main trends working against sustainability in the world today: human overpopulation, overconsumption, and underconservation.

The population of Earth is increasing exponentially. The world's population in 1960 was 3 billion; in 1975, it reached 4 billion; and by 1999, it hit 6 billion people. There is a limit to the number of people Earth can sustain—what this limit is, we can only guess. Overconsumption, however, is a characteristic of developed countries and is driven by rampant consumerism in these countries, including the United States. The third main problem, underconservation, magnifies the problem of overconsumption. We use too many of Earth's natural resources and do not reuse enough products. All these trends affect sustainability. The goal is to develop technologies that promote sustainability and do not add to the negative influences on the world.

The widely published Brundtland Commission Report on sustainable development titled *Our Common Future* forecasted a future world based on trends of today. This world in 2050 would have technology that was twice as efficient, a world population of 10 billion people, and a world economy five times larger than in the late 1980s. If the developed countries continue to consume at the rate they are consuming today, the environmental reality of this future would be terrible.

More than 175 world governments committed in the early 1990s to Agenda 21, a United Nations (UN)–sponsored program with the goal of achieving sustainable development. The UN is planning summits every 10 years to assess the progress toward sustainable development and to make recommendations for the future. The major goals for Agenda 21 are clean water; the protection of oceans, forests, and biodiversity; the elimination of poverty; sustainable development and technology transfer; and food security.

Sustainable-development efforts are successful for all parties only when they are infused with information from both the donor and the receiver. The top-down and externally driven development model has inherent limitations. For development to be successful, providers must listen to the local users. After development efforts have ended, it is the local users who must sustain any new technologies.

Traditionally, development has been equated with economic growth. A common belief was that positive development occurred when it directly increased a country's economic structure. Along with this emphasis on economic progress, there has been a tendency to focus on the following initiatives: privatizing government industries, such as the telephone and electric industries; reducing the regulations in a marketplace by removing trade barriers, tariffs, or import restrictions; and formalizing intellectual-property rights through patents. This type of development is rooted in the capitalistic perspective of the United States and most other Western countries. These types of development activities assume the entire world would benefit from living under a capitalistic system.

Since we, in the United States, do live under a capitalistic system, it is difficult to imagine residing in a country without these principles. The goal of development

under capitalism is to create a world with a single borderless economy. In this economy, corporations would have unlimited access to markets and could sell their products globally. Corporations would also use the cheapest sources of natural resources, labor, and supplies as they build their products.

This type of development assumes any problems with the environment or social structure would be solved through the normal processes imbedded in a marketplace. Unfortunately, the reality shows this has not been the case. For several decades, the United States and other Western manufacturers have been moving their assembly plants offshore to developing countries. The Maquiladora Program in Mexico is a perfect example of this type of offshore activity.

The Border Industrialization Program, known as the *Maquiladora Program*, began in the mid-1960s. The Mexican government gives financial incentives to foreign companies, most of which are from the United States, to open factories in certain areas in Mexico. Before the Maquiladora Program, Tijuana, Mexico was a sleepy border town of 200,000 people, mostly visited by tourists on day trips from San Diego. Today, it is an industrialized complex of light- and heavy-manufacturing and assembly plants. There was an increase in population because of the increased number of jobs in Tijuana (and other maquiladora cities). Maquiladora cities tend to draw internal immigrants from rural areas because of the greater number of jobs available to the immigrants. As the number of immigrants increased, the area became crowded with makeshift housing. Today, Tijuana has more than five times the population it had 30 years ago—almost 1.5 million people.

Business in the Maquiladora Program has boomed. At least 1 million Mexican workers are employed in maquiladora plants. These plants account for 45% of Mexico's exports. The maquiladora plants range from low-tech woodworking shops to high-tech electronics firms. While the business is booming, the local environment is not. The level of industrial pollutants in the maquiladora plants is very high.

The typical worker in maquiladora plants is a woman aged from the late teens to mid-twenties. See **Figure 8-13.** This type of worker is popular in the maquiladora industry because the manufacturers consider women more pliable and easier to manage. The problem is that most of these women are also married with children. They are forced to work long hours at the maquiladora plants and then come home and care for their families. Considering the paternalistic nature of the traditional Mexican family, these women are both the breadwinners and the caregivers. Indirectly, the maquiladora plants undermine the traditional gender roles in Mexican society.



Figure 8-13.
This typical maquiladora worker is forced to work long hours. (James J. Biles)

The Maquiladora Program is a successful development program, but is it an AT transfer? From the workers' points of view, the workers have employment, but at very low wages. The alternative, however, is no employment at all or having to cross the U.S.-Mexico border (possibly illegally) to go to work. From the environmental point of view, this development is not appropriate because both the Mexican workers and the people who live around the plants have to contend with increased pollution.

This is not a good model for appropriate (or sustainable) technology from the perspective of the Mexican workers because it does not help the community. The Maquiladora Program pollutes the land and exploits the worker. From the Mexican government's and the industrial firms' perspectives, this technology transfer is very appropriate because these maquiladora plants provide jobs, increase the tax base, and allow Mexico to become more industrialized. When we judge the appropriateness of the technology transfer from the perspective of the workers, however, this assessment will most likely change.

Helping less-developed nations deal with the enormous environmental and social problems they face is no longer a simple matter of morality or altruism. Environmental degradation in Third World countries has very direct implications for the United States. Specifically, ecological or environmental instability contributes greatly to political instability in many areas of the world.

Unmanaged population growth outstrips the capacity of less-developed countries to support their people. Uncontrolled soil erosion undermines a community's capability to provide enough food for its residents. Unmonitored forest destruction deprives the local population of raw materials needed for fuel and shelter. Citizens who must confront these problems on a daily basis represent a potential source of revolutionary discontent. It ultimately becomes difficult, if not impossible, to address the question of environmental protection when your own survival has no assurance.

Haitian immigrants to the United States are not only refugees from politics; they also left behind a country whose land has been virtually destroyed. In many areas, 50% of the land surface has eroded to bare rock. There are no forests left on the island. Jamaica provides another example. Massive emigration from this country is due in part to the deterioration of Jamaica's natural resources.

In South America, the high Andean mountain regions are suffering perilous soil erosion since traditional systems of agriculture have all but disappeared. Developmental aid in the 1950s and 1960s was devoted to the introduction of cash crops for export, in order to attain the foreign currency needed to develop industrial centers. Many of these crops were not suitable for the soil. Likewise, the undermining of traditional farming practices in the Sahel region of West Africa has caused severe environmental problems. In contrast to Western-driven development models, ***agroecology*** attempts to understand how traditional farming systems in developing countries have achieved sustainability. This field of agricultural development, instead of prescribing what is needed first, investigates what practices exist in local agriculture and how these practices relate to the local social, economic, and technological systems in place.

Some years before armed conflict broke out in El Salvador, scientific and technical observers noted problems of deforestation, soil erosion, stream siltation, and the harsh effects of fuelwood harvesting on natural vegetative recovery. Air and water pollution were not monitored. The birthrate ultimately exceeded the capacities of existing health, education, and welfare programs. Social and ecological decline eventually prepared the ground on which subsequent social wars have been fought over the years.

Despite these worsening problems and the underlying threat on international stability, governments seem to be unable to effectively come to terms with them. The tendency has often been to delay the implementation of long-term solutions in exchange for improvisational decision making. This form of stopgap measure is best described as crisis management. Many development efforts evolve because of crisis situations. It is much easier to throw money at a problem than investigate the best way to prevent the problem. The nature of development efforts also creates a gap between the donor and the receiver. The donor has the money and perceives it has the correct technology, while the receiver has few choices, except to accept or reject the technology. This situation of power inequity makes the development experience even trickier. Added to this equation are cultural and social differences. It is no wonder successful development is hard to achieve for the long-term.

Some development agencies have moved away from large-scale development efforts to promoting smaller-scale, locally conceived projects. An example of a successful development effort is the biogas project in Vietnam. Funded by the United Nations Development Programme (UNDP), this project promotes biogas (gas produced from the decomposition of organic materials) as a renewable energy source. The biogas project has helped families reduce household chores by 40% and has provided a way to use animal waste. See **Figure 8-14.**

This project is especially interesting because it shows a new trend in development activities—a focus on bringing the benefits of technology to women worldwide. The UN has a development program especially targeted to women, the United Nations Development Fund for Women (UNIFEM). UNIFEM focuses on three areas: strengthening the economic capacity of women, enabling women to have more of a voice in decision-making processes affecting their lives, and promoting women's rights and transforming the development process into a sustainable one. The technology needs of women in the developing world are different than those of men. Most development programs, however, assume technology will be applicable to users of both genders. UNIFEM has found through its research that women are not receiving equal benefits from technologies. More interestingly, technologies that would benefit women are often not investigated.

Since technological development is not spontaneous, ignoring a critical constituent group can radically change whether or not a technology is even developed. An example of this can be seen in the production and processing of sorghum in Botswana. The traditional method of processing sorghum, in addition to being tedious and time-consuming, is considered to be a woman's job. Many people in Botswana choose to eat maize imported from South Africa, rather than spend the time processing sorghum, because of the time sorghum processing takes. The development of a technology to assist in the processing was not at first considered because this processing was considered to be a woman's task. A local ***nongovernmental organization (NGO)*** decided to look into this problem and adapted a Canadian cereal mill to process sorghum.

Whether a transferable technology is destined for women, men, or both, it is critical that the development agency or country listen to the voice of the user. In-depth assessment is needed before any technology transfer takes place, in order to achieve sustainability. Development partnerships are much more successful in the long run than turnkey development schemes are.



Figure 8-14.
This tubular polyethylene, low-cost biodigester is on the ecological farm of the University of Tropical Agriculture in Cambodia. Farmers in Vietnam have purchased some 10,000 units of this type (material cost is between 30 and 50 U.S. dollars). The primary benefit of this design is its low capital cost, relative to other designs. At the same time, this design does not compromise the numerous other benefits of biogas-digester technology as an energy supply source. (The University of Tropical Agriculture Foundation)

Another issue in development and technology transfer is energy. Access to energy varies significantly among the countries of the world and among people in the countries. One-third of the world's population relies on traditional energy sources. These people cannot take advantage of the possibilities of new technologies because they lack the energy to make them work. Appropriate development and AT transfers must take into account the inequities in infrastructure in developing countries before they can be successful. Only after a full assessment of a technology and its demands can we assess the technology's appropriateness for transfer.

In the next section, we focus on three areas directly addressing the issues of appropriateness from an international perspective. There have been diverse approaches to applying the AT concept internationally because of the different perspectives on and definitions of *AT*. Business and corporate interests drive ISO 14000, while ethnobotany has emerged from the scientific field. The fair trade movement has evolved from consumer demand for products that give more money

to the producers of commodities such as coffee, tea, and chocolate, instead of to the middlemen. Each of these initiatives has the goal of encouraging ATs in the world.

International Organization for Standardization (ISO) 14000 and Environmental Management

The ISO 14000 standards for ***environmental management*** were a result of the focus on sustainable development emerging from the UN Conference on Environment and Development in the early 1990s. After this conference, the ISO developed ***International Organization for Standardization (ISO) 14000*** to provide a model for companies to follow "sustainable business development." The focus of ISO 14000 is managing environmental issues through appropriate business strategies. ISO 14000 is not a series of steps a company has to implement. Rather, it is a management tool describing how a company can manage its business in an environmentally friendly manner. ISO 14000 requires a company to implement an environmental management system (EMS). For companies that have implemented ISO 14000, the benefits of an EMS include reductions in the use of energy and materials and, at the same time, a reduction in waste produced. Other benefits of ISO 14000 are less tangible. Since ISO 14000 is an environmental-management approach, adherence to these guidelines and certification can improve the public image of a company. For a company, there are six steps to developing an EMS:

- **Environmental policy.** The company defines its own environmental policy.
- **Planning.** The company develops its own plan for identifying the environmental impact of its manufacturing and service processes.
- **Implementation.** The top management in the company assigns resources and people to implement the plan.
- **Corrective action.** The company monitors its success in implementing its environmental plan.
- **Management review.** The EMS plan is reviewed on a regular basis.
- **Continuous improvement.** The EMS is revised to improve the management of environmental issues in the company.

After a company develops its EMS, an external auditor who can certify that the company meets the ISO 14000 standards evaluates the EMS. The company then joins the list of ISO 14000–certified companies worldwide. Since the first ISO 14000 certificate was issued in the early 1990s, the number of companies receiving ISO 14000 certification has exploded. Across the globe, there is an unequal distribution of ISO 14000–certified companies, both by country and industry. The largest ISO 14000 sector consists of companies in the basic-metal and fabricated-metal industries. The smallest sector consists of companies in trades and services. There are also differences in ISO 14000 certification by country. See **Figure 8-15.** ISO 14000 is more popular in Europe and Asia than in the United States. In 2006 alone, there was a 16% growth in ISO 14000 certifications worldwide. Despite its slow growth in the United States, ISO 14000 will continue to expand across the world. As the principles of environmental management spread, this certification should become more acceptable to U.S. companies.

The Fair Trade Movement

Fair or alternative trade provides a contrast to the conventional free market approach to international trade. Instead of putting the consumers first, fair trade puts the producers first. Directly, fair trade means

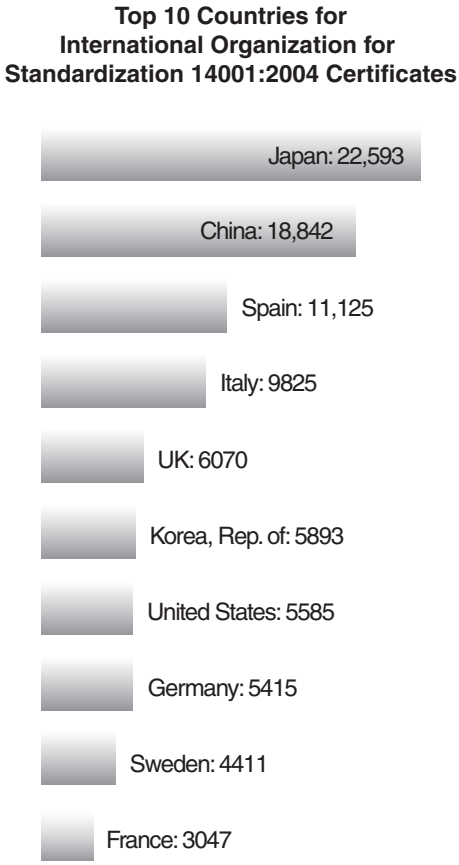


Figure 8-15.
ISO 14000 certificates by industry, as of December 2006. (Adapted from ISO)

that any goods produced, whether they are commodities, such as coffee or tea, or manufactured products, such as textiles or crafts, must bring a good price to the producer of the good. Beyond the issue of a good price, the fair trade movement attempts to blend the market-based economy with social justice and environmental concerns.

The largest segment in fair trade is food products, with coffee having the most prominent role. Fair trade coffee has 2%–5% of the market share in developed countries, but more importantly, fair trade coffee is widely available in these developed countries. More than 90% of fair trade coffee is distributed in conventional supermarkets.

Fair trade is promoted in a variety of ways. Several NGOs, including Oxfam Trading and Traidcraft, act as marketing agents for fair-trade producers. In this model, the NGO pays the producer a fair price for her products and then markets the products on behalf of the producer in developed countries. The producers in this model are similar to subcontractors in a regular business organization. The NGO bears the risk for trading the commodity. In addition to trading, NGOs offer technical assistance and support to producers. The International Resources for Fairer Trade (IRFT), affiliated with Traidcraft, provides consultant services in accounting and supply-chain management to small Indian businesses. In this way, the NGO helps community-based businesses gain the knowledge and skills that make them able to have a greater influence in the marketplace.

NGOs are not the only means through which fair trade is conducted. Other fair trade organizations are sponsored by governments or are community-based organizations. No matter how goods are traded, the key issue is fair price. As with many other parts of AT, there is disagreement as to what constitutes a fair price. Is it a fair price if it is higher than the price other international traders offer, or is it a fair price only when it is high enough to allow a producer to have a reasonable living standard?

Although the market share for fair trade products is small, it is growing, especially in areas with higher-income consumers. Switzerland, a wealthy country in Europe, has the highest purchasing rate of fair trade coffee. In October 2006, over 1.5 million producers worldwide directly benefited from fair trade, with an additional 5 million community members benefiting from infrastructure- and community-development projects.

As the disparities in income and living standards across the world confront Americans even more, buying products under the fair trade banner allows Americans to personally affect people from another country. Interestingly, several e-commerce Web sites are being used to promote and sell fair trade products. Fair Trade on-line is an Internet e-commerce site selling fair trade food and crafts from around the world. See **Figure 8-16.** Although most fair trade products are commodities or crafts, high technology can benefit the producers who are able to sell their products through fair trade organizations.

Ethnobotany

Ethnobotany is the field of science investigating how indigenous people use plants in their lives as food, shelter, and medicine. This field holds the most promise in the field of medicine. For centuries, indigenous people have used their own native plants to cure diseases. Today, the industrialized world is increasingly taking advantage of this information to design modern drugs that might cure a range of diseases. In the United States alone, about half of the 25 top-selling prescription drugs were developed from

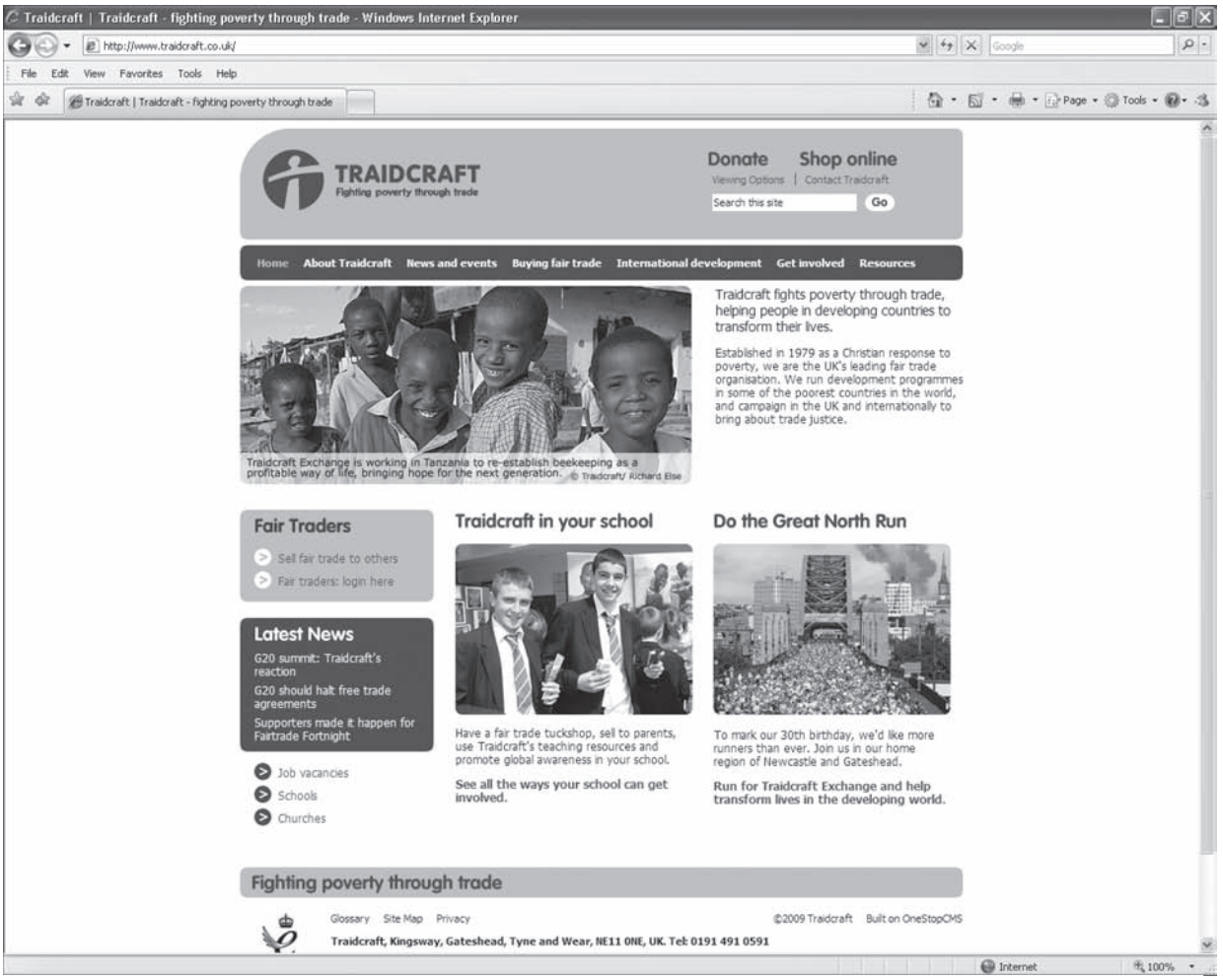


Figure 8-16.
Two NGOs, Traidcraft and Oxfam, along with Yahoo, established Fair Trade on-line to provide easy access to fair-trade products.

natural or plant sources. The remote areas of South America, including its jungles and rain forests, contain a diverse number of plants, some of which Western scientists have never seen or used.

The Western world has been developing drugs from non-Western sources for centuries. One of the earliest was quinine, which the Spanish extracted from the bark of the cinchona trees found in the Andes in the early 1500s. Other products derived from plant extracts indigenous to countries in the world's Southern hemisphere include cocaine, curare, and pilocarpine, used for the treatment of glaucoma. Despite the sources for these drugs, the financial benefits were not distributed to the native people who really discovered these medicines. This situation is changing with the new growth of ethnobotany. Most modern ethnobotanists now work with native healers to investigate plants and their properties. There is increasing emphasis on sharing the financial benefits of the new medicines with the people living in the countries where these new medicines are found.

Recently, there was a landmark agreement between the AIDS Research Alliance of America and the country of Samoa. An ethnobotanist working in Samoa had found that Samoan healers used the bark of a plant to treat hepatitis. The chemical compound from this plant, called *prostratin*, was synthesized by the National Cancer Institute and is being tested as an anti-HIV drug. The AIDS Research Alliance of America agreed to return 20% of any profits to Samoa. Part of this money will go to the Samoan government, while a portion will also go to the village where the drug was found and to the healers who found the drug.

The exploration of wild plants and animals and their uses is called *bioprospecting*. In contrast to traditional prospecting for gold and other minerals, bioprospecting implies minimal disturbance of the natural environment. Since Western companies have tested only a few of the thousands of traditional medicines, there is potential for profits exceeding those in farming and ranching. Since most of the tropical forest is lost to farming and ranching, bioprospecting can slow down the rate of loss of the tropical rain forest. Since the early 1990s, Merck, a Western pharmaceutical company, has worked with the Costa Rican National Institute of Biodiversity to search for new drugs in this country.

As more Western companies exploit the resources of the developing world, there should be financial benefits as well for these developing countries. At the same time, the use of plants and other organics from the rural areas can increase the statures of these countries, and thereby ensure their survival. In Chapter 9, we note that logging and grazing are depleting the rain forest. If developing countries are able to view their rain forests as sources of wealth, however, there might very well be a stronger motivation to maintain them. Ethnobotany and the medicines derived from it can lead to a more positive environment for these countries.

Technology Equity

As technologies are developed and distributed, they generally are not distributed equally to all different social and economic classes in our society. Positive technologies, including the computer and the Internet, are more available to the wealthier segments of our population. On the flip side, negative technologies, such as waste-recycling plants and power plants, are found more frequently in areas where poorer people live. The issue in both of these cases is equity. ***Technology equity*** implies all technologies are available to and used by all socioeconomic segments in a society. How can the United States, never mind the world, guarantee equal access to technology for all people?

From the information-rich vantage point of the United States, it is difficult for us to understand that most of the people in the world do not have access to a telephone, much less the Internet or other advanced telecommunications. In the United States itself, about 215 million people are on-line. This represents about only 70% of the U.S. population. Computer and Internet use, however, are not evenly distributed by racial group. At all income levels, fewer African-Americans and Hispanic-Americans use either a computer or the Internet. Americans living in low-income households have the lowest levels of computer and Internet usage. This is sometimes referred to as the *digital divide*.

The digital divide exists globally as well. Although Internet use is rising worldwide, it is not equitably divided among all the countries in the world. A lot of this has to do with infrastructure. Many of these developing countries do not have extensive telephone systems. In Bangladesh, for example, for every 100 people, there are only 23 telephone lines or cell phones. Providing access to a computer does not decrease the digital divide if a large portion of the population cannot read and write. This is the case in India, where 34% of the population cannot read. To solve the problem of technology inequity worldwide, we need to take a look at the technologies themselves. More access should mean better access and should bring better opportunities for people around the world. We are optimistic that, in a few decades, the digital divide will be a fact of history. The only way this will happen, however, is if the United States and other developed countries share their knowledge with developing countries in the world.

Summary

The development and use of AT require us to consider every technology artifact as more than a device. We must consider how each artifact is used, affects the environment, and impacts social and gender roles in society. Many different ways of looking at AT are proposed in this chapter. What do they have in common? AT is a nontraditional way of evaluating technology. The technology artifact is considered in the context of how it is used in society. Technology is seen as a social force interwoven into the lives of its users. If we view technology as multifaceted, we can begin to look at it with a more critical eye.

Since humankind has existed, we have been changing this planet—sometimes for the good, and sometimes not. In the future, new unimagined technologies will emerge in our society. Using these technologies responsibly can make them ATs.

The issue of appropriateness is linked to the social and political environment of a particular country. All countries and all people have basic needs—food, shelter, and security. A country must balance the needs of its people with the people's desires for new and better technologies. Since we, in the Western world, are only beginning to deal with and acknowledge the issue of appropriateness, it is simplistic to assume we can provide all the answers for the rest of the world. Indeed, appropriateness assumes a level of self-reliance and self-governance about technology, its benefits, and its risks. As responsible citizens of the world, our desire should be to use all our technologies so we minimize the damage we cause to our environment and ourselves.

Discussion Questions

1. Take a trip to your local hardware store. Find at least three different green products you could use in building or renovating your home. For each product, describe its advantages and disadvantages.
2. Research an ISO 14000 company either in the telephone book or on the WWW. How do these standards affect the way a company is managed?
3. Considering where you live, which renewable energy sources would work best in your region? Why?
4. Describe two different techniques used in sustainable agriculture.
5. Research the availability of free trade products in your local supermarket. What types of products are sold? Are they widely available in your area?

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Chapter 9

Environmental Issues

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DATELINE

Inverness, Scotland

The world's first commercial wave power station is located off the Scottish island of Islay. The station generates enough power to run about 400 homes on the island. The plant, called *Limpet*, works well off the coast of Scotland because of the strong waves buffeting the coast. The incoming waves power turbine engines, which then drive a power generator. This produces the electricity.

Although the cost of the power Limpet generates is higher than the cost of power from conventional sources, the power's source (waves) is definitely renewable. Waves push water through a turbine as they advance and recede from the shore. Through the turbine, the wave energy is converted into electrical energy.…

Introduction

When we think of the relationship between technology and the environment, we tend to view technology as having a negative impact on our environment. In fact, the evolution of the phrase *environmental impact* as a modifier for such words as *assessment*, *report*, and *statement* is directly related to this mode of discussion and debate. Protection of the natural environment has become a key issue in almost all dialogue surrounding the international advancement of technology.

Although the issue of environmental protection has a relatively short history when compared with the history of technology, it has received a great deal of media attention throughout its existence. Participation in these often-dramatic cover stories has not been limited to the scientific, technological, and political arenas. The general public has continually maintained an active voice at the grassroots level, which has stimulated much of the regulatory legislation currently in effect.

Widespread concern about the long-term effects of technology and its many by-products on the natural system of the biosphere began during the mid-1960s. The UN Conference on the Human Environment, held in Stockholm in the early 1970s, placed a series of environmental issues on the official agendas of national governments around the world. Through the final decades of the twentieth century, the environment gradually became an item of greater priority on the prospectus of international affairs.

An attempt to generate a comprehensive list of the critical areas of environmental concern would be challenging. The degrees of technical and scientific background possessed by the respondents surveyed would also directly influence this list. Without question, some of the more serious matters dictating a sense of urgency include air quality, climatic stability, moist tropical forests, arable lands, water potability, and the management of hazardous materials. At mid-twentieth century, none of these topics were political discussion topics, let alone issues of international magnitude.

The intent of this chapter is to familiarize you with several environmental conditions that can no longer be overlooked or ignored, if future generations are to be assured of a natural, hospitable environment. The extent to which these conditions are either a direct

result or an indirect result of the advancement of technology in society will most likely remain a debatable issue. This chapter provides a continuing dialogue that can ultimately respond to the following questions:

- ❏ What does it mean to be labeled as an *environmentalist* in today's social circles?
- ❏ Has there been any significant progress made in international environmental cooperation?
- ❏ What effect has governmental intervention had on the quality of air we breathe in this country?
- ❏ What strategies are currently being proposed or implemented to deter the degradation of the world's remaining tropical forests?
- ❏ How can the dangerous waste materials that advanced technological societies generate be managed most effectively?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

acid rain
Air Quality Index (AQI)
common space
environmental-impact analysis
environmental release
evapotranspiration
global warming
greenhouse effect
modern environmentalism
Pollutant Standards Index (PSI)
Superfund

The Contemporary Environmentalist Profile

Not long ago, being referred to as an *environmentalist* in American society signified radical behavior and an antiestablishment perspective on most issues. This perception is being replaced with a whole new array of characteristics. Across the United States, Americans' concerns about their environment are increasingly being expressed through the all-inclusive, yet somewhat elusive, phrase *quality of living*. One simple definition of *quality of living* suggests it is a balance between what people need and want and the extent to which the environment can provide for them. Some of the typical quality-of-life indicators sociologists and cultural anthropologists use to study this concept include standard of living or per capita income, psychological and mental well-being, environmental stability and quality, general climatic conditions, and opportunities for self-sufficiency.

The quality-of-living concept carries slightly different meanings from one person to another or from one geographic region to another. Consistency among these definitions, as related to the environment, can generally be found within the universal values of clean air, pure water, and an appreciation for the diversity of the natural environment. Many individuals have come to expect these items as part of their birthrights. They also realize technology is threatening these values.

Daily newspapers continually bring revelations of a toxic spill, a hazardous-material incident, or a natural resource in jeopardy to our doorsteps each morning. The disheartening nature of these reports, coupled with the desire to live in a quality environment, has prompted an eagerness on the part of the general public to correct these situations. Being called an *environmentalist* today no longer connotes countercultural viewpoints.

Environmentalism

Modern environmentalism is a term used to describe an information-based perspective supporting the need for harmony between industrial objectives and environmental goals. For most of the twentieth century, people accepted pollution as an expected by-product of technological progress. See **Figure 9-1.** In the 1960s, however, this perspective was challenged (along with other societal norms). In the early 1960s, Rachel Carson published her book, *Silent Spring*, which describes the effect the pesticide dichloro diphenyl trichloroethane (DDT) has on birds. News stories about pollution in America's rivers added to the impact of this book, particularly the fire on the Cuyahoga River in Cleveland, Ohio in the late 1960s. The river was so full of industrial waste that it literally caught on fire.

Growing in public interest and participation, environmentalism has become a strong movement in the United States. First of all, the modern environmentalist recognizes that environmental goals cannot be pursued without regard to their consequences elsewhere. For example, effective energy policy cannot be based solely on environmental values. A clean environment is only one of the many results we want in the development of a national energy policy. A clean environment is not the central driving force. The second component of the modern environmentalist

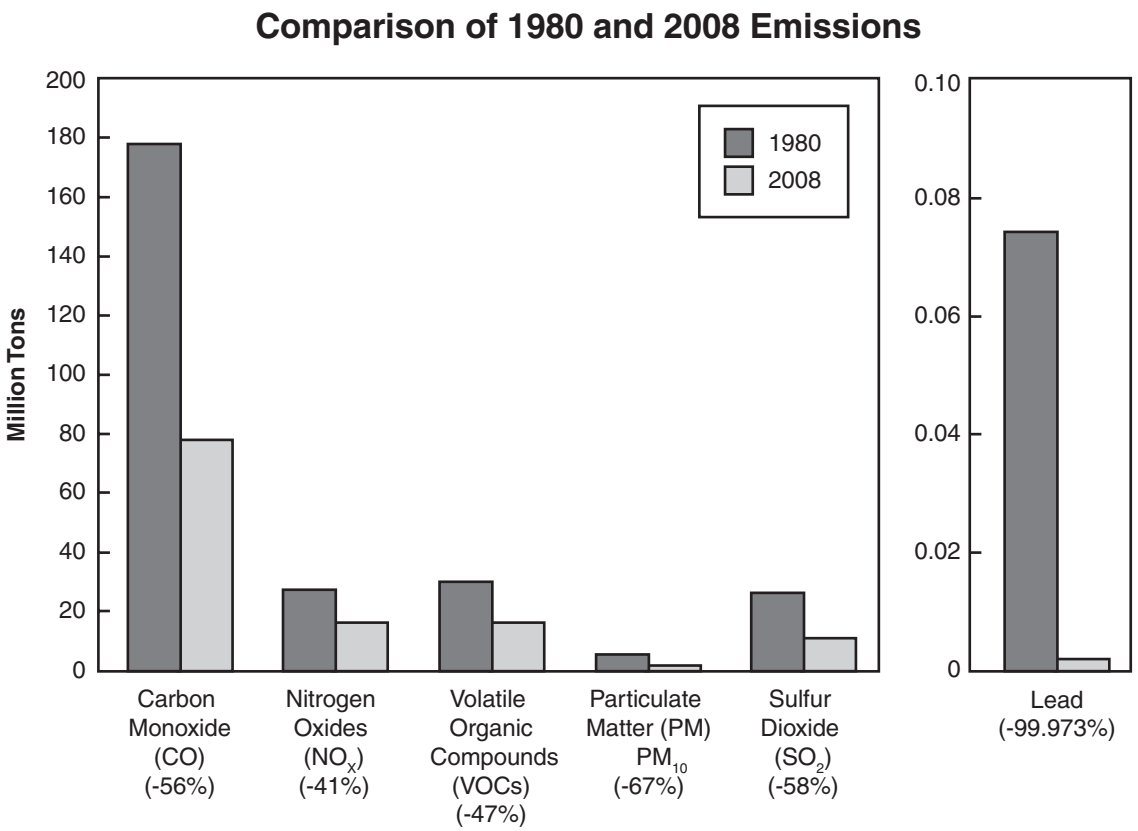


Figure 9-1.
Vehicle usage and GDP have risen nearly 200%, while energy consumption and population have remained relatively stable at 50%, since 1970. What does this tell us about our technology, lifestyle, and social values? (Environmental Protection Agency)

perspective involves the realization that it is both necessary and possible to minimize the destructive environmental side effects of technological progress through careful assessment and planning.

The key phrase in our description of modern environmentalism is an *information-based perspective*. Environmentalists who suffer from chronic narrow-mindedness today seem to be in the minority. Environmental rhetoric has, for the most part, been replaced with scientific- and technical-data accumulation, resulting in reflective and systematic decision making. In other words, a brainstorming session between upper management and the production workers in a manufacturing firm regarding the firm's safe and effective storage and disposal of toxic solvents is more indicative of contemporary environmentalism than the bumper sticker reading "You Choose: Cancer or Clean Air!"

Industrialists and environmentalists alike have mellowed with age. Neither faction in this struggle has a monopoly on virtue. Both groups create opportunities to enhance our standard of living. They also create problems challenging our ingenuity and willingness to confront changes. Together, these individuals have begun to consider options to stimulate technological development and simultaneously strive to preserve the natural environment.

Public Support of the Movement

In many countries, the viability of public programs, political platforms, and social movements is very dependent on a strong measure of public support. One of the more remarkable aspects of the environmental movement in the United States has been the durability of public support for its programs, projects, and proposed regulatory legislation. Despite the fact that many sociologists and politicians predicted public interest in ecology would fade as soon as some other cause surfaced on the scene, the public's support for environmental programs continues to grow. Widespread dissatisfaction with the social costs of careless technology moved environmentalism from a concern of a few individuals to an accepted truth among the populace.

Regardless of support, most people do not identify pollution, tropical-forest resource management, and other environmental issues as the most serious tasks at hand for our nation's administration. World peace and economic concerns are more commonly found to overshadow environmental protection as national priorities. This tendency does not necessarily detract from the strength of the environmental movement or the extent to which people demonstrate personal interest in this movement's programs. The tendency merely connotes that the environmentalist movement has gone through a process of maturation and achieved a credible position on our country's political agenda. As compared to many other countries, environmentalism in the United States operates within the existing political structure, rather than being a separate political unit.

We can compare environmentalism in the United States with Germany, for example. In Germany, there is a separate political party, *Die Grünen* ("the Greens"), that has increased its membership significantly since its foundation in the late 1970s. As a political entity, it is so powerful that it was a part of the coalition government of Germany under Chancellor Gerhard Schröder in recent years. In Germany, as in most other European countries, the environmentalism movement is a political movement exerting considerable influence over the policies of the government. The Greens convinced the German government to shut down all power plants by 2020, increase investments in renewable energy, and increase the taxes on fossil fuels. In the United States, in contrast, the environmentalism movement tends to work within existing political boundaries.

Another measure of public support for the environmentalism movement can be gleaned from the membership rosters of several influential environmental organizations. Whereas the number of members who contributed to the organizations remained somewhat stable throughout the environmental decade of the 1970s, the Sierra Club and the Wilderness Society have dramatically increased their memberships since then. The Wilderness Society now has over 300,000 members, and the Sierra Club now has more than 1.3 million members (up from 114,000 in 1970). Active participation in smaller organizations, such as Friends of the Earth and Defenders of Wildlife, has also increased significantly in recent years. Furthermore, these organizations have begun to receive strong verbal backing from many American citizens who are not even actual members. See **Figure 9-2.**

The National Environmental Policy Act (1969) established a set of guidelines federal agencies must follow before they undertake any significant action. Subsequently, a network of federal laws, supported by amazing volumes of regulatory materials, has been created to protect the air, lakes and rivers, land, and seas—at least on paper. Almost every new construction project built in the United States must include an ***environmental-impact analysis***. The analysis includes an in-depth study of the potential impact of the construction



Figure 9-2.
People stop the logging truck from removing the killed old-growth trees from the Siskiyou National Forest. Other people chain themselves to the truck's axle and on top of the load. (Francis Eatherington)

on the environment. These voluminous and complex reports are difficult for the layperson to comprehend.

Surveys taken during the early 2000s show a rekindled interest in environmental issues among the general public. A major problem confronting the leaders of this movement is how to capture the energy of the American public in a new commitment toward improving environmental quality. Many people might feel their votes for an environmental initiative (such as clean water and hazardous-waste sites) on the ballot are the largest, and often final, measures of support needed to get things going in the right direction.

Recognize that it is not enough to be sensitive to environmental issues, as some public-opinion surveys seem to surmise. Support for the environmental-protection movement must be personified through actual changes in behavior. This change is often difficult for many of us. The decisions people make when commuting to work illustrate the separation between a sensitivity to environmental issues and a change in behavior. On a global level, most Americans realize that they produce greenhouse gases each year through driving their cars to work. Although cars have been getting cleaner over the past two decades, people are driving more. Since 1990, the vehicle miles Americans drove each year increased by over 50%. Also, most Americans see the benefits in carpooling, in order to reduce air pollution. Anyone who drives on an American highway, however, can attest that few people choose to carpool each day. Many of the global issues discussed in the following section might be familiar to you. If the present environmentalism movement expects to make any sort of dent in devising solutions for these problems, active public support and action must be reignited at the grassroots level throughout the world.

Key Issues on a Global Scale

The United States is confronted with numerous international environmental issues essentially falling into three general categories:

- ❏ Handling domestically important issues requiring the cooperation of other nations.
- ❏ Dealing with areas of our world falling under some sort of international jurisdiction.
- ❏ Assisting developing countries in contending with their own seemingly localized environmental problems.

The extent to which progress is expected to occur in any of these areas is still questionable. We remain, however, cautiously optimistic.

International Cooperation

There are increasing technological by-products posing a threat to the stability and quality of the U.S. environment that can be dealt with only on an international level. Potential menaces to the global climate, such as ozone depletion and carbon dioxide (CO_2) buildup, are the clearest examples. Strategies the United States enacts alone will be insufficient to deal with these problems. The magnitude of these dismal trends requires a concerted, cooperative action from a number of national governments.

The track record of accomplishments over the past couple of decades justifies optimism, albeit qualified, regarding the abilities of nations to cooperate on international environmental issues. Joint efforts have occurred in marine navigation, air quality, public health, and agricultural practices. Specifically, a large number of international treaties of major environmental significance have been initiated. Many of these have only recently begun to seriously take effect:

Bonn Convention on Conservation of Migratory Species of Wild Animals (1979); Convention on Wetlands of International Importance (1971); International Treaty on Long-Range Transboundary Air Pollution (1983); Vienna Convention for the Protection of the Ozone Layer (1985); Montreal Protocol on Substances that Deplete the Ozone Layer (1987); and Kyoto Protocol to the UN Framework Convention on Climate Change (1997).

Besides these recent agreements, older international treaties have been given renewed significance, due to the growth of concern for the environment. The Boundary Waters Treaty that was signed in 1909 between the United States and Canada has been applied to a growing number of present-day environmental issues. Although much still remains to be achieved in order to improve the quality of water in the Great Lakes, some observable progress has been made. On another border, water-quality agreements between Mexico and the United States have updated a 1945 treaty via the more recent construction of a large desalinization plant on the lower Colorado River.

The most notable progress in international cooperation appears to have been made through multinational scientific investigations. Scientific programs organized through specialized agencies in the UN have been implemented cooperatively with various international scientific and technical associations. The International Council of Scientific Unions (ICSU) has been most effective in launching these ventures.

If one reviews the direction of international cooperation, rather than the actual results of the above described projects, there is more reason for optimism. Some governments have been willing to sign treaties or adhere to international programs only in which very little follow-up action was expected or required. Other countries have refused to sign international agreements related to the environment. In 2001, for example, the United States was the only industrialized country refusing to sign the Kyoto Protocol on Climate Change to reduce the emissions of CO_2 and other greenhouse gases. Furthermore, in those environmental agreements in which decisive activities were accepted among the signatories, implementation has not always followed. In many instances, the inertia of human behavior has been detrimental to full-scale progress in solving global environmental problems.

It is atypical for people, as well as political entities, to plan for living more than a few years into the future. On the other hand, we must begin to act with a view toward future consequences, in order to solve today's environmental problems. Some researchers project it is already too late to bring serious and often dangerous situations under our direct control.

International business in agriculture and forestry is altering the ecosystem of Earth quite rapidly. Unfortunately, affected nations have been unable to control these changes in ways that will allow the advantages of technology to be retained without destroying the riches of the natural environment. Effective environmental policy (as well as international cooperation) requires a type of foresight and benevolence for future generations that is rare in society.

International Jurisdiction of Common Spaces

Several regions of the world are regarded as ***common spaces*** and are, either in whole or in part, considered international territory. These areas are becoming increasingly significant as more is learned about their potentials as sources of strategic raw materials. Areas presently beyond national jurisdiction include the open ocean outside the territorial sea limits of a country, the extraterrestrial

space surrounding Earth, and the continent of Antarctica. Despite the existence of international common spaces, there is disagreement among countries as to the extent of these spaces. The sea that coastal countries claim directly affects the size of the common space in the ocean.

COMMON SPACE
A region of the world entirely or partially considered to be international territory. These areas are beyond national jurisdiction.

Balancing environmental concerns with the economic advantages of technological development and exploitation continues to be a major issue for these areas. Until recently, these areas were customarily regarded as belonging to no one, and the common availability of their usage was not debated. Advancements in technology have subsequently created a scenario in which the natural resources indigenous to these areas can be more readily pursued. Even still, no general agreement for the governance of these regions has been reached. Perhaps this is due either to the fact that the environmental problems and opportunities these areas present are very unfamiliar or to the fact that the abilities of nations to explore, occupy, or exploit these regions differ a great deal. Only a few technically advanced countries presently have both the economic and technological capacities to conduct research activities on the ocean floor, in Antarctica, or in outer space.

The Law of the Sea Treaty was sponsored by the UN and negotiated over a 14-year period, commencing in the late 1950s. This agreement provides for an international authority to license and regulate deep-sea mining and to allocate a share of any of the potential profits among less advantaged countries. Several governments, including the U.S. government, have expressed dissatisfaction with this arrangement. Although there is no general governance in place for the high seas, treaties to prevent ocean dumping and other forms of marine pollution have been ratified. Proposals regarding the protection of whales and other marine-life species have also been negotiated.

The fact that not all nations possessing maritime capabilities are party to these treaties creates the potential for oceanic resource depletion and degradation. Even though some measure of progress has been made toward international responsibility for the oceanic environment, the future viability of this environment remains vulnerable to pollution and exploitation. Nations placing their immediate economic interests ahead of a marine environment characterized by richness and diversity pose the greatest danger in the upcoming years.

Similarly, outer space has no general governing body. It is unlikely one will be established in the near future. The penetration of outer space by artificial satellites and manned vehicles after the close of the 1950s opened a new domain for possible national jurisdiction.

A body of proposed space law rapidly appeared on the scene. Treaties concerning telecommunications, remote sensing, and military uses governed specific aspects of outer space. The UN sponsored a general treaty in the late 1960s favoring the peaceful use of outer space. Conversely, present military proposals among leading industrial nations make future agreements regarding the integrity of the outer space environment seem improbable.

Antarctica presents a case in which the time to choose between international cooperation and conflict has most definitely arrived. The continent has been treated as a scientific reserve since the Antarctic Treaty of 1959. Antarctica has been maintained in

its natural state without permanent occupancy, resource development, or pollution. A consultative committee of nations has administered the terms of this treaty. At the time of the initial signing of the Antarctic Treaty, technological capabilities were insufficient to justify economic interest in this unique environment. In 1991, the involved nations adopted an additional protocol, The Protocol on Environmental Protection to the Antarctic Treaty. This protocol designates Antarctica as a "natural reserve devoted to peace and science."[1] Mineral activities were prohibited for at least 50 years, except for scientific research. Today, 46 nations have agreed to the Antarctic Treaty and its protocols. This represents about two-thirds of the world's human population.

Unlike the governments of other nations, the U.S. government recognizes no national claims to Antarctic territory and makes no claims of its own. Not surprisingly, it also possesses the greatest fund of knowledge, experience, and technological prowess essential for Antarctic resource development. Therefore, it seems the United States is in the proverbial driver's seat, with reference to Antarctica's future status in the international community. The directions for development here will be toward either a reserve for scientific co-operation or an arena for international conflict.

Climate Change and the Global-Warming Debate

Some of the more potentially serious air-pollution problems are not even occurring near Earth's surface. The upper atmosphere has been selected as a laboratory, where a dramatic technological experiment is taking place. For over a century, scientists have been debating about what will occur as a result of loading a large amount of CO_2 and several other gaseous elements into Earth's upper atmosphere. Some degree of agreement among them has evolved over the years, and trends toward ***global warming*** seem likely and possibly irreversible.

CO_2 in the atmosphere has unquestionably increased over the past several decades. This increase is the direct result of human activities largely related to industrialization and the advancement of technology. Specific examples of the types of activities that have contributed to the CO_2 buildup include the combustion of a greater number of fossil fuels and tropical deforestation (discussed further later in this chapter). If the production and use of fossil fuels continues to increase at the same rate, projections indicate that CO_2 concentrations in the atmosphere will double preindustrial levels by the middle of the twenty-first century and will lead ultimately to severe changes in global climate. Overall, greenhouse-gas emissions related to human activities have grown since preindustrial time. Specifically, greenhouse gases have increased by 70% from the mid-1970s to the middle of the first decade of the twenty-first century.

While it is not totally clear how an increase in the mean global temperature will affect weather patterns, some scientific analyses have been made. In 2007, the UN's Intergovernmental Panel on Climate Change (IPCC) published a series of wide-ranging reports on global warming and climate change. According to the IPCC, global warming appears to be accelerating, resulting in higher increases in global temperature and higher rises in the sea level. Between 1995 and 2006, 11 of the 12 years were the hottest years since 1850. Of more concern are systematic changes to the continents. North America, South America, and northern Europe are getting wetter, and southern Europe and southern Africa are getting drier. There are other changes related to global warming. Sea levels have risen approximately 6"–9" in the last century, precipitation has increased by 1%, and glaciers and the Arctic

[1]Secretariat of the Antarctic Treaty. http://www.ats.aq.

sea ice are beginning to melt. If warming continues, as it most likely will, these changes will be amplified in the next 100 years.

Various studies have surmised that the buildup of CO_2 could eventually melt the ice cap at the North Pole or South Pole, leading to a rise in sea level that would submerge many coastal cities. Between the mid-1950s and the middle of the first decade of the twenty-first century, the observed loss of sea ice in the Arctic was three times faster than scientific models predicted. Small changes in the mean global temperature could cause large shifts in weather patterns, creating a higher frequency of droughts, hurricanes, freezes, and floods. A decrease in annual rainfall within the world's prime agricultural belts, coupled with other losses of water from rivers and foliage, could virtually ruin the productivity of some of the most fertile acres of land on Earth.

If warming brings about climate changes, they will most likely start occurring during the lifetimes of roughly half of the people alive today. Although it is easy to envision the dates 2035 or even 2050 as excellent movie titles, they do have a certain unrealistic quality to them. Even something closer at hand—perhaps increasing numbers of hurricanes for the next 20 to 30 years—commands less attention than the dollar's robustness in the international money market. What should the government's policy response to CO_2 be, and what sort of research in this environmental area needs the greatest financial backing?

What is the greenhouse effect? Energy from the sun heats Earth's surface. See **Figure 9-3.** The surface then radiates the heat back into space. Some of this heat, however, is trapped in our atmosphere and warms the planet. This is called the ***greenhouse effect*** because it acts somewhat similar to the glass panels in a conventional greenhouse. Although many people do not know this, the greenhouse effect is critical for life on Earth. Without the natural greenhouse effect, temperatures would be much lower.

The problem is not the natural greenhouse effect, but it is the increasing temperatures because of the use of fossil fuels. Since the Industrial Revolution, there has been an increasing dependence on fossil fuels to create power. In the United States alone, the burning of fossil fuels is responsible for about 94% of U.S. CO_2 emissions. The United States is the biggest contributor, by far, to greenhouse gases in the world. About one-fourth of all greenhouse emissions are from the United States. Individually, the average American household adds over 4000 pounds of greenhouse gases each year to the environment.

An issue such as the greenhouse effect of global warming requires Congress to look decades ahead. This legislative branch of our government is typically not interested in solving long-term problems. Many lawmakers seem to be unable to think ahead more than a couple of years, and because the United States is the number one greenhouse-gases polluter in the world, it makes the situation even more difficult from a political point of view. One of the reasons the United States decided not to sign the Kyoto Protocol (to reduce fossil fuel emissions) was that the U.S. economy would be hurt. Another reason was that the Kyoto Protocol applies only to developed countries. Whether one believes global warming is important or not, the problem is that the climatic changes will occur long after an individual legislator or president leaves office. Politically, this makes any serious reduction in fossil fuel emissions a difficult prescription to take in the United States.

At the very least, it is imperative to embark on an energy-conservation program that also encourages the development of other energy sources less likely to increase

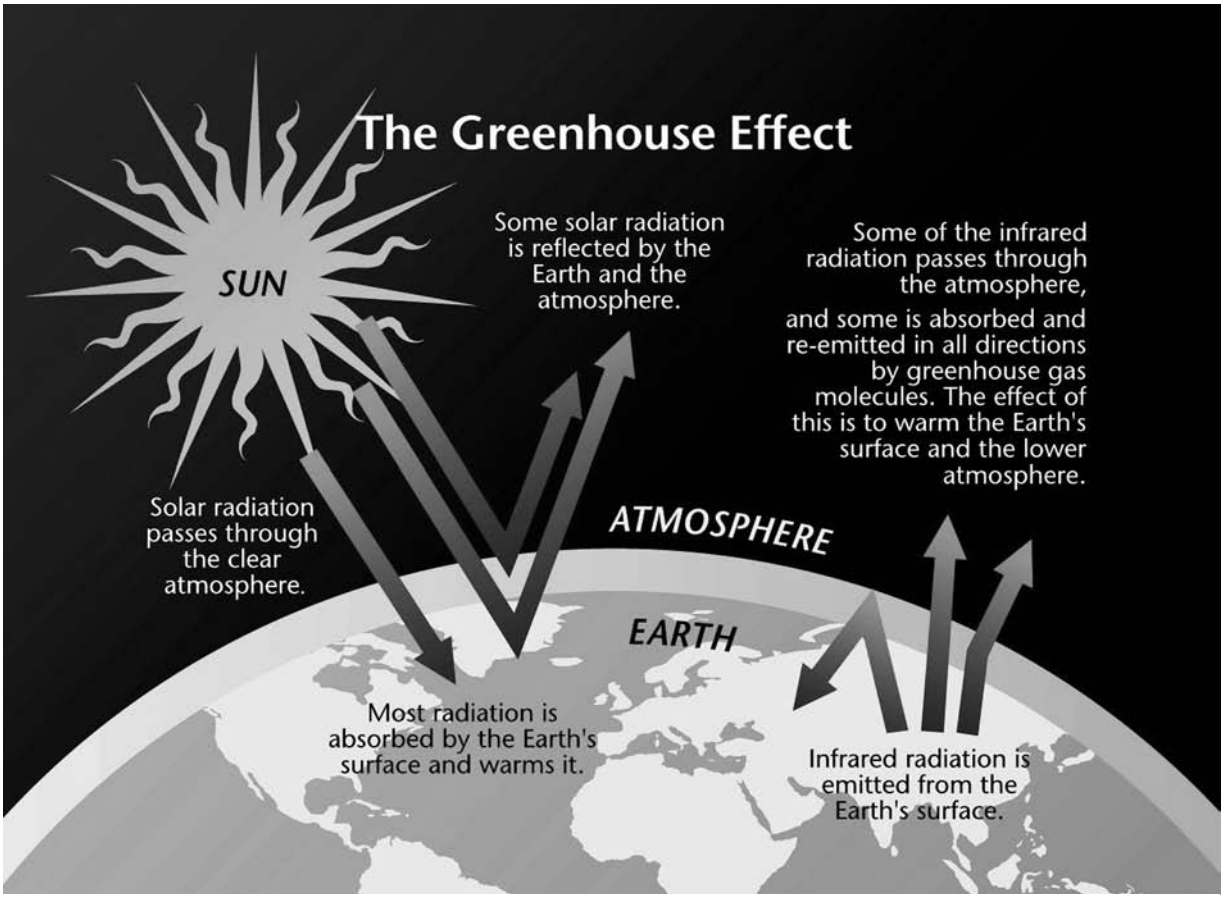


Figure 9-3.
The U.S. Global Change Research Program (USGCRP), which has initiated a national assessment on the potential consequences of climate variability and change for the nation, developed this visual depiction of the greenhouse effect. (USGCRP)

atmospheric CO_2 levels. There should be more research into the climate dependencies of various staple crops, and farmers should be encouraged to use water more efficiently. Irrigation projects and large-scale water supply networks should take into account the possibility of future shifts in rainfall patterns. International reforestation programs are essential, and countries such as Brazil and Malaysia should be admonished to discontinue the destruction of their rain forests.

On paper, at least, there is widespread support for reducing greenhouse-gas emissions. The EU has already committed to achieving emissions cuts of 20% below 1990 levels by 2020, and 192 countries signed the UN Framework Convention on Climate Change. The United States and China, two of the biggest emitters, however, have yet to commit to any specific goals. Also, developing countries are hesitant to agree to cuts that will stop economic development in their countries. The costs of reducing global warming worldwide are staggering. The UN estimates that this reduction will cost in the range of $15 to $20 trillion over the next 20 to 25 years. It is unclear if all the world's governments can be persuaded that this investment is worthwhile for their economies.

Localized Environmental Problems

At first glance, environmental problems tend to fall into two categories—local and global. The line between these two categories, however, is often blurred. In the case of pesticides, a local problem with pesticides can be a polluted field or stream. Since an international corporation sells the pesticide, however, the problem can then be considered global.

Many environmental issues have both local and global aspects. Here, we focus on two current environmental problems—pesticides and water scarcity. These are local problems for selected countries, but they also are global problems affecting multiple states and countries.

Pesticides

Pesticides have become a critical part of the food cycle, not only in the United States, but globally as well. Since the 1960s, the major increases in the efficiency of crop production can be linked to the use of pesticides in farming. A pesticide is any substance used for the prevention or destruction of any pest, including insects; animals; weeds; or microorganisms, such as viruses and bacteria. Most chemical pesticides create some risk to humans or the environment because their purpose is elimination of pests. The problem has always been to try to choose the pesticide causing the most good with the least harm.

The EPA is responsible for the regulation of pesticides in the United States. Not all countries around the world, however, have the same level of pesticide protection. DDT is a good example of a pesticide that has caused problems throughout the world. This pesticide, discovered in the late 1930s, was used widely in the United States and globally from after World War II to the 1970s because it was particularly effective in killing the mosquitoes spreading malaria. After it was used for many decades, however, problems emerged with DDT. DDT is very toxic to fish, and it builds up in the fatty tissue of animals over time. These problems brought DDT into the food chain and exposed many people to unacceptable levels of DDT. Also, DDT lasts a long time after being spread on a field (from 2 to 15 years). The use of DDT was banned in the United States in the early 1970s because of these problems.

The key word is *use*. A U.S. company can no longer use DDT. Such a company can manufacture DDT, however, and that is what happened. Despite DDT's ban in the United States, American chemical companies still manufactured DDT and other banned pesticides for export into other countries. Today, DDT is manufactured in only two countries, India and China. See **Figure 9-4.** In addition to educating the developing world about hazardous pesticides, there is the problem of the storage of these pesticides. According to the Food and Agriculture Organization of the UN, developing countries have gained possession of more than 100,000 tons of obsolete pesticides, including DDT.

This problem is close to being solved on a global scale. In 2001, the Stockholm Convention on Persistent Organic Pollutants took effect. The treaty outlaws 9 of the "dirty dozen" chemicals and restricts the use of DDT to malaria control. This ban, however, covers only the 12 pesticides. New pesticides are being developed at a fast rate each year. How long will it take for us to know the impact of these new pesticides on the environment, and then, how long will it take for us to ban the undesirable ones?

Water availability

In the United States, we take water for granted. We get up in the morning, walk

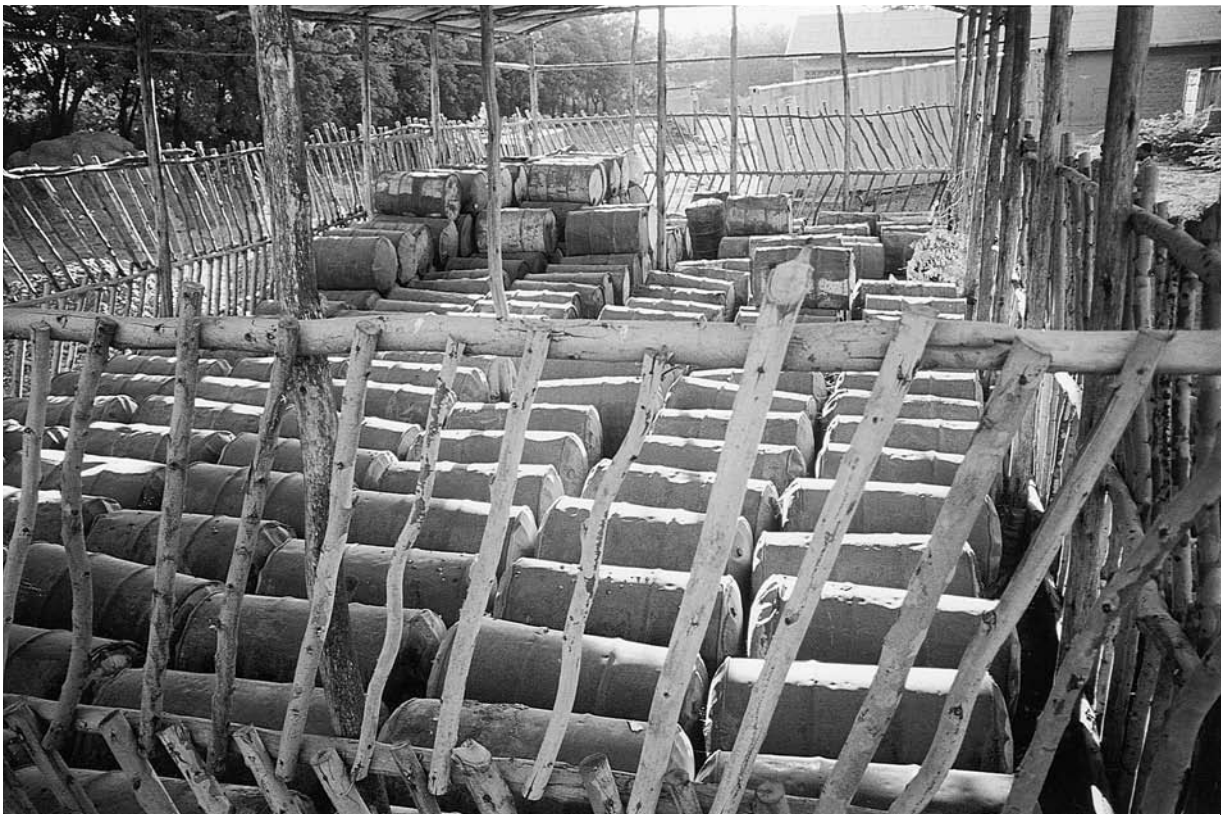


Figure 9-4.
Middle Awash State Farm is massively oversupplied with pesticides now leaking into an environmentally sensitive flood plain. An international expert task force visited Ethiopia in the late 1990s to assess what needed to be done to rid the country of huge quantities of widely dispersed obsolete pesticides that have accumulated. (Pesticide Action Network, UK)

to our kitchens, and make our morning coffee by turning on the water faucet. We do not think about where the water comes from and how clean it is—at least, not very often. Water, however, is not as limitless as we suspect. True, Earth is 71% water. Only 3% of that water, however, is freshwater. In addition, most of the freshwater is inaccessible to humans. This freshwater is present as ice and snow at the two poles. Only about 1/10,000 of Earth's water is readily available for human needs.

Water, similar to other natural resources, is not evenly distributed around the world, and much of the problems about water relate to its distribution, rather than to its global availability. The world's population is rising by about 74 million people a year. This population growth also is not evenly distributed. Much of the growth will occur in three regions: Africa, Asia, and South America. At the same time, these regions have severe water shortages (or increasing water pollution). Even if a country has sufficient rainfall, often the people are not located where the rain does fall. In Central America, half of the population lives on the Pacific seaboard. Unfortunately, the water for these people comes via heavily polluted rivers from the interiors of their countries.

Also, global warming is decreasing the amount of rainfall in several continents, including parts of Africa and Europe. Currently, water scarcity affects 4 out of 10 people in the world.

Even when water exists in developing countries, it is more likely to be polluted. In most developing countries, wastewater goes from the home directly into rivers and streams without any treatment. The UN estimates that, worldwide, 1.1 billion people do not have access to safe drinking water. In just one developing country, Bangladesh, between one-fourth and one-half of the population drinks water that has unacceptable levels of arsenic. In China, one of the unintended consequences of rapid industrial growth has been pollution of the country's water, air, and soil. Air and water pollution cause over 400,000 deaths in China each year. Even when water is available, disputes about water are common. Currently, there are several water sources being disputed by one or more countries, including the Euphrates River (Turkey, Syria, and Iraq), the Sea of Galilee (Israel and Syria), the Nile River (Egypt, Sudan, Ethiopia, and others), and the Senegal River (Senegal and Mauritania). There is some good news in this area. Over the past two decades, the UN has led an effort to improve drinking water worldwide. The percentage of people worldwide who have access to an improved water supply grew from the early 1990s to the middle of the first decade of the twenty-first century by 5%. This equals over 1.2 million people.

In the United States, despite the Clean Water Act of 1977, the cleanliness of your water depends on where you live. Americans living in rural areas generally have poorer water quality than those living in cities do. Also, certain states are more vigilant than others about addressing the issues of toxic water. There is a "dead zone" at the mouth of the Mississippi River about 4500 square miles in size (about the size of the state of Connecticut) because of the large amounts of fertilizer and animal-waste runoff from farms.

As population increases throughout the world and more stress is put on existing water supplies, water will increasingly become an issue. Unlike other resources, such as oil and coal, there is no substitute for water. We all need water to live, and in the future, countries will have to do a better job managing their water supplies so there will be enough good water to drink.

Air-Quality Standards

The central goal of the monumental Clean Air Act and its subsequent amendments has been to manage air quality to protect human health. This act was the first of the major environmental regulations adopted in the United States. This legislative decision required the U.S. EPA to establish strict limits on several major pollutants existent in industrial centers, including sulfur oxides, nitrogen oxides, and particulate matter. These limits were set at the federal level during the early 1970s. As a result, this environmental law has been the most costly one ever enacted, requiring businesses to bring their production facilities into compliance. During the first 20 years after the establishment of the Clean Air Act, the EPA found that the actual costs were over $500 billion.

In terms of the pollution problems that the types of pollutants regulated in this federal act caused, air quality in the United States continues to improve. Throughout the 1970s, the number of days when air quality in densely populated areas reached harmful levels declined by at least one-third. Since many areas of the country still continue to experience periods when air-pollution levels

create human health risks, the struggle is far from over. These tough areas of urban pollution (such as Los Angeles and Houston) might ultimately prove to be too expensive and difficult to clean up. Optimists, however, hope this is not the case.

The World Health Organization (WHO) has ranked air pollution as 1 of the top 10 causes of disability. In the early 2000s, WHO estimated that, each year, 2.3 million deaths were related to different types of air pollution, from both indoor and outdoor sources. Present control efforts do not effectively address these hazardous pollutants and other unconventional air pollutants. Furthermore, existing sulfur-oxide controls appear to be grossly inadequate to protect lakes and forests against the problems acid rain causes. The relentless buildup of CO_2 in the atmosphere might spell disaster for global climatic stability. Finally, even though most Americans spend a majority of their time indoors, there are minimal (if any) efforts being made to control air-pollution levels in these areas.

Procedures used to monitor air quality are not as reliable as some of the people reporting cleaner air trends would have us believe. We do not have a national system for monitoring air quality. Instead, different states and localities across the country operate area monitors. The locations of these monitoring stations change periodically, records are often incomplete, and quality control practices are not always satisfactory.

On the surface, data might suggest air quality has improved significantly over a specified period of time. Recognize, however, that year-to-year improvements might occur for a variety of reasons not directly indicative of the success of pollution-control efforts. For example, a major source of pollution might have closed down and moved to another site, where pollution levels are increasing; temporary economic slumps might have caused an equally short-lived reduction in industrial emissions; or more favorable climatic conditions might have developed, with steady breezes dispersing the pollutants elsewhere. Since monitoring data is not usually adjusted in consideration of these variables, caution should be exercised in the overly optimistic interpretation of air-quality changes on a yearly basis. Generally speaking, it takes more than a year or two to substantiate a trend in any field of study.

Ambient Air Quality

National efforts to control air pollution have commonly been focused on improving ambient air quality in high-tech and urban centers. The six conventional pollutants toward which most of the attention has been directed are total suspended particulates (TSPs), sulfur oxides, nitrogen oxides, carbon monoxide, lead, and ozone. Numerous industrial emitters of these pollutants have subsequently switched to cleaner fuels and have adopted control technologies, such as electrostatic precipitators. The EPA estimates that emissions of the conventional pollutants from most of the major sources have declined or held steady since concerted cleanup efforts began in the early 1970s. See **Figure 9-5.**

In the mid-1970s, the EPA developed the ***Pollutant Standards Index (PSI)*** in cooperation with the Council on Environmental Quality, in an attempt to standardize air-pollution reporting. This index enabled comparisons to be made among different regions of the country. The PSI converted the concentrations of several commonly occurring pollutants to a number between 0 and 500. In 2000, the EPA updated the PSI and renamed it the ***Air Quality Index (AQI)***. The AQI includes data on two additional pollutants (ozone and fine particulate matter) and a new health-risk category, "unhealthy for sensitive groups." See **Figure 9-6.**

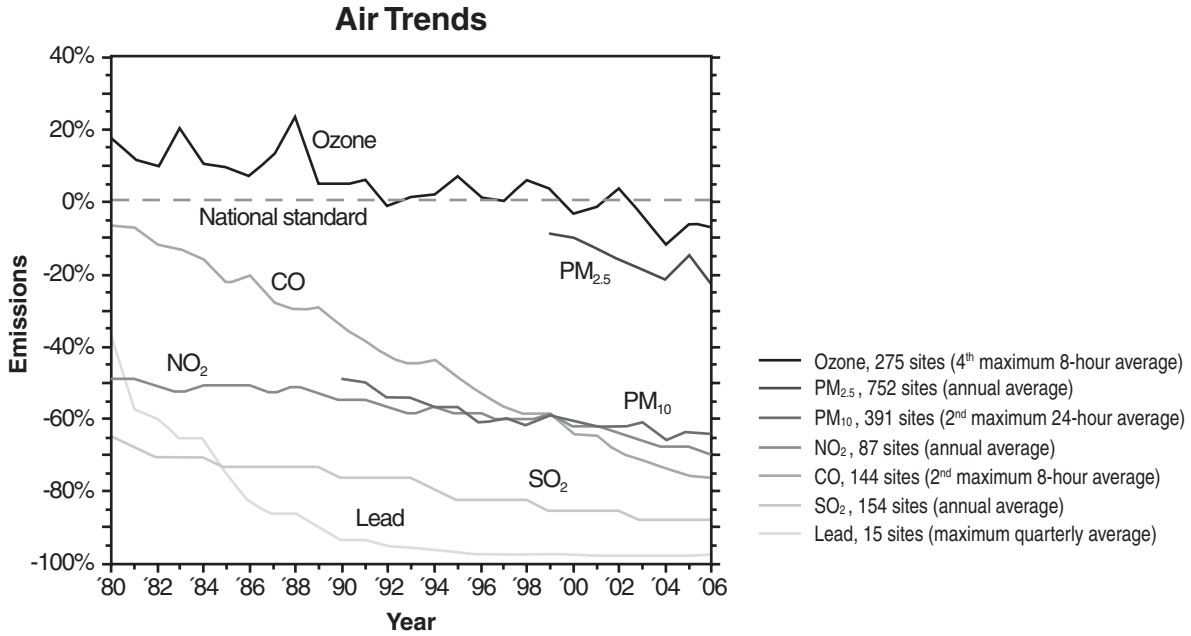


Figure 9-5.
The EPA estimates that the major pollutants have decreased since 1970.

AQI							
Category	**Good**	**Moderate**	**Unhealthy for Sensitive Groups**	**Unhealthy**	**Very Unhealthy**	**Hazardous**	
Index Value	0–50	51–100	101–150	151–200	201–300	301–400	401–500
Pollutant	**Concentration Ranges**						
CO	0.0–4.5	4.5–9	9–12	12–15	15–30	30–40	40–50
NO_2	—	—	—	—	—	1.2–1.6	1.6–2.0
O_3 1–Hour	—	—	—	—	.20–.40	.40–.50	.50–.60
O_3 8–Hour	.00–.06	.06–.08	.08–.10	.10–.12	.12–.37	—	—
PM 2.5	0–15	15–40	40–65	65–150	150–250	250–350	350–500
PM 10	0–50	50–150	150–250	250–350	350–420	420–500	500–600
SO_2	0.0–.03	.03–.14	.14–.22	.22–.3	.3–.6	.6–.8	.8–1.0

Figure 9-6.
This AQI table converts the concentrations of common pollutants to a number from 0 to 500.

The index value of 100 represents the concentration for each pollutant below which adverse health effects have not been observed. This value was selected to correspond to the short-term (24 hours or less) National Ambient Air Quality Standards the EPA set. The highest AQI value of 500 corresponds to the concentration of each pollutant that should never be reached. State and local agencies are required to take emergency action to prevent air pollution from ever reaching this level by enforcing such measures as temporary restriction of automobile traffic or manufacturing processes. On the average, ambient air quality in U.S. metropolitan areas, as measured by the AQI, has been improving consistently since the early 1970s. The table presented in **Figure 9-7** reveals the extent to which air quality has, for the most part, improved and, in a few cases, worsened in selected cities across the United States since the late 1990s.

The Acid Rain Dilemma

Acid precipitation results from the presence of sulfur oxides and nitrogen oxides in the atmosphere, which then react with moisture to form dilute sulfuric and nitric acids. These resultant aerosols are eventually carried back to Earth as rain, snow, fog, or dry particles. In some areas, the acid is buffered by Earth's natural alkalinity and apparently causes little damage. In other locations, however, the acid reacts with soil, leaches away important nutrients, or drains off the land and accumulates in lakes and ponds. The ecosystems of these bodies of water are then severely disrupted, and many of them die and become unable to support aquatic wildlife of any type.

In the past few decades, ***acid rain*** has received widespread recognition as a serious environmental problem in many parts of the world, including Canada, Scandinavia,

Number of Days with AQI Values Greater than 100 at Selected Cities in the United States

Metropolitan Statistical Area	1999–2006 includes $PM_{2.5}$	1999	2000	2001	2002	2003	2004	2005	2006
Atlanta, GA		73	39	24	20	12	12	11	18
Bakersfield, CA		130	132	123	150	141	131	85	97
Boston, MA-NH		4	0	3	9	8	1	4	1
Chicago, IL		19	13	33	20	10	9	23	5
Dallas, TX		16	20	14	7	5	9	10	13
Denver, CO		3	2	8	7	17	0	1	6
Detroit, MI		23	15	31	26	19	5	24	6
Houston, TX		51	42	28	21	31	22	28	18
Los Angeles-Long Beach, CA		54	63	81	81	88	65	43	34
New York, NY		22	19	19	27	11	6	15	11
Pittsburgh, PA		40	32	50	50	37	39	48	36
Riverside-San Bernardino, CA		121	144	153	146	138	116	103	97
Sacramento, CA		65	41	47	57	36	26	39	43
Washington DC-MD-VA-WV		41	20	27	33	12	10	18	18

Figure 9-7.
This table shows national air-quality trends. The EPA defines AQI values of more than 100 as unhealthy.

Japan, and the northeastern United States. Scientists have been systematically monitoring the evidence of acid rain's environmental effects since the mid-1970s. They often indicate that acid rain is only a minor contributor to the environmental damage for which it has been blamed.

ACID RAIN
A serious environmental problem resulting from the presence of sulfur oxides and nitrogen oxides in the atmosphere.

The U.S. federal government established a National Acid Precipitation Assessment Program (NAPAP) in 1980. This program was commissioned to conduct a 10-year research, monitoring, and assessment effort to determine the degree to which acid rain might be responsible for certain environmental problems. Earlier research attempts usually assumed acid rain was the cause of the damage at hand and proceeded to ascertain how the actual process of degradation worked. NAPAP scientists designed their research around three main questions regarding the acidification of U.S. lakes:

- Has there been a significant increase in lake acidity?
- Might something other than acid rain be contributing to lake acidification?
- Might something other than acidity be affecting the survivability of the fish?

Retrieving straightforward, reliable answers to these questions has not been easy. There still does not appear to be any scientific consensus on this issue. NAPAP was reauthorized as an open-ended program under the 1990 Clean Air Act. The 1990 Clean Air Act also established the EPA's Acid Rain Program (ARP) to reduce emissions of sulfur oxides and nitrogen oxides. Phase I of the ARP began in the mid-1990s and targeted the largest coal-fired power plants. Phase II began in 2000. This phase set restrictions on small coal-, gas-, and oil-fired plants, as well as on large coal-fired plants.

Most of the NAPAP analyses dispute the viewpoint that acid rain substantially degrades exposed structures and building materials. They suggest natural weather conditions such as freeze-thaw cycles, coupled with a variety of air pollutants, cause the observable damage. More importantly, NAPAP scientists have found that most urban pollution comes from local emissions, rather than from distant emissions borne by rainfall. It therefore seems likely we should focus on local automobiles and nearby industries, in order to reduce the impact of pollutants on urban-area structures.

The ARP has been successful in reducing sulfur dioxide emissions from 16 million tons in 1990 to 9.4 million tons in 2006. The ARP goal was to reduce nitrogen oxide emissions by 2 million tons each year. This goal was reached in 2000 and has been met for each year since then.

Despite the successes seen in North America, acid rain is increasing in other parts of the world. As the emissions levels go down in North America, they are increasing in Asia. China now leads the world in sulfur emissions, and experts predict that, with the large increase in industry in Asia, there will be a tripling in nitrogen oxide emissions. Worldwide, there is no doubt that, unless all governments work on this problem, there will be increasing levels of industrial emissions and, therefore, increasing acid rain.

Indoor Air Quality

Air pollution is no longer exclusively an outdoor problem. Concentrations of air pollutants such as carbon monoxide, radon, formaldehyde, asbestos, and passive tobacco smoke are often far greater inside buildings

than outside. Since many people spend a bulk of their time indoors, these pollutants pose significant health threats.

It might be time to establish a formal indoor air quality–monitoring program, similar to the ones devised for outdoor air, at the federal, state, and local levels. Several factors indicate indoor air quality might be worsening. Ironically, energy-conservation practices in homes and office buildings tend to reduce the escape of indoor air and allow pollutant concentrations to increase. The increasing popularity of burning alternative fuels, such as wood and kerosene, in the home is responsible for the release of numerous hazardous pollutants. Additionally, the use of synthetic chemicals such as formaldehyde and volatile organic resins in home construction and furnishings can have toxic effects on humans.

Wind speeds, architectural designs, and ventilation systems further complicate the relationship between concentrations of indoor and outdoor pollutants. Structures with forced ventilation to the outside or natural ventilation via open doors and windows have roughly similar pollutant concentrations inside and outside. Many new buildings are designed with reduced air infiltration. Reducing the number of air exchanges between inside and outside lowers heating and cooling costs, but it simultaneously increases the concentrations of the indoor pollutants listed above.

Historically, regulatory strategies concerning air quality in the United States have centered on the concentrations of ambient, or surrounding, pollutants. This approach has involved the measurement of outdoor pollution levels at particular locations. These indices are then assumed to be the primary determinants of exposure for the people residing in that area. This procedure is far from comprehensive. Further research into indoor air–quality programs is necessary if human health risks associated with air quality are to be accurately assessed.

Globally, indoor air pollution is a major health problem because over 50% of the world's population uses poorly ventilated stoves to meet their energy needs. Cooking and heating with open fires or stoves without chimneys produce indoor pollution, including soot and dust particles that are breathed. The WHO estimates that over 1.6 million people die each year from indoor air pollution. Women and children in developing countries are most affected because they spend more time near the cooking and heating sources.

Tropical-Forest Resource Depletion

Scientists and world leaders consider tropical deforestation to be one of Earth's most serious environmental problems. The longevity of their concern, combined with the current tropical-forest destruction rate, provides undeniable validity for this apprehension. The term *tropical forest* refers to forests in the humid, semiarid, and arid regions of the world. Forests ranging from moist (or closed) tropical forests to dry (or open) woodlands are generally included in the description.

The destruction of tropical forests in the world today is so extreme and so devastating that humanity might very shortly lose its richest, most diverse, and most valuable biotic resource. The damage being done might not be entirely visible to those of us who reside in the United States, since the tropics are faraway lands about which we know very little. For many people, the word *tropics* brings to mind a picture of pristine nature, mysterious ceremonies, large mammals, exquisite orchids, and palm trees. The scene is quite reminiscent of old movies and is difficult to authenticate anywhere in the continental United States.

Once thought to be limitless and expendable—a renewable resource, so to speak—the rain forests are presently disappearing at an alarming rate. Although the rate of deforestation has slowed over the past 10 years, estimates of rain forest deforestation range from 8 million to 30 million acres per year. Each year, 3 million acres of this loss are in the Brazilian Amazon alone. Moist tropical forestlands encircling Earth's equatorial sector cover approximately 6% of the Earth's surface area. Just since the end of World War II, more than half of this rain forest has been destroyed in the name of logging, farming, ranching, mining, and road building.

What has been lost already is literally irreplaceable. Contrary to the popular cliche, the jungle does not reclaim its own. Even where a healthy second growth manages to come back, the species it breeds are not the same as those previously in existence. The primal tropical rain forests reach back through evolution. Their brilliant flora and fauna reflect continental drifts and the ebb and flow of ice ages. Scientists project that approximately 50,000 species of plants and animals each year are becoming extinct because the forests are continually degraded. Furthermore, if the current pace of exploitation remains unchecked, the rain forests will have vanished forever within the next several decades.

The Importance of Tropical Forests

For the inhabitants of the world's tropical nations, the forests provide fuel, food, medicines, building materials, wood for lumber and paper, and many other basic needs. Forests help to maintain soil quality, limit the erosion process, stabilize hillsides, modulate seasonal flooding, and effectively protect nearby waterways from accelerated siltation. The tropical forests can also represent an important source of foreign exchange, export revenue, and employment for local residents.

The potential benefits acquired from tropical forests are not limited solely to the tropical nations. World trade in tropical wood is significant to the economic prosperity of both the producing and consuming nations. The United States is one of the largest importers of tropical wood and wood products. U.S. demand has been growing steadily over the past several decades.

Tropical forests also provide a broad array of nonwood products, including oils, spices, and rattan. These items are valuable for both subsistence and commerce. The annual world trade in rattan and the oils and spices extracted from tropical plants exceeds $4 billion. Some of the more familiar oils and spices found in many American homes include camphor, cassia, cardamom, citronella, and cinnamon. Thus, the export of industrial wood and nonwood forest products earns substantial foreign exchange for nations trading with the United States.

A cursory glance through the contents of the typical American household's medicine cabinet provides further verification of the importance of the tropical rain forests. The wide array of rain forest plants and animals provide at least one-fourth of the ingredients needed to produce the prescription drugs on the market today. The snakeroot plant of India's monsoon forests yields reserpine, which is an alkaloid providing the base for many tranquilizers. The corkwood tree of eastern Australia provides scopolamine, a drug used in the treatment of schizophrenia. In the Amazon basin, one finds the plant derivative curare, which is an essential agent for treating Parkinson's disease. There are research biologists who estimate that over 1000 plants found in the tropical forests might have potential anticancer properties.

The agricultural stability of the United States is also directly related to the existence of tropical rain forests. These regions provide habitats for many of the world's migratory birds and various endangered avian species. Approximately two-thirds of the birds breeding in the North American continent migrate to Latin America or the Caribbean for the winter season. Some of these birds play a significant role in controlling agricultural pests found to afflict U.S. farmlands. Depletion of their tropical habitats might ultimately spell their extinction.

The tropical forests are also critical to the economic viability of U.S. investments overseas and, as previously mentioned, to the political stability of developing nations. For example, flooding, siltation, and other environmental damage deforestation causes can erratically disrupt U.S. foreign-assistance programs (technical, as well as financial). Inappropriate deforestation practices also reduce food sources and jobs, both of which are necessary to maintain political stability in these countries. In sum, the tropical rain forests represent the planet's "biological warehouse," where the diversity of plant and animal life found within a single-acre plot is simply staggering. Destroying these rain forests means losing 80% of the world's vegetation and up to 4 million varieties of life-forms, many of whose benefits are still unknown.

The Causes and Consequences of Tropical-Forest Destruction

The main causes of forest destruction and degradation stem from the following situations: rapidly rising populations, requiring more land for food production; increasing levels of mining and logging operations; primitive methods of agriculture that produce low yields and ruin soil fertility; and the chronic failure of political institutions to execute programs with an eye for long-range prosperity. In parts of Latin America, where a very slim percentage of the population controls a vast majority of the arable land, encroachment on the forests is simply a response to social pressures. The availability of land in the rain forests is a tempting solution to this land-distribution problem for many countries. Overall, the nonindigenous population of the Brazilian Amazon has increased from 2 million to 20 million since the 1960s. This increased number of people puts pressure on the rain forest. Millions of Central American inhabitants do not have enough land to provide for their subsistence. Government officials subsequently view the land that forests currently cover as the answer to overcrowded conditions and extreme levels of poverty among their constituents.

Starting sometime in the mid-1970s, vast tracts of Central American forest were cleared for ranching. One stimulant for this activity, which destroyed some 8000 square miles annually through the 1980s, came from the U.S. demand for low-cost ground beef and pet food. It is doubtful that very many Americans consider the environmental consequences of tropical deforestation when they feed their dogs or purchase a deluxe hamburger at their neighborhood fast-food establishment. The most unsettling aspect related to this particular economic activity is found in the short life span of these graze lands. The "slash-and-burn" methods of cultivation used limit the graze lands' productivity cycle to a period of 3 to 5 years. See **Figure 9-8.** On the average, pastures become severely degraded and heavily weed infested within 5 to 10 years after they are initially developed. In other words, the short-term yields acquired do not justify the tremendous investments required to develop pasture in tropical-forest regions.



Figure 9-8.
Much of the tropical rain forest is being cleared using slash-and-burn techniques. This photo shows the remnants of the clearing of a rain forest in Belize. (Rhett A. Butler)

Elsewhere in the Third World, the simple need for wood used as fuel, together with logging by international corporations, is denuding (stripping of covering) tropical rain forests. Nigeria has lost more than 90% of its forest cover. From 2000 to 2005, Nigeria lost over 50% of its forests. Traditional timber producers, including Malaysia, Thailand, and the Philippines, might soon face the prospect of becoming timber importers themselves, due to excessive logging ventures.

The potential costs of tropical deforestation discussed in the scientific and technical literature seem to fall into three general categories:

- ❏ Severe changes in global weather patterns.
- ❏ Loss of cultural and biotic diversity.
- ❏ Desertification of the forest lands.

Due to the vastness of the tropical rain forest segment of the planet, its disappearance poses an extreme threat to global climatic stability. Scientists estimate that the respiration processes of forest trees and plants return at least half of the rainfall dropping on the forest back into the air. Conversion of the rain forest to pasture drastically reduces the evapotranspiration cycle. ***Evapotranspiration*** is the water removed from the soil by evaporation from leaf and plant surfaces. For instance, as the South American forest shrinks, the Amazon basin could dry out irreversibly, grow warmer, and shift weather patterns in the United States and Canada, pushing the grain belt northward.

There is also a growing concern about the contribution of deforestation to the greenhouse effect. Scientists estimate that 18%–25% of the CO_2 emissions worldwide are due to deforestation. Destruction of many plant and animal species is another serious consequence of tropical-forest destruction. Many species of tropical rain forest trees live at low densities and lack seeds adapted to long periods of stressful environmental conditions. The species of plants and animals native to primary tropical rain forest conditions might be unable to recolonize large clearings or open areas.

In addition to the loss of entire species, we face the morally unforgivable prospect of ethnocide (death of a cultural group) of many small, isolated, and vulnerable groups of indigenous, or local, people. These individuals hold much of the knowledge and culture necessary to understand and utilize the rain forest's resources. Their obliteration or social displacement cannot be ignored in the midst of technological development.

The bold razing of the tropical forests under the guise of farming or ranching produces only short-lived profits. The ash released from the burnt logs, initially a rich fertilizer, disappears quickly from the plot of cleared land. Denuded of its protective canopy and deprived of its fertile carpet of decaying plant life, tropical downpours soon wash away the thin topsoil typical of these rain forests.

The process continues for a few years, until the land can no longer support human life. Farmers and ranchers then cut still deeper into the forest, leaving behind desolate scrubland of near-desert conditions. Once the new patch of trees has been cleared, the torrential rains once again erode the soil and further expand the problem of desertification.

In an era when environmental issues are of overriding importance to the well-being of society, the scientific and technological communities must focus their concern on those issues deemed most critical. Tropical-forest resource management is an issue of great importance. It appears that the technologies needed to abate the process of tropical deforestation do exist. Even still, significant inroads into the problem of deforestation and resource depletion have been slow to appear. There have been tremendous political, cultural, and economic constraints to overcome. Many of the actions needed to halt and correct forest resource deterioration can come only from the governments and citizens of the tropical nations themselves.

Technologies developed in the United States and other developed countries can be used in the tropics, but it is critical that they be adapted to the different climatic and social conditions of the tropics. For example, while satellite technology can provide very clear imagery of the forests and other vital information that could be used to improve tropical-resource management to determine the extent of global deforestation, desertification, and habitat destruction, the primary constraint to developing countries is a lack of adequately trained personnel. Other technologies, such as those for improved harvesting and handling of timber, can also be modified to be appropriate for use in the tropics.

Technology's Role in Resource Management

As the *Dateline* news flash indicates, there are more opportunities to create energy without causing any environmental damage. This type of appropriate technological intervention can occur only following comprehensive environmental-impact analyses. Water itself can naturally create energy by transmission of its wave power to electric power, without causing any adverse ecological effects. Instead of farming or ranching, ecotourism can replace subsistence farming as a source of income for dwellers of the rain forest. Both of these are examples of technology management of environmental problems. Using modern technology to save natural resources can be a new way to manage the environmental problems older technology caused.

Water Management

When water is scarce or unavailable in certain places, governments manage the water supply to provide water for people, farming, and industry. The history of water management shows that, each time a water source is diverted or altered, there are unintended consequences. A major reason water is diverted is for agriculture. As populations increase globally, so does the need for food, and unfortunately, modern agriculture requires water to be diverted. See **Figure 9-9.**



Figure 9-9.
Women pump water from a borehole in the village of Pinsolo-Dougou, 60 kilometers east of Katiola. Under the rural-infrastructure component, the project is improving the water supply to rural villages by constructing or rehabilitating 60 boreholes and equipping them with hand pumps. (IFAD/C. Nesbitt)

After the crops are harvested, countries are left with the by-products of agriculture. Runoff from farmland increases the sediment in rivers, and nutrients drained from fields flow into the water supply. In the United States alone, agriculture accounts for about 65% of the total national phosphorus and nitrogen discharges annually. Industrial waste and by-products add to the pollution of the world's waterways. Historical research by scientists found that farming has a great impact on the Mississippi River, for example. Both the volume of water discharged from the mouth of the Mississippi and the levels of bicarbonate in the water have increased over the last 50 years because of farming. The increase in volume of water discharged is particularly troubling because the Mississippi then discharges more nutrients and pollutants into the Gulf of Mexico. The United States is not alone in dealing with these issues. A by-product of the breakup of the Soviet Union and the Communist bloc was increased industrialization and pollution in these formerly Communist countries.

Growth and shifts in population also directly affect water management. Between 1950 and 2001, the U.S. population increased by 80%. By 2050, the U.S. Census Bureau projects that an additional 120 million people will be living in the United States. People are not, however, choosing to live in water-rich areas. In the United States, for example, some of the nation's driest

areas—Las Vegas, Tucson, Phoenix, and southern California—are among the fastest-growing areas. This population shift puts enormous pressure on the limited water supplies in these areas.

There are many ways countries manage their water supplies, including irrigation, water desalination, water reclamation and reuse, and dams. Desalination is the process of converting salted water into drinking water. This process is an expensive, energy-intensive process. Currently, the countries using desalination on a large scale are located in the Middle East. The desalination plants in Saudi Arabia alone equate to almost one-fourth of the total world's capacity. The largest desalination plant in the United States is located in Tampa Bay, in Florida. The Tampa Bay plant produces 25 million gallons of drinking water each day and provides 10% of the region's water supply.

Water reclamation and reuse occurs when water is captured after its first use, cleaned, and then reused. Commonly, many U.S. counties and companies use reclaimed water for irrigation and industrial cooling. Few cities use reclaimed water as drinking water. Denver, Colorado is a leader in this area in the United States. Each day, the Denver Metro Wastewater Reclamation District treats around 130 million gallons of wastewater and discharges the treated wastewater into the South Platte River. In addition, the wastewater treatment produces over 70 tons of biosolids daily, which are used to make compost. The methane gas the process produces is recovered and used to create electricity.

Both dams and irrigation have existed for thousands of years. Dams in particular, however, have had a resurgence in popularity in the last half-century. Since 1950, the number of large dams (at least 50' in height) has increased from 5700 to 41,000, worldwide. As of the middle of the first decade of the twenty-first century, there are 1500 dams under construction, mostly in developing countries. New dams are diverting more water because of the increasing size of the dams. The 610'-high Three Gorges Dam in China, scheduled for completion within this decade, will stretch for more than one mile across the Yangtze River and will generate hydroelectric power. See **Figure 9-10.** The technology underlying the Three Gorges Dam is described in detail in Chapter 7 of this book. The water behind this dam is planned to be diverted to provide 10 trillion gallons for agricultural irrigation. Also, this dam requires the movement of between 1 and 2 million people to make way for it. The problem with this dam is that the changes in the flow of the Yangtze River will affect more than China. Scientists predict that, if as little as 10% of the river is diverted, temperatures in Japan might be raised several degrees.

What is China to do? China is faced with an increasing population and the need to produce more food to feed this population. The possible long-term effects of this dam seem small, in comparison to the starvation of the Chinese people. This example highlights the problems with water management. Often, these strategies are designed to solve the pressing problems of today. Unfortunately, they then cause new problems for tomorrow.

Hazardous-Waste Management

At thousands of hazardous-waste sites across the United States, toxic chemicals are contaminating the land, air, and groundwater supplies. During the mid-1980s, the EPA estimated that dangerous chemicals were leaking out of at least 16,000 landfills throughout the countryside. The management



Figure 9-10.
A boat navigates the Yangtze River through gorges that are expected to flood when the $25 billion Three Gorges Dam is completed in 2011. (China Photos)

of the toxic wastes that a progressive technological society produces has become yet another environmental issue demanding immediate attention.

Toxic waste has become a national problem in this country. This problem is an issue that has emerged through a confusing web of scientific, legal, community-based, and industry-related perspectives and discoveries. Often out of ignorance and neglect, Americans have been carelessly disposing of immeasurable volumes of waste materials since the end of World War II. Manufacturers, farmers, and the general populace have poured chemicals, pesticides, herbicides, and industrial solvents into ponds, streams, storm drains, and poorly prepared ditches, with little regard for geological limitations.

Research has revealed the potential health hazards created as a result of these neglectful activities. These hazards range from minor discomforts (headaches and nausea) to life-threatening ailments (cancer and birth defects). The environmental damage related to this form of contamination might involve loss of vegetation, destruction of animal habitat, and eventual elimination of certain species of wildlife within the affected geographic area. Public anxiety has stimulated widespread demand for immediate action to somehow rectify the current dismal scenario, with reference to handling hazardous wastes. In most cases, however, these demands seem to overlook basic questions:

- ❏ Who should engineer the cleanup?
- ❏ Who should pay for it?
- ❏ What should be done?

- ❑ How clean is clean?
- ❑ How should the cleanup be implemented?

The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly referred to as ***Superfund***, was enacted to provide for cleanup at sites where hazardous wastes had been abandoned or previous hazardous-waste disposal procedures had already contaminated the environment. Under CERCLA, the EPA is responsible for collecting information about sites needing emergency or long-term cleanup. The act essentially requires the EPA to generate a National Priorities List of the most critical dump sites and to develop formal regulations for implementing the Superfund Program. In the middle of the first decade of the twenty-first century, there are 1305 identified Superfund sites in the United States.

Generation of Waste

Efforts to estimate the amount of hazardous waste materials generated each year in this country seem to be almost futile. It is difficult to identify those corporations, small manufacturing firms, or individuals directly responsible for producing these waste materials. A portion of the difficulty stems from an array of inconsistent definitions regarding the specific wastes considered to be hazardous.

For instance, the Resource Conservation and Recovery Act (RCRA) of 1976 defines *hazardous waste* as improperly managed solid waste found to cause an increase in morbidity and mortality or posing a significant threat to human health or the environment. If you find this explanation rather vague, you are probably not alone. The EPA adds that substances are considered hazardous if they possess the following characteristics: ignitability, corrosiveness, reactivity, and toxicity. This agency further includes some, but not all, carcinogens on its list. The EPA feels the testing procedures akin to carcinogenesis are still somewhat unreliable. Unlike the description provided in the RCRA, the EPA holds that hazardous wastes occur in any physical form—solids, liquids, semisolids, or gases. On the other hand, the EPA definition does not include releases to sewage-treatment plants, treatment in tanks possessing permits under the Clean Water Act, or wastes beneficially used or recycled at the factories where they are generated.

According to the Environmental Technology Council, more than 280 million tons of hazardous waste are generated each year. The process of identifying those establishments generating dangerous substances in the course of their production and manufacturing activities is difficult. The computer revolution is fueling the production of waste worldwide. Not only do computers generate hazardous waste during their manufacturing, they again generate hazardous waste when they are discarded. Semiconductor plants use arsenic, phosphorous, and boron to improve the conductivity of silicon crystals. Subsequent solutions of nitric and sulfuric acids are used for etching the prepared chips.

To add to the waste, the average computer is now being used for a shorter time. Today, with the reduced costs of new computers, it is frequently cheaper to buy a new computer than to upgrade or refurbish an old one. Where does the old computer go? Most go into a basement, in a garage, or to the dump. The EPA estimates that most used or unwanted electronics, including computers, are discarded in landfills, with only around 20% being recycled. Overall, around 1.5 million tons of electronics end up in landfills each year in the United States. See **Figure 9-11.**



Figure 9-11.
A dumping ground for old computers creates even more waste. (Office of the Attorney General, State of Missouri)

Treatment, Storage, and Disposal Techniques

Guidelines that the RCRA provides indicate that some form of treatment, storage, or disposal process should manage hazardous wastes. In some instances, waste materials might go through all three stages. It is also possible for a single process, such as surface impoundment, to be used for all three purposes.

The law (RCRA) requires facilities that treat, store, or dispose of hazardous waste to obtain operating permits from the EPA. These permits require periodic monitoring, record keeping, personnel training, emergency planning, and plant-closure procedures. Specific design and operating procedures, such as approved double liners and restraining walls for landfills, are also recognized as components of more recent permits the EPA issued.

Land disposal remains America's dominant method of managing toxic wastes. Secured landfills, industrial lagoons, and deep-well injection systems all rely on a timeworn trust in the resilient nature of soil. Approximately 50% of America's toxic wastes are injected into deep wells. Other less widely used

management techniques include incineration, waste recycling, and the use of genetically engineered bacteria to destroy these substances, thus neutralizing the toxic effects of the substances on the environment. The latter example illustrates the role of biotechnology in environmental protection. This example also provides evidence for public concern about an accidental ***environmental release*** of these powerful bacteria that could have severe unwanted effects on the habitat they were engineered to clean!

A great deal of attention has been directed toward the need to limit the types of substances deposited in landfills and the increased use of protective measures, such as more comprehensive monitoring and more effective containment liners. Nearly one-third of the sites identified on the EPA's National Priorities List developed for Superfund were surface impoundments. Many of these establishments were found to be negligent in their use of monitoring wells to ensure that nearby aquifers used for drinking water had not been contaminated.

Underground injection wells are often used to dispose of liquid wastes, including acid and alkaline solutions, solutions containing metals, and solvents. These wastes are pumped into underground strata, where they are assumed to be contained by impermeable rocks. The technology of underground injection has been used extensively in the oil and gas industry, but its viability on the toxic-waste management agenda remains questionable.

Some waste-management experts believe that incineration of toxic wastes could spell some form of relief and substantially reduce the amount of dangerous substances going into landfills. Modern technology has introduced incinerators designed to destroy 99.9% of the organic waste material they handle. Materials that escape up the flue are then scrubbed out of the flue gas with auxiliary equipment. Needless to say, this is an expensive treatment and disposal process. Moreover, communities near incinerators have objected to them, due to their anxieties over potential emissions from the stacks.

Perhaps the best disposal solution for hazardous waste is to recycle it or recover valuable materials from the waste. Although this is not yet possible in all situations, some waste solvents used in the electronics industry have been shown to contain compounds of sufficient quality to be used again as virgin materials in other industrial settings. The EPA estimates that a small, but still measurable, percentage of industrial wastes can be reused in this manner. This agency has encouraged the establishment of waste clearinghouses to implement this treatment strategy.

Hazardous-Waste Cleanup

A truism is that prevention is usually cheaper than cleanup. In the case of hazardous wastes, however, the situation has gotten out of hand, to the point of crisis, in many areas of the country. Unfortunately, cleaning up the mess after the fact is easier said than done. Regardless of the cleanup procedures selected, the work is slow, complex, and costly. A quick fix is next to impossible.

Although the CERCLA (Superfund) provides funding for cleaning up the more critical hazardous-waste sites, it does not provide standards for determining the degree of cleanup required. This oft-referenced "how clean is clean?" issue is at the core of one of the most pressing problems confronting the Superfund Program. Unlike earlier federal environmental legislation, Superfund does not include standards for cleanup actions at hazardous-waste sites. Some citizens would like to see this legislation modified.

Nevertheless, the EPA has difficulty determining standard levels of cleanup at this point, since its experience in developing remedies for hazardous-waste sites is limited. Each site has unique characteristics meriting individual attention. The agency has also acknowledged that circumstances frequently occur in which there are no clearly applicable standards for determining acceptable levels of hazardous substances in soil and other media. Developing standards for the literally hundreds of substances encountered in cleanup activities could ultimately deter the progress of the procedures presently being used.

Two types of cleanup actions are classified with the Superfund Financing Program—emergency actions and long-term cleanup. Dangers of fire, explosion, or acute physical effects from direct contact are typically considered as candidates for possible emergency action. Longer-term cleanup activities move more slowly and commonly entail waste removal, treatment, or containment; data collection via testing; feasibility studies; and detailed design of remedial measures.

The cleanup of the massive quantities of hazardous materials across the United States requires leadership, initiative, imagination, diligence, and patience from all segments of society. Several studies illustrate the prospect of speeding up the cleanup process, with both government and industry taking the initiative.

- New Jersey established an aggressive Spill Compensation and a Hazardous Discharge Fund to help pay for cleanup.
- California initiated an aggressive program to phase out land disposal of cyanides, strong acids, polychlorinated biphenyl (PCB) liquids, and all halogenated organic substances.
- The Florida Department of Environmental Regulation is laying the groundwork for an in-state system of hazardous-waste management.
- Major firms, including Dow, Kodak, Dupont, and 3M, are recycling and incinerating their own dangerous waste materials.
- The Arkansas city dump was cleaned through a partnership between the Kansas Department of Health and Environment and the EPA.

Financial and manpower constraints make it impossible for the federal government to do it all. The private sector, which provides jobs and revenue for local governments and communities, chiefly generates the hazardous-waste problem. Government-sponsored scientific research projects seem to be moving in the right direction, toward a clearer definition of the problem, as well as proposed regulatory and technical solutions. The hazardous-waste problem is not amenable to a quick fix, but it is an environmental issue that can be handled through effective cooperation among citizens, industries, and government agencies in our society.

Summary

Environmentalism has surfaced around the world, as an information-based perspective on the intelligent use of technology to prevent adverse effects on the environment. The modern environmentalist is no longer perceived as an antiestablishment radical in our society. There are several key environmental issues requiring dedicated, international cooperation during the upcoming decades.

This chapter focuses on problems associated with the atmospheric buildup of CO_2, the jurisdiction of common spaces, global issues, air-quality standards, the consequences of tropical-forest destruction, water management, and the management of hazardous materials. Each of these situations might seem dismal at the present, but none

of them are totally insoluble. Progress can be made in all areas to safeguard environmental quality for the generations to follow. Cooperation between the public and private sectors in all nations is necessary to get the momentum underway.

Discussion Questions

1. Describe what the term *environmentalism* means in today's society. How does your personal opinion concerning environmental issues compare to this description?
2. Identify and discuss some examples of successful environmental policies that have emerged as a result of grassroots movements during the past five years.
3. Develop a future scenario depicting at least two prospects for the fate of Antarctica in the world community.
4. With reference to at least three contemporary environmental issues, describe what is meant by the general cliche "Prevention is usually cheaper than the cure."
5. Considering the need for pesticides in agriculture, what is the best way to regulate them in an individual country? On an international scale?
6. Explain what the greenhouse effect means. Discuss the possible causes and consequences of the concept labeled *global warming*.
7. How would you respond if you discovered that your state planned to establish a hazardous-waste dump on a vacant property near your home? What questions would you ask? What safeguards would you expect? How might you determine whether or not a comprehensive environmental-impact analysis had been completed and by whom?

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An aerial view of a slash-and-burned forest near Pangkalanbun, Kalimantan. (Rhett A. Butler)

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DATELINE

Pearl Harbor, Hawaii

The United States was able to test the capabilities of the Missile Defense Agency (MDA) program recently. An ailing U.S. spy satellite was dropping from orbit. Crew members on the USS *Lake Erie* were able to fire a missile that destroyed the errant satellite while it was still in orbit around the Earth. A missile launched from the Navy cruiser struck the 5000-pound satellite orbiting 150 miles above the Earth's surface. Secretary of Defense Robert Gates pointed out that this trial showed that the MDA program works. Now, he says, the issue is when the United States should use this technology. "I think, actually, the question of whether this capability works has been settled. The question is: Against what kind of a threat [do we employ the technology]? How large a threat? How sophisticated a threat?" Gates said during a meeting with the press.…

Introduction

Standing amidst the social, economic, and political debris that the dissolution of the Soviet Union, the disintegration of the Red Army, the collapse of the Berlin Wall, and a general easing of East-West conflicts created, our view of the world is somewhat obscure. This murky perspective follows six decades during which many Americans lived in fear of nuclear annihilation, triggered by an altercation between the United States and the former Soviet Union. As we proceed further into a new millennium, we are in the midst of a dramatic shift of power from the bipolar world of the cold war to the uncertainty of a multipolar, new world order. The profile of international defense policy is anything but cut-and-dried.

There are new terrorist threats to the United States. These threats have demonstrated weaknesses in our defense strategies. For our purposes, we define ***terrorism*** as the ability and determination to use readily available technologies as tools of mass destruction. For generations, the American people had thought of national defense in terms of war. Now, there is a new previously unperceived terrorist threat. *Bioterrorism* has become a new, frightening term Americans are only beginning to comprehend. The nature of unexpected terrorist attacks has changed the way most Americans view both the military and national defense. Many Americans have begun to question their personal safety and security on their home continent because of these fears.

With the new century underway, Americans have begun to adopt a more global perspective on the potential threats of pollution, terrorism, overpopulation, gross climatic changes, AIDS, nuclear power plants, and nuclear-weapons proliferation. While these concerns have quite possibly diluted the disproportionate emphasis placed on the risk of a global conflict, the United States cannot afford to abandon its commitment to military strength and national security. Even as the American public has seemingly begun to dismiss the possibility of a direct nuclear attack from the former Soviet Union, it can do so only on the premise that the United States remains strong.

While the affairs of Russia continue to waver between confusion and outright chaos, the uncertainty is unsettling. Perhaps the worst scenario imaginable is a civil war among the newly declared independent states of the former Soviet Union, in which nuclear weapons are actually used. Of critical concern are an estimated 27,000 nuclear warheads that are potentially hazardous to the world's health and stability. These warheads are in at least eight countries. Just under 50% of these bombs and intercontinental ballistic missile (ICBM) warheads are strategic. The rest are shorter-range tactical weapons for the battlefield.

When the topics of weapons superiority, defense policy, and military paradigms are addressed these days, traditional models of combat are often set aside. Pentagon officials categorize the type of periodic battles the United States is likely to enter into with regional powers as mid-intensity conflicts (MICs). This evolving paradigm joins previous models that assumed U.S. forces should be prepared to fight the former Warsaw Pact on European soil (high-intensity combat) or guerrillas in Central America (low-intensity war).

As with the 1990 Operation Desert Storm in the Persian Gulf, the war in Afghanistan that began in 2001, and the Second Gulf War (also called *Operation Iraqi Freedom*), these future MICs will be fast paced and high-tech. Military planners envision unrestrained use of our most sophisticated weapons. Essentially, this scenario suggests that the United States will be conscripted to do battle with emerging Third World powers through the use of weapons initially designed for a war with the Soviets. Gone are the days when conflict in developing nations conjured up an image of simple, low-tech warfare that did not require complex weapons systems. In today's global society, Third World nations are armed with First World armaments. Widespread proliferation of chemical weapons (CWs); increased access to nuclear-weapons capacity; and the availability of cruise and ballistic missiles, submarines, and high-performance aircraft mean more nations than ever before can wield deadly forces on the battlefield.

As U.S. military advisors and government officials continue to ponder the long-term implications of the Second Gulf War, the resurgence of Russia as a military power, and the current war on terrorism for future defense policy, there is reason for scientists and technologists who design and build our weapons of war to continue their work. The cold war might be over. A massive number of nuclear weapons, however, are scattered throughout the world. This reality, combined with contemporary American worries about whether or not the United States can retain its competitive edge in the world economy, seems to preclude a slowing of R&D for military technology. The commonly held presumption that a nation's technological edge often goes hand in hand with the nation's international military stature will not disappear in the foreseeable future. The progressively popular conviction that economic competitors pose a greater threat to national security than military adversaries do, however, might overshadow it.

The extent to which scientists and technologists will ever be able to fulfill past President Reagan's vision, in his almost legendary *Star Wars* speech, of an "impenetrable shield" remains a question. Regardless, Strategic Defense Initiative (SDI) projects, including exotic lasers, hypervelocity projectiles, sensitive radars, and ground-based interceptors, received a significant share of our nation's R&D budget into the early 1990s. The SDI's most recent incarnation has been as the MDA program. Currently, the United States hopes to have an initial MDA system in place by 2020 that will include

ground-based interceptors, early-warning radar, and satellites. It appears that the new justification to keep the comprehensive SDI program alive (and funded) is that emergent nuclear powers are not likely to be deterred, as the superpowers have been, by the specter of mutual assured destruction (MAD). The ***Strategic Defense Initiative (SDI)*** will eventually need to shift its focus to ground-based interceptors for defense against regional missiles. These missiles' flight trajectories are not outside the atmosphere.

For many of us, the sophistication level of the technologies associated with military prowess is beyond our wildest imaginations. International defense policy is dynamic and evolutionary. This policy's profile seems to change a little each time we hear about another new sensor device, smart missile, deadly chemical superweapon, genetically engineered biological agent of destruction, or enterprising missile-basing scheme. As you review the topics introduced in this chapter, you might begin to grasp and understand the reason many historians single out war as a primary trigger for technological change. For centuries, the human instinctive response to any sort of threat to survival has been enmeshed in a technology of some sort. Prior to the onslaught of our contemporary nuclear era, every new weapon prompted a defense that could counter it. Even when civilian populations became the target, effective defense strategies appeared on the scene. The bombs that brought an end to World War II changed that chain of development forever. The instant annihilation of Hiroshima shifted the balance between offense and defense to a point where there was no longer an optimal maneuver to protect the civilian population in war. Nuclear weapons are quite simply instruments of mass murder. During the cold war, the notion that any country could wage a small-scale nuclear war without risk of global suicide was an absurdity. In our contemporary multipolar world, larger powers might tolerate regional conflicts (perhaps nuclear), rather than risk globalizing the war in the name of ideology.

Military technology projects might bear some resemblance to other technology-laden disciplines. Their ultimate objectives, however, represent a clear point of departure. A competitive and often nationalistic spirit drives military scientists and technologists. They most assuredly struggle with ethical and moral issues as they improvise and craft more lethal weapons in the laboratory. These same struggles are said to stimulate performance among biotechnologists who are paving the future course of genetic engineering, medical technologists who study alternative procreation methods, and manufacturing engineers who contribute to the global market of technological gadgetry. On the other hand, military technology remains in a class by itself, from the standpoint that its capacity to destroy an opponent's capacity to wage war defines its primary goal. This pursuit commonly leads to the loss of human life along the way. The following questions are addressed in this chapter:

- ❏ Will the superpowers continue to be the "keepers of the keys" of military superiority in the global arena? On the other hand, did the end of the cold war signal the end of superpower prominence?
- ❏ How does the emerging military stature of developing nations factor into the equation of international defense-policy making?
- ❏ What projections are being made to describe the nature of war on tomorrow's battlefield? What are the probable environmental consequences of these battles?
- ❏ Is the MDA program a worthwhile military investment? What other Pentagon black-budget projects might you suspect are earmarked for funding, now that we have entered the twenty-first century?

- ❑ From the perspective of economic competitiveness, how will the U.S. military budget influence employment patterns and enhance industrial leadership?
- ❑ If contemporary government leaders profess to be concerned for the sustenance of human life, how should they attempt to reconfigure their national-security objectives?
- ❑ What will be the effects of bioterrorism and cyberterrorism on the quality of life and our perceptions regarding freedom in the United States?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

biological weapon (BW)
bioterrorism
chaff
chemical weapon (CW)
cluster bomb unit (CBU)
command, control, communications, and intelligence (C^3I)
command, control, communications, computers, intelligence, surveillance, and reconnaissance (C^4ISR)
compellance
Cooperative Threat Reduction (CTR) Program
counterforce targeting
countervalue targeting
cyberterrorism
decoy
deterrence
first strike
low-intensity conflict (LIC)
mid-intensity conflict (MIC)
mutual assured destruction (MAD)
nuclear winter
Single Integrated Operational Plan (SIOP)
smart weapon
Strategic Defense Initiative (SDI)
swaggering
terrorism

Military Goals in the Global Arena

There is no question that national security has always been a topic of concern among the general public. National security is commonly used to justify huge public expenditures to maintain global deployment of armed forces, develop and procure new weapons systems, and manufacture armaments. Much of what we know about U.S. national-security (as well as foreign-security) policy appears to us in brief snippets in the evening newspaper or on one of the numerous analytical commentaries or news programs broadcast on cable television. Set against a backdrop of uncertainty about the future, news bits and editorials heighten the impression that military planners continually modify the conditions of our security policy to coincide with the latest weapons developments or foreign event. Regardless of these political shifts, there are some regularities and patterns. These patterns allow a few generalizations to be made about the present and future U.S. defense policy.

Since World War II, international security objectives have become inextricably linked with the quest for military supremacy. The timeless nature of the national-security issue is based on assumptions that the principal threat to one's safety (and perhaps freedom) comes from other nations around the globe. The idea that countries everywhere should be prepared to do battle and defend themselves at all times from an external invasion is relatively recent. Prior to World War II, countries mobilized their troops in times of

war, instead of maintaining large, permanent military installations. **Figure 10-1** contains global defense expenditures for selected nations. The dollar figures for military strength have grown enormously. Further, the number of people in the United States alone who are, in one way or another, employed in defense-related jobs remains quite high. Among industrialized countries, the United States spends a greater amount of money and a higher percentage of its total research money on defense-related research than on any other type of research. See **Figure 10-2.** About 60% of the U.S. government's 2008 R&D budget was devoted to this area, in comparison to less than 10% in Germany, Canada, and Japan. In addition to high levels of funding for defense-related R&D, the United States spends more on its military budget than the rest of the Group of Eight (G8) countries—a group of the eight most affluent countries in the world, consisting of Canada, France, Germany, Italy, Japan, the UK, the United States, and Russia—combined. In 2008, the overall defense budget for the United States was $623 billion.

For years, the primary stimulus behind global militarization has been rooted in the ideological conflicts between the former Soviet Union, with its socialist allies, and the United States, in alliance with the world's industrial democracies. More recently, the emergence of Third World countries as potential threats to global stability confirms the fact that the process of militarization and weapons procurement is independent of economic status, political ideology, or level of technological advancement. Since the mid-1940s, the dominant influence in world politics has been entrenched in a bipolar rivalry between the Soviet Union and the United States. One of the hallmarks of this geopolitical struggle has been the intense proliferation of nuclear arms. In light of the dissolution of the USSR and the Warsaw Pact,

Top 30 Countries in Military Expenditures (in Millions of Dollars), 2005		
1	United States	503,000
2	China—Mainland	85,300
3	UK	55,900
4	France	52,900
5	Japan	43,800
6	Germany	38,100
7	Italy	33,500
8	Russia	31,100
9	Saudi Arabia	25,400
10	India	18,800
11	South Korea	18,500
12	Brazil	13,300
13	Canada	13,200
14	Spain	13,100
15	Australia	13,000
16	Israel	10,800
17	Turkey	10,300
18	Netherlands	9570
19	China—Taiwan	7830
20	Iran	7210
21	Greece	6750
22	North Korea	6720
23	Syria	6140
24	Poland	5540
25	Sweden	5520
26	Singapore	5470
27	Norway	4880
28	Columbia	4560
29	Chile	4360
30	Belgium	3240

Figure 10-1.
The top 30 countries in military spending in the world (in millions of dollars) in 2005. (Adapted from the 29th edition of *World Military Expenditures and Arms Transfers [WMEAT],* released in 2009 by the Department of State)

Government R&D Support for Selected Countries, by Socioeconomic Objective: 2005 or 2006

Percent

	Defense	Human Health	General University Funds	Nonoriented Research	Space	Industrial Production	Energy	Agriculture	Other
United States (2006)	57.9	21.8		5.5	7.6	0.3	0.9	2.0	4.0
Japan (2005)	4.0	3.9	33.9	16.3	6.7	7.3	16.8	3.3	7.8
Germany (2005)	5.8	4.3	40.6	16.3	4.9	12.6	2.8	1.8	11.6
France (2005)	22.3	6.1	24.8	17.8	9.0	6.2	4.5	2.3	6.9
UK (2005)	31.0	14.7	21.7	16.0	2.0	1.7	0.4	3.3	9.1
Italy (2006)	1.4	10.0	44.2	6.3	9.5	10.2	4.1	3.8	10.5
South Korea (2005)	13.3	7.8		20.7	3.0	26.9	6.4	8.0	13.9
Canada (2006)	3.6	15.0	32.6	8.0	4.2	11.4	4.8	6.7	13.6

NOTE: Countries listed in descending order by amount of total goverment R&D. R&D classified according to its primary government objective, although it might support several complementary goals (for example, defense R&D with commercial spin-offs is classified as supporting defense, not industrial development).

SOURCE: Organisation for Economic Co-operation and Development, special tabulations (2007). Appendix table 4-41.

Science and Engineering Indicators 2008

Figure 10-2.
The distribution of government-supported R&D for selected countries. (Adapted from *Science & Engineering Indicators—2008* and the NSF)

this bloc leadership model has been challenged. Instead of worrying about a reliable adversary, the United States must now worry about more unpredictable defense challenges. There have been resurgences of militarism in both North Korea and China; continued conflicts in the Gulf region; and post–cold war instability in many countries, from the Balkans to Asia. The United States is reconsidering its bases in Japan and Germany and planning to relocate many of the soldiers to more troubled areas in the Balkans or Africa.

The price for functioning as the world's police officers has reached astronomical levels. Disproportionately high defense spending drains any growth resources critical to a dynamic, industrial society. Much of the initiative for the strategic arms reduction talks (START) in the late 1980s came from the superpowers' realizations that it had become far too expensive to maintain the forces needed to police their worldwide spheres of influence, the nuclear arsenals to guarantee an extended and assured deterrence, and the commitments to preserve their influences in key areas of the Third World.

Bear in mind, as you continue to read this chapter, that the powerful visions of promoting military security and conquering outer space were instrumental in building U.S. technological thrust and boosting the U.S. "ACE complex" to international prominence. (ACE includes the aerospace, communications, and electronics companies supporting these objectives.) It is the perfect time to restructure our economic order so the next round of technological investments will promote an environmentally sound, physically healthy, and politically stable

society around the world. U.S. leadership on those fronts should hold at least as much international clout as its long-term quest for military supremacy.

As this new century begins, the American people seem torn about the role of the military in the future. It is too soon to know the long-range effects of the terrorist attacks on the United States in 2001. Will the American people continue to support, even demand, more military spending to increase their perceptions of security? On the other hand, will there be a backlash toward the increased militarization of American society? It might be some time before we witness any resolution regarding these events. In any case, we can be sure more lawmakers and citizens will heed the goals and desires of the U.S. defense complex in the next few years.

Rationale for Military Force

Why do governments invest heavily in new weapons, while they simultaneously explore possibilities for arms-control negotiations? This is truly the essence of the contemporary arms race between the superpowers. Beginning sometime in the late nineteenth century, the applications of technology in the tools of war were acknowledged for their capacity to provide quantitative and qualitative advantages for their owners.

Unlimited use of armed force as an instrument for attaining meaningful political ends is a well-known agenda. The reasons any one nation decides to mobilize its military forces are far too diverse to enumerate individually. Military historians believe many of these reasons can be loosely categorized into four general rationales. These rationales are discussed in the following sections.[1]

Defense

Defensive use of military force is directed to prevent attacks or reduce damage. This use entails the deployment or threatened deployment of sufficient military power to defeat the military force of an adversary or to attack its opponent's territory. Perhaps the most traditional view of the role of the military in our society, the term *defense* encompasses the direct application of military force offensively.

Contemporary nuclear weapons are couched in technological sophistication. ***First strike*** connotes a nuclear attack so powerful as to leave one's opponent with forces inadequate to inflict substantial damage on the attacker. Second strike is a procedure following a nuclear attack in which weapons can still be used in retaliation against the enemy. This concept implies the ability to survive, if only for a short time, a preemptive first strike.

The defensive use of one's military forces might employ counterforce targeting. ***Counterforce targeting*** is a strategy in which weapons are aimed at the military forces of the opponent, particularly at strategic or theater nuclear forces. Conversely, ***countervalue targeting*** specifies a program aiming its weapons at softer targets, such as urban population centers, industrial facilities, and economic enterprises.

Deterrence

In contemporary society, the purpose of deterrence is to protect a country from physical attack by an adversary. ***Deterrence*** involves the threat of military power to convince an enemy not to undertake certain actions. Essentially, one country deters an opponent by convincing it that the consequences it will ultimately encounter outweigh the benefits of undertaking certain actions.

Nuclear deterrence is perhaps the most compelling illustration of a deterrent use of force. Counterforce targeting (in an offensive first strike) requires extremely accurate missiles, in order to be successful against

[1]See Stoll, Richard J. 1990. *U.S. national security policy and the Soviet Union.* Columbia, SC: Univ. of South Carolina Press.

hardened missile silos and obscure military control centers. The Tomahawk® missile, a long-range missile that can fly at low altitudes at very high speeds, is a prime example of a U.S. first-strike weapon. See **Figure 10-3.** In the Second Gulf War, over 1900 Tomahawk missiles were used. When both sides have the ability to absorb a first strike and deliver a retaliatory second strike capable of inflicting an unacceptable level of damage, a situation of ***mutual assured destruction (MAD)*** is said to exist. Retaliatory attacks are generally aimed at countervalue targets, such as civilian-population centers. Since there is little point in targeting empty missile silos (they would be empty after an offensive first strike had been launched), a countervalue targeting strategy seems likely to have the greatest deterrent effect.



Figure 10-3.
A Tomahawk cruise missile is launched from the USS *Philippine Sea (CG 58).* (U.S. Department of Defense)

The concept of deterrence has dictated U.S. planning for nuclear war since the late 1940s. Ostensibly, the logic behind this strategy has been the more powerful the nuclear arsenal is, the less likely the need for its use. This philosophy of deterrence is at odds with the modern types of war, however. These types have been and are expected to be regional conflicts involving both developed and developing countries. The threat of nuclear war does not appear to be a deterrent to many Third World countries, as conflicts continue to develop among them. As the United States and other developed countries evolve their defense strategies to address this changing type of war, we will no doubt have a new definition of *deterrence*.

Compellance

A government's compellant use of military force is often designed to persuade an adversary to change its behavior. ***Compellance*** involves the deployment of military power in order to get another nation to change its behavior to make the behavior more satisfactory to the aggressor. The selection of targets for compellance, in order to either threaten or actually administer punishment, is complicated. If, for example, the aggressor (X) wishes for its opponent (Y) to either start doing something or stop doing some other thing, X might compel Y by targeting what Y values most (countervalue targets, such as refineries, power stations, communications networks, transportation systems, and population centers). If, however, Y is engaged in some type of military operation X finds threatening or objectionable, it might be more effective to target Y's military establishment—its capacity to continue its inexcusable behavior.

Compellance can easily be confused with both deterrence and defense. The motivation for the compellant use of force is not to destroy an opponent's forces (defense) or ensure its continued acceptable behavior (deterrence). The underlying goal of compellance is best envisioned when country Y exhibits a behavior deemed punishable, for whatever reason, by country X.

Swaggering

To swagger, literally, is to walk or conduct oneself with an outward air of boldness or arrogance. In the present context, ***swaggering*** (also called *posturing)* equates to the deployment of military power by a government to enhance prestige, national pride, or the personal ambitions of its rulers. Swaggering military forces are not usually deployed directly against the forces or territory of an opponent. Hard combat does not generally occur.

It is difficult to define the focus or target of swaggering military actions. Two examples indicative of swaggering are general military exercises ("Look at what we can do!") and the procurement of high-prestige weapons (the conspicuous consumption phrase, "Look at what we can afford to buy!"). Both examples bring to mind the comely peacock strutting his tail feathers simply to attract attention. Still, government officials find swaggering useful to carve their niches as reputable players in the global defense arena.

Post–Cold War Nuclear Policy

For most of the recent past, the United States and Russia, each of whose multileveled approach to strategic decision making has effectively deterred the other from a preemptive first strike with nuclear weapons, have molded international discourse devoted to the formation of nuclear-weapons policies. A major innovation in U.S. action policy came with the first ***Single Integrated Operational Plan (SIOP)*** created in 1960. Since that time, all U.S. strategic forces have been part of the same coordinated plan. See **Figure 10-4.** The SIOP contains a list of targets that U.S. long-range nuclear forces would attack and assigns weapons to targets, based on established damage criteria, routing, and timing.

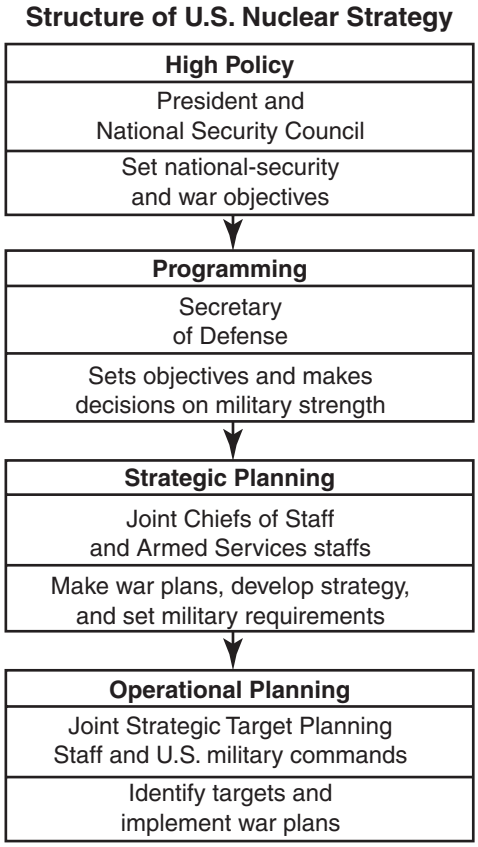


Figure 10-4.
The structure of U.S. nuclear strategy, from the standpoint of strategic-planning levels in our government. Each of the four levels of strategic planning can head in a direction different from the others, as each responds not just to guidance from levels above, but to separate organizational needs and restraints. These bureaucratic structures help account for contradictions and divergences emerging among the stated policy of the President, the force posture of the Defense Department, the plans of the Joint Chiefs of Staff, and the final implementation of plans by the Joint Strategic Target Planning Staff and the military commands.

Detailed war plans also involve war-gaming (computer simulations and board games) to assure their viability under various conditions. Prior to the breakup of the Soviet Union, the SIOP specified several basic target categories. These categories were Soviet strategic nuclear forces, other military targets, military and government facilities, and economic and industrial structures in urban centers. Attack options have ranged from conducting selective attacks with a few weapons to the engagement in a full-scale nuclear exchange using thousands of warheads against more than 20,000 targets in Russia and the other countries of the former Soviet Union.

While the present likelihood of an all-out conflict between the United States and Russia seems remote at the present, it is far too early to suggest that all nuclear weapons be scrapped as relics of the cold war. International leaders around the globe will watch the unfolding drama between the U.S. and Russian leaders. These leaders attempt to downsize nuclear arsenals, rethink nuclear policy, and redefine military plans and force requirements. Regardless of the level, or degree, of U.S.-Russian cooperation borne out of these negotiations, it is quite probable that military planners on both sides will find ways to somehow preserve or even enhance the destructive power of their nuclear arsenals.

The rapid political disintegration of the Soviet Union, coupled with a disjointed, dispirited Red Army, means the country's huge nuclear stockpile is no longer securely under the control of an authoritarian central government. After the breakup, almost 40,000 nuclear warheads remained in Russia and the various countries evolving from the former Soviet Union. In 2002, the United States and Russia signed the Moscow Treaty. This treaty mandates a maximum number of 1770 to 2200 nuclear warheads for both countries by 2012. Unfortunately, at the same time, nuclear proliferation has expanded to more countries around the world. These countries include Pakistan, in 1998, and North Korea, in 2006.

Various names have been ascribed to nuclear policy over the course of the nuclear-proliferations era. A few of these include *massive retaliation*, *assured destruction*, *flexible counterforce*, *countervailing strategy*, and *defense dominance*. Political rhetoric aside, nations will undoubtedly continue to seek nuclear weapons and also perceive them as a threat. Given this reality, we need a globally accepted policy requiring all countries possessing nuclear weapons to assume a serious posture of minimal nuclear deterrence.

Third World Threats

While nuclear weapons can and must play a diminished role as the cold war smolders with fewer embers, the specter of what have been adroitly labeled ***mid-intensity conflicts (MICs)*** remains. Nuclear forces constitute the ultimate defense of every country that has them. The immensity of their destructive power almost makes conventional weapons resemble a parody. Nevertheless, military powers have officially devoted a great deal of effort preparing for conventional conflict in a nuclear age, in order to prevent a nuclear war from breaking out. Since we always define *special arms* (biological, chemical, and nuclear) to be weapons of mass destruction, does this then suggest that tactical surface-to-surface missiles are weapons of only mere destruction? Not really. The profile of contemporary war has already revealed the firepower of modern conventional systems to be quite foreboding. Since the leverage reserved for the superpowers by virtue of their technological superiority has diminished, the line of demarcation between conventional and unconventional

warfare might appear somewhat blurred. The distinction between the two is not the weapons used, however, but the manner in which the war is waged. A conventional war is a conflict between recognized, uniformed armed forces. Unconventional struggles might involve guerrilla warfare, subversion, sabotage, and other terrorist operations of a covert or clandestine genre. When you do not know whom you are fighting (unconventional personnel are commonly out of military uniform), you assume you are fighting everyone. This is the nature of unconventional warfare.

An overwhelming majority of the armed conflicts fought around the world since World War II have been described as ***low-intensity conflicts (LICs)***. Some of the principal characteristics of this dominant military motif (border skirmishes, internal battles, police work, civil uprisings, and regional conflicts) include the following:

- ❑ LICs tend to occur in less developed areas of the world.
- ❑ Small-scale armed conflicts rarely involve regular armies on both sides.
- ❑ Generally, conscripted forces on one side fight against guerrillas, terrorists, and child soldiers.
- ❑ Most LICs do not rely on the use of high-tech weaponry. They often, however, involve people who willingly engage in suicide missions to inflict damage on their opponents.

By comparison, MICs involve warfare between the large and medium powers of the Third World or between a First World country, such as the United States, and a Third World country. Regional powers who only decades ago were equipped with a few obsolete tanks and subsonic aircraft are now purchasing a huge quantity of modern aircraft, stealth technology, tanks, lasers, and cruise and ballistic missiles. The subsequent ability of these emerging Third World powers to conduct sustained military operations on a regional or even continental scale is having a profound impact on the world military environment and defense profile. The perceived risk of MICs will prevail well into the twenty-first century. Nations such as Syria, Libya, Iran, and Brazil continue to harbor ambitions that could ultimately lead to a collision with the United States. Aspiring powers already possess modern arsenals including nuclear, biological, and chemical (NBC) munitions.

For these and many other reasons, it is quite probable that U.S. security policy will align itself with the new military paradigm carved out of the MIC formula. The nations who typically stand out as formidable military powers in the developing sectors of the globe include Argentina, Brazil, Egypt, India, Iran, Israel, North Korea, Pakistan, South Africa, South Korea, Syria, Taiwan, and Turkey. Without question, socioeconomic and political stability is the exception to the rule in these nation states. Their overriding commitments to working their own agendas, coupled with the determination of the United States to protect its natural resource and raw material interests, present a whole new set of challenges for our military forces. An MIC-oriented military posture is evidence in the United States of a de-emphasis of the Soviet threat and preparation for clashes in the Third World.

The technologies being used increasingly determine the nature of battle today. The digital revolution did not bypass the military. In contrast, in many ways, the military is exploiting the digital world to a greater extent than the civilian world is. Almost every new vehicle and weapon today includes computer-based or digital capabilities.

Arms Control and Nonproliferation

Along with the evolution of war scenarios from large-scale conflicts to MICs and LICs, the United States has added nonproliferation to its defense goals. It is much easier to stop the sale of weapons to a potentially unfriendly country than to disarm the country. The increasing amount of dangerous weapons worldwide, particularly NBC weapons, has created additional uncertainty for the United States.

One Defense Department initiative is the ***Cooperative Threat Reduction (CTR) Program***. The primary goal of this effort is to prevent the widespread acquisition of NBC weapons. Along with the prevention efforts, there is an increased emphasis on arms-control treaties. Since the breakup of the Soviet Union, these nonproliferation efforts have assisted three former Soviet republics—Ukraine, Kazakhstan, and Belarus—to become non–nuclear weapon states. The United States has also purchased tons of uranium from dismantled Russian weapons and converted this uranium into reactor fuel.

The CTR Program also aims to improve the transportation and security of nuclear weapons. As part of this effort, it is working with several former Soviet republics—Russia, Ukraine, Kazakhstan, and Belarus—to convert weapons facilities into factories that will produce products for consumers. Also, S & T centers have employed over 17,000 former Soviet weapons scientists and engineers in civilian research.

The United States and Russia, along with 31 other countries, approved a new international agreement on the transportation and sale of weapons, the Wassenaar Agreement. The goal of this agreement is to promote restraint and transparency in the transfer and sale of weapons. This agreement shows the evolution of military planning since the end of the cold war. Instead of targeting a particular group of countries, the members of the Wassenaar Agreement agreed to prevent the sale of arms to certain countries if they appear to be unstable. Currently, the countries in this category are Iran, Iraq, Libya, and North Korea.

Nonproliferation treaties will work only if all the weapons producers in the world accept and follow them. Unfortunately, each weapon-producing country has its own agenda and rationale as to which countries they will and will not sell weapons to. Unless there is a new global agreement about weapons control, nonproliferation will remain an uphill battle.

International Peacekeeping

As arguably the only remaining superpower, the United States has taken on an increasingly larger role in law enforcement and peacekeeping exercises worldwide. See **Figure 10-5.** In the last two decades, U.S. troops have been involved in peacekeeping activities in the Balkans. These activities include stationing troops in Bosnia and Kosovo. Most of these peacekeeping activities are coordinated through the North Atlantic Treaty Organization (NATO). About 20% of the NATO-led peacekeeping force in Bosnia were U.S. troops.

An unfortunate remnant of modern war is land mines. A portion of the peacekeeping forces are involved in removing these land mines. See **Figure 10-6.** The removal of land mines is critical to building the security and peace of a country. These products of technology, however, are notoriously difficult to remove. It costs between $300 and $1000, on average, to clear one mine. Experts estimate that, if we remove or neutralize 75% of the existing land mines in 25 years, it would cost about $2.25 billion.



Figure 10-5.
A U.S. Army soldier distributes humanitarian-assistance items at a community center in Eastern Baghdad, Iraq, on September 14, 2008. (U.S. Department of Defense)

The United States and other countries have realized that these peacekeeping activities bring great benefits. The entry of a NATO force into a troubled area allows the development of stability. Since LICs and MICs are most common in troubled developing countries, peacekeeping can also reduce the number or length of these conflicts. This expansion of the DOD's responsibilities is sometimes at odds with the primary goals of the defense of the United States. The U.S. military has realized, however, that isolationism is not an effective strategy for maintaining peace in the world.

The Nature of War on Today's Battlefield

Real-time exposure to armed conflicts on the other side of the globe is no longer the stuff of science fiction fantasy. Many older Americans grew up with nightly depictions of our soldiers doing battle in the remote jungles of Southeast Asia during the Vietnam War. Younger Americans can remember live network coverage of the Persian Gulf War, Operation Desert Storm, Operation Iraqi Freedom, and the peacekeeping forces in Bosnia. The saga of Operation Desert Storm unfolded before our eyes in the dubious comfort and privacy of



Figure 10-6.
An explosive-ordinance technician sweeps a path to a suspected antivehicle mine at Tuzla Air Base, Bosnia. The suspected mine is determined to be a harmless ammunition casing lid. (U.S. Department of Defense)

our living rooms. Americans were mesmerized for hours by live coverage of the horrific terrorist attacks on the World Trade Center towers and the Pentagon. As long as our international communications networks make it possible to beam images of events back and forth across the world's time zones, we, as laypeople, will be privy to the nature of future MIC battlegrounds. Some of the most powerful images that will dominate the television screen are technology-laden weapons. More chilling images depicting the aftermath of an attack using chemical or biological munitions might also be shown. Portrayals of the extent to which the use of highly destructive weapons gives credence to the ***nuclear winter*** theory might also cross the airwaves.

The world environment has changed. Instead of focusing its planning efforts on one large foe, the Soviet Union, the United States must deal with a future marked by opponents who are not so easily described or determined. It is likely that there will not be another world superpower in the next 10 to 15 years that could amass enough conventional military strength to challenge the United States. There will be increasing challenges from smaller countries, however, in a potentially wide range of regional conflicts. In the Middle East, there is a continued state of conflict among Israel and its neighbors, as well as tension among the United States, Iraq, and Iran. In Asia, Korea remains split between the North and South. North Korea continues to build its defense infrastructure. Beyond these known areas of conflict, additional ones could easily become problem areas. Whenever the future problems occur, the demand for smaller-scale military operations is likely to remain high in the next 10 years.

In the late 1990s, the DOD developed a plan for the Army of today and the future. This plan was called *Joint Vision 2010*. In 2002, the DOD revised this future plan. The plan became Joint Vision 2020. The goal of Joint Vision 2020 is to transform war through the use of new ITs and advanced weapons. By the mid-2010s, the DOD expects to reshape itself so it can more easily respond to threats in the future. Key items on the Pentagon's MIC wish list prescribe mobile firepower; advanced tactical aircraft; command, control, communications, and intelligence (C^3I); and high-tech weapons,

including cluster bombs. Since potential adversaries possess their own cruise and ballistic missiles (notably the Russian-made Scud), U.S. military planners are forced to seek countervailing defense systems. See **Figure 10-7.**

Command, Control, Communications, and Intelligence (C^3I)

In rapid-paced, high-tech MICs, U.S. forces need to quickly detect enemy movements, communicate intelligence data, and channel battle orders through the chain of command. For several years, military planning included R&D related to the use of computers and other communication devices. The C^3I systems are vital to survival against unfamiliar adversaries in uncharted, forbidding terrain. Sophisticated, highly efficient C^3I systems enable commanding officers to initiate lightning offensives and forceful counterattacks and have knowledge of the locations and intentions of both friends and foes.

U.S. ***command, control, communications, and intelligence (C^3I)*** are heavily dependent on satellites to pinpoint the locations of distant missile sites for attack by its bombers. Key links in the network are the Defense Satellite Communications System, the NavStar® GPS, and Central Intelligence Agency and Defense Intelligence Agency (CIA/DIA) spy satellites. For precise, up-to-the-minute information on enemy movements, the U.S. military has access to the Joint Surveillance Target Attack Radar System (JSTARS). JSTARS is an airborne command station. The JSTARS planes are equipped with radar and computer systems that gather detailed information about the enemy's troops on the ground. This information is relayed to ground forces. These forces can use the information to plan their response to enemy troops. JSTARS was successfully used in the NATO Kosovo operations and in Iraq during the 2003 U.S. Operation Iraqi Freedom.

COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE (C^3I)

A network that provides information about communications, counterintelligence, security, information surveillance, and reconnaissance to the military forces so they can succeed in every mission.

Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C^4ISR)

Under Joint Vision 2020, the scope of C^3I is going to be expanded to encompass more functions. The expanded information plan of the military, called ***command, control, communications, computers, intelligence, surveillance, and reconnaissance (C^4ISR)***, will use improved ITs to enhance military operations. The five components of C^4ISR follow:

- ❏ Multisensory information that can provide information about the battlefield to both commanders and field forces.
- ❏ The implementation of software and hardware to allow battles to be managed faster and more flexibly.
- ❏ Information systems that can interfere with or manipulate an enemy's forces.
- ❏ An enhanced communications grid.
- ❏ An information defense system to protect the DOD's communications from any interference by the enemy.

Information and the effective use of information will be overriding issues for the military of today and tomorrow. Almost all



Figure 10-7.
The first ground-based interceptor was lowered into its silo at the missile defense complex at Fort Greely, Alaska, on July 22, 2004. The interceptor is designed to destroy incoming ICBMs before they reach U.S. airspace. (Missile Defense Agency)

new vehicles and equipment developed for the DOD include ITs. Much development work has occurred in updating the various planes and tanks the military uses in both its wartime and peacetime operations.

Smart Weapons

In addition to including IT on vehicles, the DOD has created a new category of weapons including new ITs. These technologies can be called ***smart weapons***. The U.S. Air Force's Air-to-Ground Guided Missile-130 (AGM-130) is an example of a smart weapon. The AGM-130 is an air-to-surface missile that comes equipped with a television or an infrared camera and a data link. After the AGM-130 is launched from a fighter, it allows the pilot to see through the "eyes" of the bomb. The pilot can either lock the bomb onto the target through an automatic guidance system or control it manually from the plane.

The recent versions of the Tomahawk missile have made it a smart weapon also. The current version has three different smart enhancements making it more effective. The Tomahawk missile uses a combination of the GPS (discussed in Chapter 4), a terrain-matching guidance system, and a digital radar image-matching system. Unfortunately, this technology does not come cheaply. The U.S. Navy estimates that each Tomahawk missile costs over $500,000!

In Operation Desert Storm, about 10% of the weapons were smart bombs. In the war in Afghanistan that began in 2001, this figure rose to 60%. In the Iraq war in 2003, the number rose again to 90%. There is no doubt that there will be continued use of smart weapons in the wars of the future.

Cluster Bombs

Arguably, some of the technologies listed suggest an aura of surgical strike capacity on the battlefield. Conventional bombs and artillery, however, continue to be used in battles. A common workhorse weapon of this genre is the ***cluster bomb unit (CBU)***. Having been gradually refined and improved since the late 1960s, these improved conventional munitions can deliver lethal explosives to personnel over greatly expanded areas. Instead of one large explosion, these bombs contain dozens, hundreds, or even thousands of bomblets. These bomblets are called *bomb live units (BLUs)*. A series of cluster bombs has been developed since they were first designed in the 1960s as successors to simpler fragmentation or antipersonnel bombs. Today's bomblets can be dropped en masse to disperse them aerodynamically. Compressed air can also spew them out in streams behind a bomber aircraft. CBUs are deftly equipped with shaped charges intended for use against hardened targets, such as tanks. Some are designed to disperse smoke, napalm, or chemical agents. CBUs have much wider areas of coverage than the standard 2000-pound bombs developed in the 1950s.

The Rockeye II is a 750-pound unit carrying 717 antitank fragmentation bomblets capable of distinguishing between soft and hard targets. A single F-15E fighter or bomber can haul as many as 22 Rockeyes into enemy territory. The BLU-26 Sadeye is a 1-pound bomblet that has a cast-steel shell with aerodynamic vanes and 0.7 pounds of TNT. Imbedded in the TNT are 600 razor-sharp steel shards. This weapon can be outfitted with fuses to explode on impact, several feet above ground, or at some delayed time after landing. The Sadeye is lethal at distances up to 40'. The CBU-75 carries 1800 Sadeyes. This is enough to devastate an area equivalent to 175 football fields.

Air Force representatives have described one 1000-pound cluster bomb, the CBU-105, used during the 2003 Iraqi War. The CBU-105 is a "smart-guided" cluster bomb. This bomb disperses smaller bombs that sense the engine heat from armored vehicles and then fire downward to destroy them. In addition, it is equipped with wind-compensating technology that steers the munitions to precise targets by compensating for launch conditions, wind, and adverse weather. This ingenious combined-effects bomb carries 10 armor-destroying bomblets. The bomblets are released when the bomb's casing breaks apart after being launched from a plane. A single B-52 strategic bomber can carry 40 of these CBUs. These overwhelming paths of destruction bear no resemblance whatsoever to a surgical strike.

Standoff Missiles

These highly accurate missiles are called *standoff missiles* because they can be launched from platforms well beyond the ranges of standard defenses. Ships and helicopters can be used to fire these missiles at hardened targets, such as air bases, command centers, military factories, and tank formations, from distant locations. Many of these weapons were used for the first time in Operation Desert Storm. They depend on sensors and computers to locate, track, and strike their targets. In the future, stealthy cruise missiles might be able to carry half a ton of explosives, essentially unobserved, with almost perfect accuracy, over hundreds of kilometers.

The most conspicuous of the new and experimental standoff missiles is the Navy's Tomahawk sea-launched cruise missile. This missile is used to attack heavily defended command posts, factories, and nuclear reactors. The Paveway® III bomb, featured in some of the more dramatic televised footage of the Persian Gulf War, is a laser-guided bomb. The newest version of the Paveway III bomb includes both laser and GPS guidance systems that allow for more precise targeting. The Pentagon continues to test and refine progressively more advanced standoff missiles with higher degrees of accuracy.

Antitactical Ballistic Missiles (ATBMs)

A ballistic missile consists of three generic groups of subsystems: propulsion, guidance and control, and the actual warhead. The focal distinction between a ballistic missile and an unguided artillery rocket is the guidance and control system. This segment is obviously the most expensive and technologically most advanced subsystem in a ballistic missile. Additionally, guided missiles are usually multistaged, allowing them to attain considerably longer ranges.

Ballistic missiles are commonly classified as being short-range or tactical (with ranges from 100 to 1000 kilometers), medium- or intermediate-range (also called *intertheater*), or intercontinental (with ranges greater than 3000 kilometers). Refer to **Figure 10-7.** Developing countries presently aspiring to obtain or develop their own missiles are motivated by regional tensions. Short- or medium-range missiles are far more suitable than ICBMs in these tensions. Most newly industrialized countries possess missiles that are of the short-range variety. These missiles, however, are extremely inaccurate. Scud missiles that the former Soviet Union widely distributed in the 1970s provide a majority of the missile capabilities of most Third World nations. They have a range of about 300 kilometers and can be expected to come within about 1 kilometer of their target.

A key U.S. ground-based antiballistic missile (ABM) called the *Patriot* was prominently featured and applauded for its performance against Iraqi Scuds during the

1991 Gulf War. Subsequent studies of videotapes taken of the fireworks over targeted cities have since revealed that the Patriot's accomplishments might have been exaggerated. A significant portion of the Scud missiles actually appears to have disintegrated (they were faulty) as they homed in on their targets on entering the atmosphere and well before the Patriot missiles intercepted them. This observation should not diminish the technical superiority of the Patriot. Merely, it points out that the Scud might not have been a respectable opponent.

Similar to many other weapons in the DOD's arsenal, the Patriot is continually being enhanced. The most recent version, the PAC-3® missile, has a revamped electronic radar system. This system allows the missile to be more effective and reliable. In addition, the rocket's altitude-control section has 180 small rocket motors. These motors allow the new Patriot to be more agile in its flight. All the enhancements give the PAC-3 missile an improved hit-to-kill ratio. This missile is better at both acquiring targets and eliminating them. The United States is not alone in the development of ballistic missiles. Recently, India tested a new ICBM, the Agni-III. This missile has a range of over 2000 miles.

Bioterrorism

The proliferation of BWs and CWs, combined with the capacity to deliver them to unprepared target areas from distant launch sites, is sure to be an important security issue well into the twenty-first century. The rapid advance of technology in the biological field has led to an increased ease with which illicit manufacturing plants for biologically derived chemicals can be concealed. Biochemical technology is entering the weapons field at an alarming rate. Genetic engineering and biotechnology will further refine the art of killing through the possible development of designer concoctions for which there are no known cures. The subtlety and sophistication of the specter of biochemical weapons might have changed. The threat itself, however, is not new.

In becoming parties to the Geneva Protocol of 1925, more than 100 nations agreed not to wage biological warfare. This document is an arms-control treaty outlawing the use of ***biological weapons (BWs)*** in war. The protocol does not, however, prohibit their development, production, possession, or transfer. More recently, more than 159 countries became parties to the Bacteriological (Biological) and Toxin Weapons Convention of 1972. This landmark disarmament treaty forbids the very possession of BWs and their associated hardware. Both agreements manage compliance and adherence via shared attitudes, mutual self-interest, and military disutility. Neither one contains adequate provisions for verification, regulatory sanction, nor other forms of punishment. The Biological and Toxin Weapons Convention clearly permits R&D for protection against biological and toxin weapons. The U.S. biological-defense research programs scattered throughout the country are open to public scrutiny and environmental legislation. No other nation comes close to this level of openness. In other words, the extent to which treaty signatories adhere fully to these agreements is unknown.

BIOLOGICAL WEAPON (BW)
A weapon using a living organism, usually a pathogenic microorganism, for hostile purposes.

During the past decade, biotechnologists have made remarkable advances in genetic engineering. The ability to more easily manipulate the genetic codes of microorganisms

might actually improve the usefulness of the potential BWs already existing or the capacity to create brand-new ones. A number of informed individuals have suggested that the 1972 Bacteriological and Toxin Weapons Convention is not comprehensive enough to proscribe the expected fruits of genetic engineering. Even after its sixth review conference held in Geneva in the middle of the first decade of the twenty-first century, there are still no procedures included to monitor compliance or investigate countries suspected of illegal efforts with BWs.

An exhaustive digest of likely biological agents is next to impossible to assemble for several reasons. First, the sheer number of potentially harmful organisms is huge. The potential targets, including many animals and plants, in addition to human beings, span a wide spectrum. The effects of the agents range from irritating to debilitating to lethal, depending on the immune system of the victim. Further, the scope of potential delivery methods is complex. These methods range between overt and covert techniques, as well as direct and indirect inflictions.

Regardless, biological agents share several distinct characteristics. First of all, they are all living pathogens producing diseases, typically lethal, in their target hosts. Second, they have the capability to spread beyond their initial site and precise moment of attack by multiplying and infecting other vulnerable hosts. Finally, since they are groups of living organisms, they act on groups of other living organisms. Depending on extant field conditions, their initial effectiveness and subsequent spread will vary a great deal. This variance makes their behavior all that much more difficult to predict. The following list identifies several known agents clearly having serious and far-reaching effects on all organic life-forms. The Centers for Disease Control and Prevention (CDC) has listed these agents as Category A diseases or agents—that is, diseases posing a risk to our national security:

- ***Bacillus anthracis.*** This is the bacterium causing anthrax, a usually fatal disease. There are three ways to contract anthrax. These are contact with the skin, inhalation, or eating contaminated meat. This disease is highly fatal if contracted by inhalation or ingestion of contaminated meat. The warning signs are a fever, flulike symptoms, and sores on the body.
- ***Clostridium botulinum.*** This is the bacterium causing botulism. Botulism symptoms usually occur rapidly, within between 12 and 36 hours, and can cause severe paralysis. Although most people usually recover, it can takes months of care.
- ***Versinia pestis.*** This is the bacterium causing plague, or black death. Plague usually causes the victim to get a particularly severe type of pneumonia. Black death can be fatal if not treated early. Millions of people died during the Middle Ages from plague that flea-infested rats carried.
- ***Variola major.*** This is the virus causing smallpox. The virus is spread from person to person through inhalation. The infected person shows symptoms of severe pain and prostration after about 12 to 14 days. A rash then develops 2 to 3 days later. The death rate for smallpox is 30%.
- ***Francisella tularensis.*** This is the bacterium causing tularemia, or rabbit fever, characterized by swelling lymph nodes. This bacterium, usually not fatal, can lead to severe weight loss, fever, headaches, and pneumonia.
- **Viral hemorrhagic fevers (VHF).** This is a family of viruses that can cause a wide range of illnesses. Two of the most common and deadly are the Ebola and Marburg viruses.

Several of the known viruses remaining high on the list of potential biological agents include rift valley fever, eastern equine encephalitis, smallpox, and yellow fever. Genetic engineers might possess the ominous power of being able to modify normally harmless or relatively benign microorganisms. Consider the possible ramifications of incorporating the genetic code for a component of deadly cobra venom into the influenza virus.

BWs have long been detested and seldom used. After the bioterrorist anthrax attacks in the United States in 2001, however, the specter of BWs is difficult to ignore. The anthrax attacks, although only a few were fatal, proved to the American people that biological organisms can be used to attack this country. Also, overnight, there was more awareness about how difficult it is to detect BWs in the environment. This fact makes a lot of people wonder, "What if?" What if anthrax was delivered on a larger scale? What if other bioagents, such as smallpox or the bubonic plague, were somehow released in the United States? Would we be able to fight them? How many people would die before we even realized what had happened? The attacks and release of biological agents put a great deal of fear into many people.

Nations do not readily admit to having BWs in their arsenals. At least five nations have possessed BWs in the past. These nations are Japan, during the 1930s and 1940s; the UK, during the 1940s; the United States, from the 1940s through at least the 1960s; Iraq, in the 1980s; and the USSR, from the 1970s through the 1990s. Although, generally, these BWs are safely stored in high-security laboratories, accidents have occurred. The United States claimed that an outbreak of anthrax in Sverdlovsk in the late 1970s resulted from an accidental release of *Bacillus anthracis* from a nearby Soviet BW research center. Soviet officials vigorously denied the allegation and attributed the outbreak to the illegal sale of contaminated meat. The world learned only in the early 1990s that the Russians had a significant bioweapons program, after inspections by joint U.S.-British scientific teams. Today, the smallpox virus is stored in only two locations. These locations are the CDC, in the United States, and the Russian State Centre for Research on Virology and Biotechnology. The knowledge that the ex-USSR scientists have, however, might cause the greatest concern. With the collapse of the USSR and the resulting economic problems remaining in Russia, some unfriendly countries are recruiting Russian bioscientists to work on BWs. For example, Iran once recruited Russian scientists to work on its BWs program by offering the scientists wages 10 times more than what they received in Russia.

Unfortunately, as the anthrax attacks in 2001 showed, there is no easy way to determine whether or not someone has been exposed to or infected by the anthrax bacteria. Also, it is difficult, if not impossible, to use a vaccine against every possible biological agent. Several companies are jumping into this void. Tetracore, a company that former researchers for the U.S. Navy formed, developed one product, the BioThreat Alert® kit. BioThreat Alert kits can test for the presence of biological agents in less than 15 minutes. This test can be done on-site, rather than in a lab. Cepheid uses another technique for its product, a portable PCR machine used to detect biological agents (PCR is discussed in Chapter 2). This product is more sensitive and can produce lab results on-site in fewer than 30 minutes.

In addition to new products and technologies identifying biological agents, there is research on other ways to combat ***bioterrorism***. Many believe it is more important to prevent a bioattack than to clean up afterward. So, there is an increased emphasis on surveillance and other technologies to make this country

more secure. The Federal Aviation Administration (FAA) has installed new high-tech scanners and chemical-trace detectors in airports across the United States. Also, the FAA is considering new face-recognition technologies to match the faces of air travelers with suspected terrorists on file. This new field, called *biometrics*, will undoubtedly boom, as more products that promise increased security are developed.

The United States has responded to the increased threat of bioterrorism by passing a new law, Project BioShield. This new law dramatically increased the funding to prevent bioterrorism from $290 million in 2001 to over $5 billion in 2007. The goals of Project BioShield are the following:

- ❑ Increased government funding for medical countermeasures to biological agents.
- ❑ Allowing the FDA to make treatments available quickly in emergency situations.
- ❑ The creation of a special reserve fund for the acquisition of countermeasures for biological agents.

Biological agents are relatively easy and inexpensive to produce for any nation with a modestly sophisticated pharmaceutical industry. Research, development, production, and even dissemination of BWs can be disguised as civilian activities or easily kept secret. World leaders cannot afford to wage an adverse biological-arms race. It is essential that all industrialized, as well as developing, nations reaffirm the treaties signed earlier and amend them as necessary to abate the potential for disaster as soon as possible.

Chemical Weapons (CWs)

Chemical weapons (CWs) killed approximately 1 million people during World War I. The Geneva Protocol of 1925 subsequently banned the use of poisonous, asphyxiating, and other gases. This protocol did not, however, ban their development, production, stockpiling, or deployment. Therefore, the United States and other nations continued to produce CWs. Nazi Germany developed a nerve gas much more lethal than the CWs used in World War I. Fortunately, CWs were not used during World War II. During the Nixon administration, the United States reaffirmed its renunciation of the first use of lethal CWs (but excluded tear gas and herbicides) and pledged it would never engage in germ warfare.

CHEMICAL WEAPON (CW)
A weapon using poisonous, asphyxiating, or other gases affecting humans when they are either inhaled or absorbed through the skin.

Shortly thereafter, the United States and the Soviet Union reached an accord on CWs. This was most likely because the unpredictable nature of CWs made both sides hesitant to use them. The United States and the Soviet Union were unable to come to terms on a ban of the production and stockpiling of CWs, however, since they could not agree on a method of verification. The United States stockpiled more than 30,000 tons of chemical warfare agents before production ceased in the late 1960s. Agents included phosgene, hydrogen cyanide, and mustard gas.

CWs, including mustard gas, chlorine, and phosgene, were used during World War I, first by the Germans, and later by the allies. Nerve gases invented in the 1940s include tabun, sarin, and soman. Each is a highly volatile vapor that disperses very quickly. Following World War II, U.S. and British scientists developed VX. VX is a more toxic, persistent, and quite deadly nerve agent.

Each of these poisonous gases affects humans when it is either inhaled or absorbed through the skin. They work by

inhibiting the action of a key enzyme in the body. By name, acetylcholine esterase is critical to the transmission of chemical messages from nerve cells to virtually all muscles in the body. Muscle paralysis ensues. This paralysis causes death by asphyxiation. In nonlethal doses, these chemical agents cause partial paralysis, dizziness, vomiting, and diarrhea.

Nuclear weapons and CWs are similar from the standpoint that their use directly affects civilian populations. CWs cause death among unsuspecting civilians who have no protective equipment. Nerve gases are so dangerous that any leak, spill, or accidental release can devastate life downwind. The uncontrolled spread of nerve agents by wind beyond a specific military-target area could be a particularly serious problem when forces are fighting on their own home territories. Even more frightening, the type of gas masks and protective gear soldiers wear to ward off mustard gas might be useless against new CWs engineered to penetrate even the most tightly woven fabrics and the most impermeable seals and gaskets. Refer to **Figure 10-8.**

The broad spectrum of chemicals on the international marketplace offers serious challenges to the verification, control, and monitoring of CW activities. It does not cost a lot to make CWs. Their manufacture requires minimal technological sophistication. Ironically, in almost every case, the chemicals and equipment required to produce chemical agents of war have legitimate industrial applications. Furthermore, they have become more available as the petrochemical, fertilizer, pesticide, and pharmaceutical industries have multiplied. See **Figure 10-9.**

The issue of CWs was moved to the front burner after Iraq used CWs twice in the 1980s, first against Iran from 1980 to 1988, and then against the Kurds from 1987 to 1988. After the first Gulf War, UN inspectors discovered that Iraq had at least five laboratories developing CWs and BWs. Following the defeat of Iraq during the first Gulf War, UN inspectors uncovered and destroyed all the country's inventory of weapons of mass destruction. These weapons included CWs and BWs. This discovery of weapons was, however, the final step in pushing the establishment and ratification of the Chemical Weapons Convention (CWC). This convention took effect in the late 1990s. Over 183 countries have either signed the CWC or accepted it officially.



Figure 10-8.
Two soldiers adjust their gas masks during a training exercise at Kunsan Air Base, Republic of Korea. (U.S. Department of Defense)

The different technologies used in the battlefield of today present a horrific variety of choices for a country. In the United States, we have been relatively isolated from the direct effects of war. If the future continues in the way it is moving today, however, we will be faced with more opponents from small splinter groups and renegade countries. These groups are more likely to use both BWs and CWs in a battle. In addition to arming ourselves with high-tech weapons, the United States needs to increasingly use diplomatic means to prevent the outbreak of war.

Dual-Use Chemicals		
Precursors for Both Commercial Products and CW Agents		
Dual-Use Chemical	**Commercial Product**	**CW Agent**
Thiodiglycol	Plastics	Mustard gas
Phosphorus oxychloride	Insecticides	Nerve agent
Dimethyl methylphosphonate	Fire retardant	Nerve agent
Thionyl chloride	Pesticides	Mustard gas
Dimethylamine	Detergents	Nerve agent
Tris-ethanolamine	Cosmetics	Mustard gas
Dimethylamine hydrochloride	Pharmaceuticals	Nerve agent
Potassium bifluoride	Ceramics	Nerve agent
Sodium cyanide	Dyes and pigments	Nerve agent
Diethyl phosphite	Paint solvent	Nerve agent
Sodium sulphide	Paper	Mustard gas

Figure 10-9.
A profile of several known dual-use chemicals.

The Nature of War on Tomorrow's Battlefield

It appears, from trends seen today, that both wars and warriors will become more computerized and digital in the future. The increasing use of both smart weapons and computers in all areas will mark this futuristic battlefield. Much of what we know and consider to be the realm of video games will be the reality of the future warrior. Infrared goggles and other night-vision equipment are used today. The future possibilities seem limited only by the imaginations of the engineers and the pocketbooks of the American public because, as weapons become smarter, they also become more expensive.

As we project the future battlefield, we first must envision our future opponents. Today, our most likely opponents are small to midsized countries over which the United States holds technological superiority. Will there be a new superpower in the future? Both China and Russia could, in a few decades, rise to superpower status. Will the United States then be back in a repeat of the cold war? In planning for the future, military engineers must consider all these possibilities.

Innovative Military Vehicles

It takes the DOD many years, sometimes over a decade, to develop a new vehicle. Right now, there are dozens of airplanes, helicopters, and transport vehicles in various stages of design, development, and testing. As the military is forced by shrinking budgets to be more cost-effective, it is exploring new ways to adapt commercial products for military use. One such adaptation is the SmarTruck® III security vehicle. The National Automotive Center, the U.S. Army's center for collaborative development efforts among industry, the government, and universities, developed this vehicle. See **Figure 10-10.** The SmarTruck III security vehicle has many hidden features giving more security. These features include hidden body armor, high-voltage door handles, detection devices, roof-launched grenades, and a roof-concealed laser. The U.S. Marine



Figure 10-10.
Monitor screens inside the SmarTruck security vehicle enable operators to control evasive systems and onboard weapons. (Public Affairs/U.S. Army)

Corps is also adapting a commercial vehicle for military use. The Marines in Okinawa, Japan are testing an electric car Nissan makes, the Nissan Hyper Mini electric car, for use as a vehicle to travel around the base. Although these two examples are only at the test and experimentation stage at this time, they show the type of changes in equipment development that the DOD is undertaking.

Many other vehicles are in the development stage. These vehicles include several different Joint Light Tactical Vehicles that Lockheed Martin and BAE Systems manufacture (U.S. Army); the Small Unmanned Ground Vehicle (SUGV) that iRobot designed (U.S. Army); and the Virginia-class, all-electric submarine (U.S. Navy). In this section, we review three new vehicles at the ends of their development cycles. They are unique in several respects. The Joint Strike Fighter® (JSF) aircraft represents a shift from designing a different plane for each branch of the service to a new plane designed to meet the needs of the three that fly (the Air Force, Marines, and Navy). The Osprey is a hybrid aircraft that can fly similarly to

an airplane, while taking off similarly to a helicopter. This aircraft, similar to the JSF aircraft, is designed to meet the needs of all flying branches of the U.S. military. A new type of aircraft is the unmanned aerial vehicle (UAV). The military is exploring several different types of unmanned aircraft to use in its operations.

Joint Strike Fighter® (JSF) aircraft

The development of the JSF aircraft represents a philosophical change for the DOD. Previously, each arm of the military funded its own development efforts for new aircraft. The JSF aircraft, in contrast, is a family of common aircraft for use by all DOD forces. Each flying branch of the military—the Air Force, Navy, and Marine Corps—will configure the JSF aircraft to meet its own particular needs. See **Figure 10-11.**

There are three different types. The first will be used by the U.S. Air Force and will use standard airfields to take off and land. The second type will be used by the Navy and will be adapted to take off and land on seagoing carriers. The third, designed for the U.S. Marine Corps and the UK's Air Force and Royal Navy, will allow for short takeoffs and vertical landings. The development costs of the JSF aircraft are distributed



Figure 10-11.
The JSF X-35C demonstrator aircraft flew near Naval Air Station Patuxent River, Maryland, in 2001. The X-35C demonstrated the handling and aerodynamic performance required of a JSF aircraft based on an aircraft carrier. Also successfully tested in 2000 and 2001 were the X-35A (conventional-takeoff and -landing version) and the X-35B (short-takeoff and vertical-landing version). The X-35B became the first plane in history to complete a short takeoff, a level supersonic dash, and a vertical landing in a single flight. (Lockheed Martin Aeronautics Co.)

among the U.S. Air Force, the U.S. Navy, and several international partners. The UK was an early participant in the development of the JSF aircraft. Several other countries, however, including the Netherlands, Canada, Australia, Italy, Turkey, Denmark, and Norway, have joined this consortium. Together, these new countries are investing over $2 billion in the JSF aircraft.

The JSF aircraft will use stealth technology to avoid being seen on enemy radar. As part of its development of the JSF aircraft, Lockheed used state-of-the-art manufacturing techniques to build its two prototypes. Two of its partners for this plane, Northrop-Grumman and BAE Systems, developed new composites and flexible tooling for the manufacturing of this fighter. The F-35B is the short-takeoff and vertical-landing model of the JSF aircraft. This model's first test flight was in 2008. The DOD expects to buy over 2800 planes through 2040, at an estimated cost of $40 to $50 million each.

The Osprey

The Osprey uses tilt-rotor technology. This aircraft takes off and lands similarly to a helicopter. The Osprey flies, however, similarly to a plane. This aircraft will be used to replace the Marine Corps fleet of Vietnam-era helicopters and can be customized to meet the needs of a particular branch of the service. See **Figure 10-12.** The Marines plan on using the Osprey to transport up to 24 troops or a 15,000-pound load at one time. The U.S. Navy plans to use the Osprey



Figure 10-12.
An MV-22 Osprey tilt-rotor aircraft lands at the Pentagon. (U.S. Department of Defense)

for search and rescue missions, air refueling, and medical evaluation. By the early 2010s, the Navy and Air Force are planning on purchasing 50 Ospreys each. The Marines plan on acquiring 360 Ospreys.

Despite the advantages the Osprey offers, its path to full use in the military has not been smooth. Two crashes in 2000 killed 23 Marines. In addition, there have been other technical and performance issues related to the design. The Osprey is back to flight-testing to determine if all the problems have been solved. In 2005, the DOD finally approved the Osprey for production. The DOD plans on buying the planes for a cost of $110 million per aircraft.

Unmanned aerial vehicles (UAVs)

UAVs are unpiloted aircraft. These vehicles are currently used in a number of ways, including reconnaisance, surveillance, and attack. They are also used in the civilian world in law enforcement, to protect our national borders, and in fire fighting. A UAV was used in the late part of the first decade of the twenty-first century to help firemen track a wildfire in southern California. The Scripps Institute of Oceanography used a fleet of UAVs to collect air samples over the Indian Ocean. In general, UAVs are used when a human operator would be at risk.

The U.S. military used UAVs extensively in the middle of the first decade of the twenty-first century in Iraq. The Predator is a UAV that the U.S. Air Force uses for surveillance and reconnaissance. This UAV can transmit real-time imagery of the battlefield to tactical commanders through its radar, video cameras, and infrared devices. The Predator can also be armed with Hellfire® missiles. The missiles can be fired remotely to hit ground targets. The military also uses small UAVs such as the Raven. This vehicle has a 5′ wingspan and is about 3′ long. The Raven is a 4-pound aircraft that can be carried in a backpack and launched by hand. See **Figure 10-13.** The Raven provides immediate information to the ground troops about the enemy's location. Each Raven costs $35,000, in addition to $250,000 for the Raven support system of three aircraft, a ground control station, and support services. The Raven is the most used UAV because of its low cost and portability.

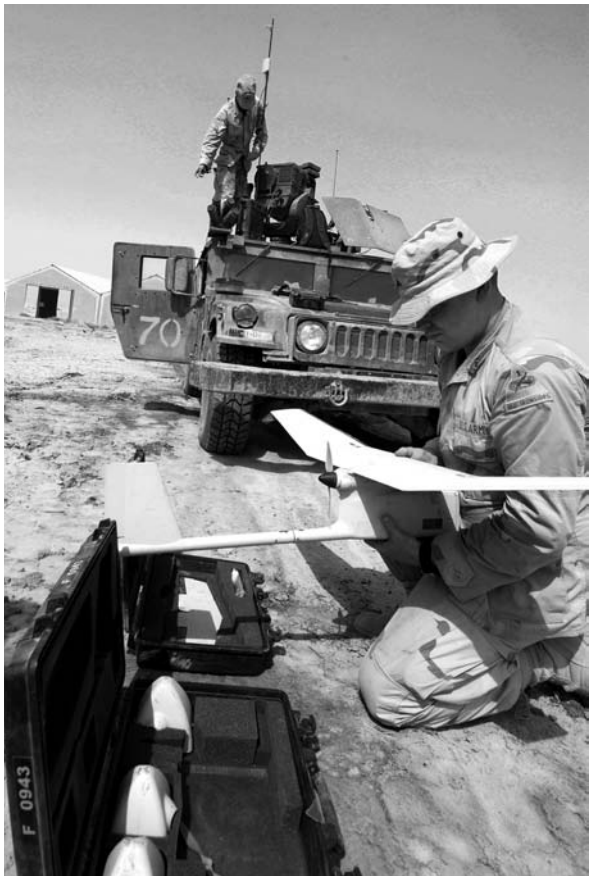


Figure 10-13.
A soldier assembles an RQ-11 Raven® UAV in order to conduct aerial tactical reconnaissance in Taji, Iraq. The Raven airplane has video cameras located on the nose cone and can relay live video back to the operator in real time. (U.S. Department of Defense)

Ballistic Missile Defense (BMD)

As threats from rogue nations seem more likely, there is an increased emphasis on defense. The concept of a nationwide missile defense was first floated by past President Reagan and dubbed "the *Star Wars* Project." The extent to which scientists and technologists will ever be able to fulfill his vision of an "impenetrable shield" remains a question.

Despite the millions of dollars invested in SDI projects, doubts about the SDI surfaced years ago, shortly after its inception. Scientists, technologists, and laypeople began to realize the impractical nature of critical SDI projects. Various aspects of the perfect space-based nuclear shield either defied the laws of physics or relied on weapons easily neutralized by enemy countermeasures (loads of sand could be hurled onto the surfaces of highly polished mirrors, reducing the mirrors' ability to deflect powerful laser beams toward targets). Over the years, however, SDI gradually lowered its sights and managed to stay afloat through a quiet, almost unnoticed evolution. Today, the SDI has been transformed into the MDA program. This new program is the result of almost two decades of R&D efforts. In the mid-1990s, then–Secretary of Defense William Perry decided to upgrade the national missile-defense efforts from technology R&D to the development of a usable system. After becoming U.S. President in 2000, George W. Bush decided to continue to work on this system and attempt to have a preliminary missile-defense system in place by 2005. The MDA has two main goals:

- To defend the United States from an attack from ballistic missiles.
- To develop and implement a Ballistic Missile Defense (BMD) system. This system will include ways to intercept missiles at all stages of flight.

The *Dateline* section in this chapter describes a test of a BMD system. The planned BMD system will be land based. This system will, however, include detection satellites in space. The ground-based interceptor is the missile that will be launched to kill an incoming missile. See **Figure 10-14.** Also, there will be ground-based radar systems and space-based infrared satellites. Tying this all together will be a complex C^3I arrangement that will act as the brains of the system. In addition to building on the technologies developed for SDI, this project is based on the Arrow Program. Israel and the United States have jointly developed the Arrow® interceptor, an experimental antitactical ballistic missile (ATBM) to intercept the Scud as well as other intermediate-range ballistic missiles.

In order to continue development of the BMD system, the United States withdrew from the 1972 ABM treaty between the USSR (now Russia) and the United States. This treaty prohibits the development and deployment of strategic missile-defense systems. Now that the United States is no longer bound to the prohibitions of the ABM treaty, it is moving forward with an even more ambitious plan for missile defense. As defense of the U.S. homeland continues to be a pressing political issue, there will be continuing efforts and money spent in this area.

Directed Energy Weapons (DEWs)

Strictly speaking, lasers are not a science fiction weapon of the future. Operation Desert Storm demonstrated the value of lasers in guidance systems for precision missiles. It is possible that lasers and Neutral Particle Beams (NPBs) might soon emerge as precise, deadly weapons in their own rights. The antipersonnel use of contemporary lasers is indeed frightening. Modern tanks are



Figure 10-14.
The U.S. Navy used a single modified tactical Standard Missile-3 (SM-3) to destroy a nonfunctioning National Reconnaissance Office satellite approximately 247 kilometers (133 nautical miles) over the Pacific Ocean, as it traveled in space at more than 17,000 miles per hour (mph). Then-President George W. Bush decided to bring down the satellite because of the likelihood that the satellite could release hydrazine fuel on impact, possibly in populated areas. (U.S. Navy)

equipped with laser range finders. These range finders are capable of blinding anyone unfortunate enough to view the laser from the downrange side. A weapon more than a mile away can permanently blind soldiers and aviators in a period of time measured in nanoseconds.

DOD researchers are presently engrossed with three directed energy weapon (DEW) projects: the Airborne Laser, the Active Denial System, and the Tactical High Energy Laser (THEL). DEWs might someday function in a strategic defense system as weapons to be used against missiles in their boost phases. Modified versions of THELs might be useful against cruise missiles, tactical missiles, and aircraft. Space-based lasers and particle beams are projected to be able to examine a large array of threatening objects and discriminate among warhead reentry vehicles, decoys, ***chaff***, antisatellite weapons aimed at themselves, sensor satellites, space mines, and junk. Smart DEWs will be able to identify, attack, and destroy targets without human intervention.

Chemical lasers

The idea of a space-based chemical laser that could shoot down missiles in their boost phases was one of the first options DOD researchers explored. Chemical lasers produce power as a high-energy beam of concentrated light. The beam is derived from a chemical reaction of the hydrogen fluoride (HF) compound. This compound is used as rocket fuel. HF lasers are the most mature DEWs. They require large mirrors to direct lethal laser power to targets thousands of kilometers away. The Air Force Research Laboratory recently created a new chemical laser combining three gases—chlorine gas, hydrogen peroxide, and potassium hydroxide—and iodine. This laser is not ready to be used as a weapon, however, as scientists estimate it will take at least five more years to make it into a weapon.

Free-electron lasers (FELs)

The word *excimer* is an abbreviation for *excited dimer*. A dimer is a pair of linked atoms. Free-electron lasers (FELs) are described in terms of radiation that electrons accelerated in a magnetic field emit. Short wavelength beams are emitted when the dimer's bonds are broken. An excimer laser, or FEL, emits beams strong enough to disable an enemy missile in a few seconds. The primary components of the FEL are an accelerator, a device producing a varying magnetic field to change the direction of the electrons (called the *wiggler*), an optical-beam line, and an output mirror. R&D on FELs is still somewhat new, by comparison to HF DEWs. Design issues still being ironed out include the complexity of the accelerator and scale-up of the technology from low-power to high-power devices. Scientists believe FELs, besides being space based, could also be mounted on ships, on aircraft, or at ground bases to attack cruise missiles, tactical missiles, and enemy aircraft.

Neutral Particle Beams (NPBs)

This high-tech weapon uses accelerators developed for experimentation in high-energy physics to produce high-current, high-energy beams of neutral hydrogen particles. NPBs can propagate through space without being deflected by Earth's magnetic field. Researchers envision NPB devices to fire a beam of fast-moving atomic particles at incoming warheads. The beam shears through the warhead and scrambles its electronics so the nuclear weapon housed inside cannot explode. NPBs would pass right through ***decoys***, while the heavier warheads are absorbing them, essentially allowing them to weigh objects in space. Developmental research in these and other evolving DEWs is expected to continue into the next few decades.

The Information Warrior

The warriors of the future will not have to depend on brute force to get their jobs done. Today, the DOD is seeking to transform the soldier into an information warrior. The U.S. Army is taking the lead in the integration of computer technologies and other ITs into the battlefield. One new IT resource is the Force XXI Battle Command Brigade and Below (FBCB2) system. See **Figure 10-15.** Inside each vehicle, there is a digital map showing the locations of all friendly and enemy forces. This map includes a GPS chip, as well as a message system. The commander can send messages to either one particular vehicle or the entire platoon. If an individual vehicle spots an enemy vehicle, the crew can target the enemy vehicle with a laser. Automatically, the vehicle will appear on everyone's screen as an enemy. The FBCB2 systems are installed on the Abrams tanks and Bradley Fighting Vehicles.

The U.S. Navy is also moving toward the digital future. The Navy has developed a new WAN, named *WARnet*, to assist it in this transition. WARnet is a wireless network that can provide for ship-to-shore and ship-to-ship communications in a 100 × 200–mile area. A variety of vehicles, including planes, helicopters, ground vehicles, and UAVs, carry the nodes in the wireless network. (For a discussion of wireless networks, see Chapter 3.) All the information from WARnet flows into an offshore headquarters



Figure 10-15.
Two Army soldiers monitor the FBCB2 and Remote Weapons System screens while looking for enemy contacts during a training exercise. (U.S. Department of Defense)

located on a battleship. There, the commander can see what is happening on an immediate basis and make quick decisions about the sea operation.

In addition to battlefield uses, the military is integrating computer technologies into its training. The Marine Corps is using virtual reality to improve the training of trainees. Trainees wear a head-mounted computer display as they practice their firing abilities. The display interposes objects onto the real-world landscape. The instructors use portable computers to move virtual targets. The trainees shoot at the targets.

The Defense Advanced Research Projects Agency (DARPA) is exploring even more fantastic technologies for the future. One DARPA-funded project is to develop an information-rich exoskeleton for the soldier of the future. Instead of relying on a vehicle for support, enhanced soldiers would have their heavy weapons, armor, and advanced electronics fastened to their exoskeletons. This exoskeleton is remarkably similar to the long-term view of the future from the mid-1990s film *Aliens*. Sigourney Weaver's character straps herself into an industrial exoskeleton to do battle with the alien in this film. Other DARPA-funded projects are a Nano Air Vehicle (NAV) Program, to develop an extremely small (less than 2") ultralightweight UAV, and the Z-Man Program, to develop climbing aids that allow soldiers to climb buildings without ropes or ladders.

The battlefield of the future will certainly contain more information and automation. At the same time, however, the soldier of the future will have to face foes who will likely use high-tech weapons. As U.S. troops become more dependent on ITs, they will become more likely to feel the effects of the loss of this information. Just as computer hackers can disrupt a network, a military hacker can cause a threat to the soldier.

This entire issue of cyberterrorism is a new one. ***Cyberterrorism*** can refer to the disruption of military information, as well as to the disruption of information in our homeland. Imagine the chaos that could result if a foreign terrorist was able to control the stock market electronically or destroy files held in a company's or the government's computers. We have not yet seen these types of attacks from foes. There is little doubt, however, we will in the future.

The Business and Politics of Defense

The astronomical costs associated with military policy and national security make international defense "big business." Without question, the military-industrial complex is an economic giant not to be ignored. This final segment of the chapter takes a very brief look at a few topics influencing future trends in defense spending. These topics include DARPA, black-budget projects, the START treaties, and the greening of defense contractors.

In the early 1990s, four strategic modernization programs seemed to form the cornerstones of the U.S. defense package. These programs were endorsed for their capacities to provide effective deterrents against missile attacks and give our troops greater capacities to respond to attacks elsewhere around the world. Specifically, these big-ticket items included the MX missile, the Midgetman missile, the B-2 stealth bomber, and the SDI. Two short years later, on the heels of the Soviet breakup, the U.S. defense budget called for the curtailment of the B-2 and Seawolf nuclear-powered submarine. The administration capped the Advanced Cruise Missile Program and abandoned production of the W88 warhead for the Trident II missiles.

As with any large-scale program wishing to keep R&D dollars flowing, the Missile Defense Program has modified and changed its goals as it went along. The contemporary justification for missile defense is that MAD might not deter emerging nuclear powers. We also hear arguments regarding the potential for dual-use benefits (spin-offs) of missile-defense technologies. Created by the Pentagon in the late 1950s, DARPA has become something of a technology-mission clearinghouse. DARPA's current thrust of operation centers on the 2–10 year kind of projects having the potential, with some risks, to have tremendous social impacts. DARPA is often credited as the entity most directly responsible for the whole field of AI, interactive computer graphics, computer-security technology, time-sharing networks, materials science, and the fields of high-definition television and supercomputing.

Less visible to the general public is a host of projects funded through the black budget, the President's secret treasury. This secret source funds all the military activities that the President, the Defense Secretary, and the Director of Central Intelligence prefer to keep hidden from public scrutiny. The black budget pays for weapons to keep the cold war won, as well as to fight World War III—and World War IV. Three such projects released for public view, after spending at least 10 years as black-budget items, include the stealth bomber; the Military Strategic, Tactical, and Relay (Milstar) system; and the Advanced Cruise Missile. The stealth bomber is probably the most expensive secret weapon since the Manhattan Project's first atomic bomb. The black budget began with the decision to build an atomic bomb. This budget remains alive today, concealing many projects bearing innocuous code names. Amidst the throes of a Soviet breakup and Third World tenacity, it is unlikely that these black-budget items will be dismissed or revealed to us any time soon.

On the brighter side, both the United States and Russia have agreed to further reductions in intercontinental missiles. In 2000, the Russian parliament approved the START II treaty. This treaty was signed in the early 1990s by former Presidents George Bush Sr. and Boris Yeltsin and ratified by the U.S. Senate in the mid-1990s. The Russian ratification was the culmination of almost 20 years of negotiation and work. The START II treaty requires both the United States and Russia to reduce their ICBM arsenals to, at most, 4250 missiles in each country. This is a major reduction from the 10,000 each country had in the early 1980s. In the early 1980s, START II negotiations began. The newest nuclear-weapons treaty between the United States and Russia—the Strategic Offensive Reductions Treaty (SORT)—signed in 2002, will cut the existing store of nuclear weapons by about 65% by the early 2010s. Instead of specifying which weapons to cut, however, this treaty lets each country choose which nuclear weapons it wants to keep. In 10 years, each country will have between only 1700 and 2200 warheads in its arsenal, a dramatic improvement, but still more than enough to cause massive destruction.

As far as the development of new technologies themselves, we are beginning to witness a slight "greening" of defense contractor industries. Ultimately, the military budget will be pared down—by how much and how quickly remain debatable. Political battles are likely to ensue between those congressional leaders who have major weapons programs in their states and others who depend minimally on the military-industrial complex. Concern over increased unemployment and loss of revenue as more weapons programs are curtailed and more armed forces bases are closed has inspired some aerospace companies, such as TRW, to direct their research proficiencies toward non-defense-related projects. It has been argued that pollution constitutes another

threat to national security. One senator managed to earmark $200 million of the Defense Department's budget for research on environmental cleanup. The Pentagon is reportedly developing a list of projects it might be willing to take on. Let's hope that the disposal of CW stockpiles and cleanup of nuclear-waste sites manage to make its agenda.

Summary

We find ourselves living precariously amidst a vast array of technological conveniences in the shapes of PCs, CD players, portable telephones, wonder drugs, nutritionally enriched foodstuff, and superior optical devices. The same basic research that delivered several of these items to your household is, in many ways, responsible for the looming specter of our strategic defense technologies. This chapter addresses the topic of national security as this security relates to international defense strategies and policy making.

The world has witnessed the end of a cold war era and the disintegration of the USSR. Nuclear weapons have symbolically become the icons of war and peace at the same time. We have lived through policies of massive retaliation, MAD, and strategic defense dominance. Perhaps a posture of minimal nuclear deterrence is our only option for a secured global community.

Weapons of the type described in this chapter really do exist. They are not a figment of our imaginations. Government leaders seem to view their military arsenals as necessary forces their constituents have given them the authority and responsibility to discharge if needed. Perhaps we can hope to cut the number of weapons to the absolute minimum and avoid future deployments whenever possible. Minimal deterrence as an international-defense posture might not be the ethical, moral, or intellectual choice of all people. This deterrence might be, however, the only choice we have. Combined with a healthy infusion of cooperative diplomacy, this should preserve the peace, making the world a safe and secure place to live.

Discussion Questions

1. Briefly describe each of the four rationales provided when a country decides to use aggressive military force. Make an attempt to provide contemporary incidents as illustrative examples of each scenario.
2. What is the purpose of the SIOP in the United States? How might the SIOP's officials make the distinction between counterforce and countervalue targeting? Provide examples of hard and soft targets in your response.
3. How do you feel contemporary government leaders should go about redefining nuclear policy into the next century? Factor the Soviet Union's disintegration and the waning of the cold war into your response.
4. List and describe the key characteristics of what the Pentagon refers to as *MICs*.
5. Comment on the ethical and moral issues associated with the following:
   a. Accepting paid employment as a cruise missile technician in the defense industry.
   b. Conducting laboratory-research experiments to build better bombs.
   c. Carrying out battlefield orders calling for the use of biological or chemical munitions.
6. What steps can you individually take to reduce the possibility of a terrorist threat? What should the country be doing to attack terrorism? How does technology fit into your plans?

Suggested Readings for Further Study

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Chapter 11

Social Response to Technological Change: Breakthroughs and Risks

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DATELINE

Pikeville, Kentucky

Students attending Pikeville College carry "very smart" ID cards in their wallets. In addition to having a unique Pikeville College ID number, each student has a personal library number and an individual 16-digit ISO number. The ISO number is the main identifier of the SmartCard system around the world. Contact smart cards contain a single, imbedded, integrated circuit chip that contains just memory or memory plus a microprocessor. These cards require some type of reader device. Contactless smart cards attach imbedded antennas to their chips and need only be passed within range of a radio frequency acceptor to read and store information on the chip.

At Pikeville College, the SmartCard includes a chip that allows for multiple electronic cash holders, loyalty files, and security keys. Students use their cards for meal plans, vending, computer-lab printing, bookstore purchases, library books, and access to locked buildings. The SmartCard is also a debit card, to which money can be transferred and later spent in vending machines. Although there are still uses for the traditional magnetic-stripe cards, smart cards can store 150 times more data and are believed to be more secure with data encryption.…

Introduction

Contemporary S & T have created the amenities of modern civilization. In countless ways, each has increased our capacities to control environmental forces and given us visions of an even more prosperous future. Undeniably, S & T have also increased both our dependence on the numerous inventions and innovations they have produced and our uncertainties about the future. While we might have increased our abilities to understand, predict, and control the natural environment around us, we might have actually lost the capacity to control the technologies we have created to help us along the way.

The impact of technology on society at large has been a prevalent theme in social, economic, and political thought for decades. Numerous essayists have debated about the extent to which continued technological growth will enhance or hinder the survival of the human race. A diverse collection of writers has drawn our attention to the increasing complexity and rate of technological change in contemporary society. They seem to be continually making projections filled with varying degrees of alarm. Their publications present the specter of an increasingly uncontrollable technology spreading similarly to a cancer among the population. Technology's consequences cannot always be assessed or accurately predicted. We are led to infer that the human race is on a collision course with ruin and imminent destruction.

On one side of the debate, some social scientists, policy makers, and technologists take the position that society should critically examine the role it wants technology to play and then take action to curtail technology's destructive tendencies. On the other side, similar groups of professionals assert that more scientific and technological research (knowledge and information) is all that is

required to cure all of society's illnesses. In some ways, the debate seems to be perpetuating itself.

While the rhetoric continues, we are living amidst an array of technologies that some people contend are simply accidents waiting to happen. When the dark side of technology reveals itself, when disaster hurts innocent bystanders, and when technology causes more problems than it solves, society often points the blame at technology's creators. When accidents do occur, the general public shakes its head while wondering what is happening to its "technological fix." Regardless, there is little chance the industrialized nations of the world will turn their backs on the promises aligned with new technologies. We have all chosen a lifestyle sustained by high technology, but that does not mean we are not apprehensive about it.

Many people of your grandparents' and even your parents' generations were, for the most part, blissfully unaware of the potentially harmful effects of man-made chemicals on themselves and the environment. They were unconcerned about the finite nature of the raw materials and resources being depleted to fuel technological progress. These days, as our reliance on S & T intensifies, we have begun to worry about the effects of acid rain on our lakes and forests. We worry about the future consequences of the buildup of CO_2 in the atmosphere and what is happening behind the closed doors of weapons research laboratories. Many of us are fearful that chemical dump sites might be leaking into our supplies of drinking water. We also worry about which foods are safe to eat and which drugs are guaranteed to not have harmful side effects on our offspring. Many of us experience anxiety regarding identity theft and the security of our confidential documents. It seems that a greater amount of information, regarding all the technological conveniences we take for granted, has most directly created a higher level of social paranoia. Even more so in the aftermath of the terrorist attacks on the United States, people are looking to technological solutions to protect themselves from deadly biological and chemical agents.

Further, as the demand for energy to drive the massive engines of S & T increases, so too does society's concern about the sources of future supplies and the ramifications of exploiting our current energy technologies. These anxieties range from concern over the disposal of radioactive wastes to worrying about the political and economic consequences of our dependence on foreign oil. (Some of our dependence on Middle Eastern suppliers might be linked to the root cause of several of our contemporary military battles.) None of these issues comes with a handbook, a set of instructions, or a glossary of terms to chart a definitive course of action for all humanity. Technological growth is replete with a series of uphill struggles—but then, it always has been.

The current international proliferation of technologies has led to an exponential widening of risk for all of Earth's inhabitants. The social excuse of being "an innocent bystander who is not responsible for technology" is severely outmoded. The concept of universalism is more evident today than ever before. This characteristic of modern technology refers to both an interdependence among nations and the diminishing number of unaffected cultures. Technological developments and the risks associated with them do not exist in a vacuum. For example, an accident in a nuclear power plant located in one country might, indeed, have negative consequences for people residing in a neighboring country. The effects of airborne radioactive contaminants do not simply stop at the border.

This chapter is structured to assist you in your evaluation of how technology and its associated risks affect all social groups—regardless of their level of technological development. The various sections present some of the issues pertinent to society's capacity to accept technological change and simultaneously take responsibility for the by-products of this change. It is next to impossible to precisely distinguish a "good" technology from a "bad" one. Yet, if society expects to benefit from the fruits of its scientific and technological labor, it must retain the strength and ethical conscience to control and direct the course of its activity. In order to keep S & T on track, it is necessary to conduct routine risk-benefit analyses, blended with a heavy dose of information, logic, and common sense. Throughout this chapter, the following questions are addressed:

- ❑ What are the implications of the accelerating rate of scientific and technological change for society at large?
- ❑ Are there any particularly effective strategies we can use to cope with the pitfalls associated with social lag?
- ❑ Is society "at risk," by virtue of its ever-increasing dependency on the fruits of technology and science?
- ❑ How does the concept of technological illiteracy fit into the threads of our contemporary social fabric?
- ❑ Is it plausible to trust the experts' abilities to carefully scrutinize the development of new technology in order to ascertain whether or not it should be endorsed or abandoned?
- ❑ Should these technowizards be authorized to decide whether or not the inevitable risks outweigh any reasonable benefits, with reference to unproven technologies?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

busyness syndrome
durational expectancy
information overload
quality of life
response mode
risk-benefit analysis
social lag
technological literacy
technology accordance
technology trap
technophobia
technostress
universalism

The General Nature of Change

The key word in the title of this chapter is *change*. The next word, based on its level of importance, is *response*. Before attempting to discuss response modes that social-group members rely on to deal with change, it is essential to understand the meaning of the elusive construct, or term, *change*. In the simplest terms, change has been the only constant throughout history. In essence, change is constant, progressive, and universal. Change is not always as great or far-reaching as we sometimes imagine it will be. To repeat a timeless phrase, the more things change, the more they stay the same.

If these assertions are valid, why do people fear change? Why do social groups band together to fight against change? Why do some individuals feel inclined to avoid making changes at any cost? Why do some professionals insist on saying things such as, "I don't mind progress, as long as

I don't have to change!"? The word *change* produces emotional reactions, since it is not a neutral word. To many people, change is threatening. Without any sort of modifier, the word *change* promises no respect for present cultural values. Change might even disrupt these values.

In some instances, the mere mention of a proposed change conjures up visions of revolution, dissatisfaction, and discontent. More inoffensive words referring to the process of change include *education*, *training*, *modification*, *orientation*, *guidance*, *indoctrination*, and *therapy*. We are much more amenable to a situation where others *educate* us, versus one where others change us. Many of us tend to feel less guilty if we view ourselves as *training* other people, rather than changing them. These substitute words are safer or less emotional, which is why they are more tolerable. At first glance, they carry the implicit assurance that the only changes produced will be good ones, compatible with society's current value system. Unlike the assortment of synonyms presented above, the word *change* is crisp and directional. This word is not lost in the translation of a phrase or couched in preconceived expectations.

Take a moment to reflect on your personal ability to confront changes head-on and deal with them as they surface in your daily living arrangement. Within a very short period of time, it should become obvious to you that there are two basic forms of change: "theirs" and "ours." This might provide a basis for the fact that society's feelings about change are often contradictory. On one hand, we welcome change, and on the other hand, we fight against it. We acknowledge "our" individual rights to stimulate change, but we oppose "their" rights to force us to accept changes we do not fully sanction. See **Figure 11-1.**

Social groups display an uncanny ability to cope with adversities. They have a great deal of difficulty, however, coping with uncertainties. The uncertain element of change is frightening and often threatening. Uncertainty suggests change beyond our control. This implies a union between uncertainty and "them."

One tenet of social behavior states that, if you want people to be supportive of a change, you should make them believe they had a part in bringing it about. Consider the production manager who makes the decision to move the hourly employees' break period from 10:00 AM to 10:45 AM. Rather than adamantly posting this announcement in an autocratic manner on the bulletin board next Monday morning, this person would be wise to involve all those who the change affects in the decision-making process. The main objective should be to convince the employees the following:

- ❏ The change will be beneficial to them.
- ❏ Their input is valuable.
- ❏ They possess a measure of control, with regard to their working environment.

Although it is not always possible to be in total command of changes affecting our lives, it is possible to assume a profile of readiness. Readiness to make changes implies a willingness to take charge of any number of unanticipated situations. This willingness does not imply wimpy behavior. A period of ***social lag***, which often varies based on the perceived severity of the changes at hand, generally accompanies a lack of readiness. We really do have the capacity to make "their" changes our own if we keep abreast of developments taking shape each day. The real challenge in the modern world is not so much related to a willingness to accept change, but to the speed with which we are willing to do so.



Figure 11-1.
Numerous peace demonstrations were organized during the late 1960s and early 1970s. These activities often revealed that the legal sector of society does not always sanction personal beliefs. The original caption for this photo taken in 1970 read "Protestors were herded by police up California Street in San Francisco into the main line of march. An estimated 5000 persons gathered in front of the Fairmont Hotel to protest the visit of South Vietnam's Vice President, Nguyen Cao Ky. Small outbursts of violence occurred when police attempted to clear various adjacent areas." (*Spartan Daily Newspaper*, San Jose State University)

The Pace of Change

If you have ever had the occasion to eavesdrop on a lively discussion in which the participants were reminiscing about the "good old days," the chances are that at least one of the members said something about the pace of change. When people reflect on the past, they have a tendency to recall the events from a nostalgic or sentimental perspective. They remember that people seemed to be less harried and that technical changes appeared to occur at a much slower rate. It is typical to view the changes that took place in S & T a few decades ago as evolutionary and to describe the ones happening right now as revolutionary.

We, as a society, are bombarded with marketing phrases such as "new and improved," "now with even more power," and "hurry, offer ends Friday" on a daily basis. We have become accustomed to this hectic pace of change, but not everyone is able to tolerate it. Technology in all disciplines is changing so quickly that individuals often believe that, if they understand certain information today, it must be obsolete. In other words, technological advancement has accelerated to a point such that a span of a few decades can easily contain more developmental breakthroughs than a span of several hundred centuries.

Some futurists tell us that the breakneck speed at which S & T changes will occur within the next couple of decades will make today's stride seem similar to a snail chasing a turtle. In the 1970s, Alvin Toffler's critically acclaimed *Future Shock* cautioned us about the physiological and psychological maladies people experience when they are forced to deal with too much change too quickly. Toffler introduced us to novel phrases such as *information overload*, *durational expectancy*, and *throwaway society*. Each of these concepts is directly related to society's acceptance of change and capacity to assimilate change very quickly.

On a personal level, ***information overload*** refers to an individual's inability to think clearly due to an excessive amount of cognitive stimulation. Overloading the human nervous system with too many bits of information (stimuli) at one time causes a breakdown in performance and logic. Very recent studies have shown that the simple act of speaking on a cellular phone while driving impairs the driver's performance behind the wheel. When this type of system demise is examined on a social level, data seems to imply that society does not respond well to what might be described as an information explosion or multisensory stimulation. Once again, the element of speed surfaces through the choice of the word *explosion* to describe a social condition. As change continues to accelerate in society, it forces a parallel acceleration within each of us. Each time that new information reaches us, we are pressured to revise and update our master image file folder. More comforting images are continuously replaced with newer, less familiar items.

Some of our capacity to tolerate the pace of change in our daily lives has its roots in our earlier childhood years. From the moment of birth, humankind's perception of time is closely aligned with an internal circadian rhythm (a biological cycle recurring in 24-hour intervals). The manners in which people respond to time, however, are culturally conditioned. One of the first things a child learns about time involves an understanding of how long things last. This knowledge eventually leads to the formulation of a vast array of what Toffler labels ***durational expectancies***. Young children are quick to learn that "in a few minutes" means something more immediate than "the day after tomorrow." Parents often explain the concept of tomorrow by making reference to the activity of going to bed at night and waking up again the next morning—that is tomorrow. For very young children, the concept of yesterday refers to every day they have been alive.

As adults, virtually all our activities are based on certain assumptions or expectations about durations. We expect a visit to the dentist to last longer than a trip to the post office, but shorter than an excursion to the theater. We make assumptions about the relationships we have with certain individuals—indeed, we believe some interpersonal agreements (marriage) are supposed to last a lifetime. Durational expectancies differ from one culture to another, but they tend to be deeply ingrained into the pace of life. When the pace of change is altered, these durational expectancies are shaken. For example, how long do you expect the investment you made in the purchase of your laptop computer to last? Chances are that you are thinking in terms of years, versus months. The resultant social response to either an accelerated or even a decelerated rate of change ranges someplace between immediate adaptability and an acute withdrawal from reality.

Those people who adapt quickly to changes in their lives have most probably internalized the principle of acceleration. An individual who anticipates that certain

situations will endure for shorter periods as time passes is less likely to be caught off guard than someone whose durational expectancies are intractable. The pace of technological change in today's world is such that many of us wonder if the word *permanence* should even be included in the dictionary.

Human beings have apparently begun to resign themselves to the notion that their relationships with certain items are increasingly ephemeral. The fleeting nature of the vast number of technological convenience products in the home is further testimony that we have become a throwaway society. See **Figure 11-2.** Some parents are actually quite reluctant to allow their children to view early-morning or after-school television programs, for fear that the children will discover that an "even more challenging" electronic plaything has supplanted their newest wonder toy. Household consumers invest in new appliances that do everything short of eating their food for them, only to be informed in the following week's news magazine that the particular model they purchased is already obsolete. Some technology skeptics sit back and wait for a newer model, believing it will ultimately cost less and perform more tricks. In the interim, these hesitant consumers observe with envy the conveniences they are missing. Neither of these situations seems very pleasant.

Regardless of your ability to deal with an accelerated rate of information overload in a world where obsolete technologies prevail, you cannot deny the fact that the relentless pace of change gets trying at times. Most of us experience the need for a rest periodically, but we seem to rejuvenate ourselves quickly, in order to jump back into



Figure 11-2.
A stroll down the paper-products aisle of your local supermarket or drugstore provides numerous examples of disposable items taken for granted and purchased as a matter of course in our society. These items provide a measure of convenience, but they also reinforce the short-lived nature of many products in our homes. (Jack Klasey)

the fast lane. While many social observers spend their time discussing the ailments associated with erratic change, a considerable segment of modern civilization seems to thrive on it. The increased conveniences that scientific and technological advancements afford have seemingly produced a culture of quickness.

Instant Gratification and the Busyness Syndrome

Do you remember the timeless cliche that says, "Good things come to those who wait"? How do you think the busy corporate executive on the fast track to success would respond to that suggestion these days? Contemporary American society is caught up in the need to be busy all the time and has no time to wait for anything. In response to the spirit of constant movement, S & T continually provide numerous artifacts designed to meet our desire to have something called *it all*. Having "it all" generally includes a highly respected college degree, an upwardly mobile career, a warm and fulfilling family life, a lean body, and an influential status in one's local community. To be well-off on all fronts, one must be outwardly busy at all times. Our fast-paced society is ill bent on instant gratification and terrified of having nothing to do. What a paradox!

The modern technological household in the United States is a resplendent island of convenience. A quick stroll through the high-tech kitchen reveals a digitized dishwashing machine and a microwave oven that talks to you. You might even spot a personal laptop computer, linked to the Internet and perched on top of the butcher block, that plans meals; provides nutritional information; and guides the user through the necessary calculations to scale down a recipe that serves 12, in order to prepare dinner for 2. See **Figure 11-3.**



Figure 11-3.
The use of a PC in the kitchen is no longer an exceptional scene.

If you stop to glance into the broom closet, you might spy a power-driven vacuum cleaner and an iron that shuts itself off automatically. The modern bathroom is also devoted to satisfying a number of contemporary pleasures—for instance, the bathtub complete with multiple Jacuzzi® jets; a mirror framed with three different types of lighting; a water-resistant radio mounted in the shower for listening to the news, rather than reading the newspaper; a microprocessor that controls the scale to announce the owner's weight in a digitally synthesized voice; and a classic English heating unit to warm the residents' towels while they sleep. The medicine cabinet is full of remedies for one ailment or another, and each of them promises "fast" relief. Who would purchase an aspirin-like product that insists it will "slowly remove those aches and pains from your tired body"? Are you kidding? This is the era of instant gratification!

Another island of technological wizardry is encased in what is fondly referred to as the *home entertainment center*. See **Figure 11-4.** This center makes one stare in awe, as the CD player; digital videodisc recorder (DVR); digital videodisc (DVD) player; and remote controlled, 50", flat-screen, high-definition plasma television with a surround-sound system reside in harmony along a portion of the wall of a normal-size room. The high-tech entertainment center certainly entertains its owners. This center enables the viewer to watch two programs at once, record a third one, and preview the highlights of a live football game in a small insert found at the lower corner of both screens! This certainly sounds very similar to information overload, but it also provides a great deal of instant gratification.

Along a slightly different vein, Americans might still value such business ethics as courtesy, reliability, and economy, but what really impresses them is speed. We demonstrate this through our affinity for



Figure 11-4.
An entertainment center featuring a flat-screen, high-definition plasma television.

such things as one-hour photo-developing services, instant replays, memory-redial telephones, and posh suntanning parlors. After all, tanning the old-fashioned way takes too much time! Americans value speed, and a number of U.S. corporate empires were established for all these people who like to be in a hurry (McDonald's, Federal Express, Domino's Pizza, and Polaroid). Advertisements for smaller convenience stores criticize full-service grocery stores, where customers are required to wait in long lines to purchase a quart of milk. Here again, the need for constant movement is exemplified.

Astute business planners recognize that Americans often refuse to wait in line. Rental-car firms still experience their share of bottlenecks, but they have tried, with much publicity over the past few years, to whisk customers into their awaiting vehicles. Airline companies now issue electronic tickets, allowing passengers to use airport vending devices or their home computers to print boarding passes in less than 60 seconds. Most major banks provide ATMs for their extremely busy customers. Across the nation, supermarkets have made an attempt to improve their slow performances by reserving a few lanes for express checkout. Doesn't it anger you when you approach one of these quick-service aisles with 2 items, for which you intend to pay cash, only to find that the person ahead of you has a cart clearly containing more than the requisite 15 items?

On the other hand, refusing to wait might mean missing out on an event or losing the opportunity to purchase an item at a reduced price. Although most of us hate to wait for anything, the classic military refrain "Hurry up and wait" has become a fact of modern life. We wait in traffic, wait for buses and trains to arrive, wait in lengthy airport-security lines, wait to be seated in crowded restaurants, and wait on hold on the telephone for most transactions in which we are the consumers. Many of us line up to buy tickets for trains that leave late and for movies that do not start on time. Waiting is an unpleasant exercise, and it seems to be on the rise in our society.

As a greater portion of our technology-dependent population commits itself to the doctrine of the busy class, the lines are getting longer. Waiting is a power game. People who hold high-status positions generally do not wait as long as those who are part of the general working class. Similarly, busyness is akin to status in our country. People who always have full calendars are usually the same ones who hold more status in the corporate business world. This is an excellent example of the contradictory nature of the current social buzzwords: *instancy* and *busyness*. Where one goal is attained, the other is partially curtailed. (For example, when things get done instantly, people might not seem to be as busy as they feel a need to be!)

The theory of the busy class is based on the notion that keeping a calendar filled proves you are in demand. Interestingly, calendars and schedules have their roots in religion. In the sixth century, the Benedictine monks, who believed it was a sin to waste God's time, popularized calendars and schedules. It is ironic to note that the conspicuous organizers and PDAs in today's business world have actually taken on a whole new aura of reverence.

A daily organizer is commonly described as a portable set of calendars with an address and telephone book and other peripherals, such as a section in which to record auto-mileage expenses and a small tablet of graph paper to satisfy that sudden urge to draw up plans for a new backyard deck. Some daily organizers contain three different types of calendars, including daily planner pages to list hour-by-hour obligations up

until 9:00 pm, the basic year-at-a-glance format, and the six-year planner for the time-conscious professional. Anyone who requires three calendars for only one life must, indeed, be very busy. The diligence with which the organizer's owner fills it out, keeps it up-to-date, and retrieves it from a briefcase for consultation almost resembles a religious ritual. Perhaps the organizer is really designed to serve as a stabilizing anchor in a fast-paced, constantly changing society. Many individuals have switched to PDA devices, instead of organizers. See **Figure 11-5.**

Another ingredient of the ***busyness syndrome*** is found in the burgeoning technology of the communications industry. We now have electronic accouterment, such as call forwarding, call-waiting, memory dialing, speakerphones, BlackBerry devices, and Palm handhelds. These features allow people to operate similarly to CEOs in the comfort and privacy of their own home offices. Household consumers can put plumbers and gardeners on hold, while checking their references with the Better Business Bureau on another line. In order to be in constant communication with important contacts while also in transit, a large number of busy people rely on cellular telephones to stay in constant touch with their colleagues and clients.

Cellular telephones were introduced in the 1980s for prices well over $2500. Their price tags have dropped considerably, making them more affordable among ordinary civilians. In fact, many contemporary wireless communications companies offer telephone devices at no cost if people subscribe to their services. Cellular telephones used to pack a double hit of status in our society. Not only did they provide the veneer of busyness, but they also gave their owners the glamour of being engaged in very important transactions,



A Traditional Planner



A PDA

Figure 11-5.
These are examples of personal time-management systems. In this traditional daily planner, pages provide space for an appointment schedule with hours identified from 6 AM to 9 PM; a prioritized, daily task list; a daily record of events; and a daily expense record. Some people have found PDAs to be more convenient than traditional planners. This handheld PDA, the Palm i705 computer, provides abilities such as storing address information, calculating, creating appointment calendars, and communicating with others. (Palm, Inc.)

regardless if the users were in their local grocery store; sitting in the waiting room of their child's orthodontist's office; or sitting in their automobile, stuck in a traffic jam. In today's modern world, it is now the exception to the rule to *not* have a cellular telephone, even if you are only 10 years old!

If some of these examples regarding the pace of life and the rate of technological change seem rather silly, perhaps it is because you are not yet wrapped up in the express track of competition. On the other hand, if they seem all too real and near to your heart, welcome to the beginning of the twenty-first century, an era of perpetual motion, and the death of permanence. In either case, your personal attitudes toward the stability of your routine and the relentless pulse of change are a lot less malleable than you might think.

Social Attitudes toward Changing Technology

In the months following the disastrous terrorist attacks on the United States, people lived in a heightened state of anxiety, fear, and helplessness. Many saw this event as an example of our technologies being used against us in a violent and harmful manner. Others remained hopeful that our technological prowess would again enable us to stage a successful war against terrorism, in cooperation with several international partners. In a *USA Today/CNN/Gallup* poll conducted shortly after this tragic event in 2001, 63% of Americans surveyed were confident that the American way of life would be preserved, and 74% stated that they believed Americans are united and in agreement about the most important values.[1] This suggests that U.S. citizens continue to possess an optimistic attitude and want to believe tomorrow will be better than today. A national conscience has awakened. Much of the credit for this positive trend toward a renewed interest in making the future a better place should actually be given to technology. High-speed printing presses, efficient—often next-day—rural delivery service, national public radio programs, and television news broadcasts via satellites have put nearly everyone in this country on the same informational level.

Social attitudes develop over time, as one generation provides the fuel of experience and knowledge to drive the next one along. Attitudes are the product of the capacity to scrutinize events and the freedom to evaluate information. Information is the lifeblood of social progress. American citizens have access to more information now than at any other point in time. The freedom to produce information has led to an almost chaotic abundance of free ideas. Subsequently, not many of us have the time to stay informed about and keep up with emergent S & T issues on the public-policy agenda. Very few of us are even interested in staying abreast of these issues. A study completed in the late 1990s stated the following:

> An analysis of public attentiveness to more than 500 news stories over the last ten years (1987–1997) confirmed that the American public pays relatively little attention to many of the serious news stories of the day. The major exception to this rule are stories dealing with natural and man-made disasters and U.S. military actions.[2]

Information concerning the many benefits we are about to reap from the miracles of S & T is plentiful indeed. Just as abundant

[1]Americans asked opinions on developments after September 11th terrorist attacks. 2001. *USA Today/CNN/Gallup Poll Results,* November 28.

[2]Parker, K. and C. Deane. 1997. Ten years of the Pew News Interest Index: A report for presentation at the 1997 meeting of the American Association for Public Opinion Research. The Pew Research Center for the People and the Press.

are the reports about technology's faults and the calamities associated with its use. The mass media, both print and electronic, are the basic means through which all parties involved in technological transactions can secure a common database. Social groups are constantly inundated with information and have, at least in this nation, the freedom to decide how to digest it all. Whatever attitudes individuals possess, with regard to change in general, influence the manner in which the individuals make these types of decisions. Overall, Americans, unlike other national communities, are not a fatalistic people. Most of us have at least a modicum of faith in the idea that everything can change—all it takes is luck, individualism, freedom, and an energetic drive to move ahead. America is still a place where the play of human nature is allowed the greatest latitude to arbitrate, judge, or develop its tools for progress.

Attitudes and Values

Social scientists define *attitude* as the general disposition to behave in particular ways toward specific objects or events. They define *values* to be social standards considered worthwhile or desirable. Attitudes and values have a great deal of influence over the directions of a nation's scientific and technological change. The following paragraphs describe a few of the attitudes seeming to be prevalent in contemporary American culture. Each of the examples provides a reflection of a "technotrend" or "scientific shift" of sorts.

Any number of social and political labels might be chosen to describe the general public's attitudes toward S & T. A few you might have heard include *cheerful optimism*, *disenchantment*, *idealistic support*, *fearful skepticism*, *cautious optimism*, *ambivalence*, *mild disillusionment*, and *compassionate conservatism*. Although attitudes are shaped over many years of experience and are not usually all that flexible, the impact of recent events cannot be ignored. Contemporary breakthroughs, as well as catastrophes, heavily influence personal perceptions about certain technologies. It takes dedicated interest and knowledge to formulate opinions about S & T. In studies that the NSF conducted during the last two decades, about 9 out of every 10 U.S. adults reported being very or moderately interested in new scientific discoveries and the applications of new inventions and technologies. Other findings that the National Science Board reported provide additional insight about the mixed and somewhat contradictory nature of our contemporary culture of S & T awareness:

- The number of adults who feel well-informed about S & T is disappointingly low. In the 2004 study, only 15% of adults surveyed described themselves as well-informed about new scientific discoveries and the use of new inventions and applied technologies. Approximately 33% of those surveyed thought they were poorly informed.
- About two-thirds of Americans lack a clear understanding of the nature of scientific inquiry and the manner in which scientific investigations are carried out. Subsequently, researchers also found that a substantial portion of the population believes in various forms of *pseudoscience*. This term is defined in Chapter 1 and includes topics such as astrology, UFOs, and magnetic therapy.
- Overall, data shows increasing percentages of Americans agreeing that "science and technology are making our lives healthier, easier, and more comfortable." In 2004, 91% of Americans affirmed this to be true. At the same time, however, 56% contend that "we depend too much on science and not enough on faith."

- In 2004, the National Science Board researchers described less than 10% of America's adult population as the "attentive public," which was down from 12% in 1999, from 14% two years earlier, and from 25% in the mid-1980s. This portion of the population reported a high level of interest in science or technology developments, felt well-informed about them, and indicated that they pursued a regular pattern of relevant information consumption (through technical journals, science newsletters, public media, and special documentaries). As we moved into the first decade of the twenty-first century, the National Science Board labeled a mediocre 15% of adults in this country as well-informed about new scientific discoveries and the use of new inventions and technologies.[3]

The expanding scope and global effects of S & T have stimulated a great deal of attention toward the need for careful government regulation of scientific research. Through the 1980s and 1990s, most government regulating agencies focused on the applications of selected technologies. The advent of disciplines requesting approval for the use of human subjects, experimentation with biotechnology, and the use of nuclear materials has called for the establishment of government policies relating directly to both basic and applied research. The judicious use of this regulatory power requires a populace knowledgeable about the benefits and risks of scientific research and technological advancement.

In broad terms, an extremely impressive majority of U.S. citizens feel that both S & T have made their lives healthier and easier. Most of these people seem to expect future benefits as a result of ongoing contributions from this nation's R&D laboratories and that, because of S & T, future generations will be much better off than we are. See **Figure 11-6.** Statistics also suggest there is widespread recognition among the public that S & T simultaneously offer the promise of fulfillment and the potential for destruction. Specifically, a minority of individuals (33%) presently expresses reservations about science and believes it makes our way of life change much too quickly. An analysis of several other contemporary technological initiatives led the National Science Board to conclude that U.S. residents are quite capable of differentiating between those technologies that are acceptable and those that should be curtailed. Public faith in scientific research in general is significantly higher than support of riskier and more costly technology endeavors, such as space exploration and genetic engineering.

In sum, regardless of how uninformed they report being, many members of the American adult population are very interested in scientific and technological events. There is an obvious prevalence of S & T themes in feature films, television programs, and published fiction. Each of these reflects the scientific and technological profile of our current culture. The expanding numbers and rising sales of popular science magazines and home computers seem to reflect the same characteristic. Prudent investors, brokers, and stock market analysts have become wise to keep abreast of S & T R&D in order to make money for themselves and keep their clients in the black.

Despite the ***technostress*** and the technophobia surrounding the lives of many individuals, there is still a dominant mood of optimism, although cautionary, in the United States. Perhaps this trait is deeply rooted in the general American character. As a people, we seem to be strongly supportive of S & T. We believe much of the prosperity of the past few decades can be most directly attributed to the contributions of S & T. For the time being, it is safe to conclude that

[3]National Science Board. 2006. *Science & Engineering Indicators—2006.* Arlington, VA: National Science Foundation.

Figure 11-6.
Statistics regarding public perceptions of the effects of S & T. (Adapted from *Science & Engineering Indicators—2006*)

Attitudes toward S & T by Country or Region

(Percent)

Statement	United States (2004)						United States (2001)						EU-25 (2005)				China (2001)				
	Totally Agree	Strongly Agree	Agree	Don't Know	Disagree	Strongly Disagree	Totally Agree	Strongly Agree	Agree	Don't Know	Disagree	Strongly Disagree	Totally Agree	Agree	Don't Know	Disagree	Totally Agree	Agree	Basically Agree	Don't Know	Don't Agree
Promise of Science																					
S & T are making our lives healthier, easier, and more comfortable.	91	28	63	0	7	2	86	14	72	3	10	1	78	78	14	6	94	65	30	4	1
Most scientists want to work on things that will make life better for the average person.	—	—	—	—	—	—	89	11	78	3	8	1	—	—	—	—	85	50	35	10	5
With the application of science and new technology, work will become more interesting.	77	13	64	1	19	2	72	9	63	5	21	2	69	69	18	10	81	46	35	14	5
There will be more opportunities for the next generation because of S & T.	86	24	62	1	12	1	85	21	64	2	12	2	77	77	12	8	78	45	32	16	6
Benefit versus Harm		B<<H	B>H	B=H	H>B	H>>B		B>>H	B>H	B=H	H>B	H>>B		B>H	B=H	H>B		B>>H	B>H	B=H	H>B
Have the benefits of scientific research outweighed the harmful results?	84	56	28	3	10	3	72	47	25	19	7	3	52	52	29	14	76	—	76	7	0
Reservations about Science																					
We depend too much on science and not enough on faith.	56	17	39	1	33	10	51	11	40	4	41	5	40	40	26	30	—	—	—	—	—
It is not important for me to know about science in my daily life.	15	2	13	0	55	30	16	2	14	1	61	22	—	—	—	—	17	6	12	9	74
Science makes our way of life change too fast.	33	5	28	1	55	11	38	4	34	2	54	5	60	60	18	21	73	37	35	11	16

contemporary American social groups will continue to look to S & T to provide an improved, though always-changing, quality of life.

Response Modes

Quality of life is an elusive concept not easy to define. One simple explanation suggests it is a balance between what people need and want and the extent to which the environment can provide for them. Some of the typical quality-of-life indicators sociologists and cultural anthropologists use to study this concept include standard of living or per capita income, psychological and mental well-being, environmental stability and quality, general climatic conditions, and opportunities for self-sufficiency. Technological pursuits serving to enhance or improve these general criteria are defined as both beneficial and progressive for society. On the other hand, technologies having the imminent potential to detract from, degrade, or destroy these criteria are defined as hazardous, risky, or detrimental to social well-being.

A number of examples have already been presented to illustrate situations in which technology is either applauded for its contribution to the quality of our lives or blamed for the problems we face. The manner in which society responds to both the conveniences afforded and the problems caused by technology is commonly associated with personal bias, preconceived notions or expectations, the amount of information available and the degree to which it is perceived to be accurate, personal interest in the issue, level of understanding and awareness, previous experience, and technology's general track record. Taking all these factors into consideration, there is a wide variety of behavioral responses used to confront the equivocal nature of technological change. Also known as ***response modes*** or coping behaviors, six are described here:

- **Immediate acquiescence.** This type of behavioral response to change is one in which the individual verbalizes implicit trust in the experts. Although the "blind faith" attitude is rare, for some people it provides a measure of security, with regard to a technology not easily understood. For others, it depicts an ingrained belief that the benefits of technology will always outweigh the costs. In 2004, public confidence in the scientific community was just over 40%. These American adults reported they had a great deal of faith and confidence in the scientific community. Comparatively, about 60% reported a high level of confidence in the nation's military forces. See **Figure 11-7.**

Public confidence in leadership of selected institutions: 1973–2004

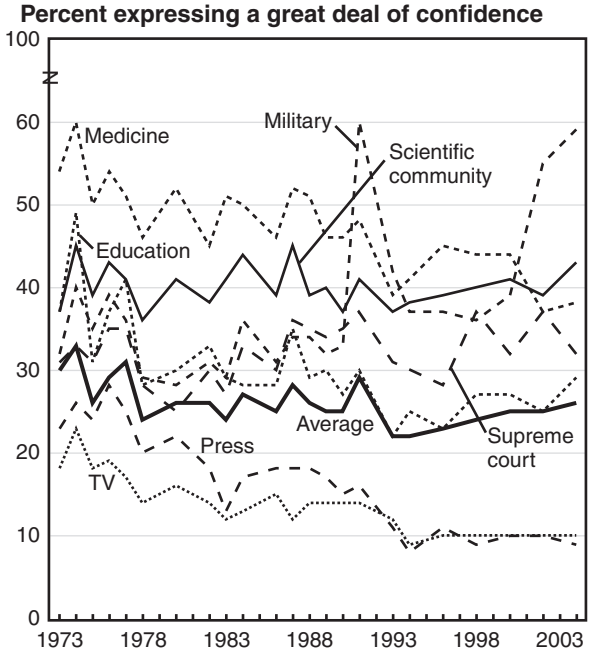


Figure 11-7.
Public confidence in social institutions that have the capacity to influence and create change in our lives. (Adapted from *Science & Engineering Indicators—2006*)

- **Apathy.** People who cope with technological development in this manner do not want to be bothered with the "boring" or "gory" details. They typically express concerns about the amount of effort it takes to keep their daily routines in order. These people do not have time to worry about whether or not genetic engineering experiments are being properly monitored. Denial is sometimes a part of apathetic behavior as well. For instance, some people refuse to believe we have the technological capacity to destroy ourselves or totally lose our identities at the push of a button. They are convinced that the visuals presented in *War Games, Star Wars, The Net,* and *The X-Files* are fictional portrayals of society that Hollywood's tycoons created for entertainment and that will not occur in our lifetime.
- **Reluctant acceptance.** When people go along with changes for fear of what might happen to them if they resist, they exhibit a response mode called *reluctant acceptance* or *partial approval.* In many cases, this is an interim behavior providing only a slim vote of confidence in the proposed or pending technology change. Reluctant acceptance is a common attitude held by those people for whom the "scientific jury is still out." This response allows people to cope with the early stages of change by enabling them to sit back and observe the effects of a new technology without going on record with any distinct opinions. While often doubtful of the benefits, this attitude is one of interested ambivalence. Current public perceptions about the future feasibility or usefulness of our costly space program might fall into this category. Also, there seems to have been significant erosion in the public's confidence in the medical profession. **Figure 11-7** shows that our positive support for medical professionals was as high as 60% in the 1970s, but it has been gradually declining since then.
- **Avoidance.** This response mode best illustrates an individual's inability or unwillingness to cope with changes that S & T create. Personal emotions such as fear and anxiety often play a role here and might result in avoidance. People who respond with avoidance make some sort of decisive actions resulting in observable, structural changes in their lifestyles. They might decide to change jobs, leave the area, withdraw from a university, or even commit suicide, in order to avoid the situation. For this segment of society, the risks associated with technology are perceived to be dominant over any benefits. This response mode might also be predicated on ethics and the moral aspects of pursuing a particular technology. A scientist's decision to leave a nuclear-weapons laboratory might fall into this behavioral category.
- **Reactionist rejection.** This response to technological changes is the one that receives the greatest amount of media coverage. People who rely on this response are willing to openly protest the technologies they oppose. Operating on emotional gut reaction, they are not afraid of the legal consequences for their actions. They might sabotage the observable artifacts of the technology. These individuals appear to focus primarily on the detrimental side effects of technology, while losing sight of any potential benefits. Many of the rallies and lobbying efforts against nuclear reactors and weapons laboratories are best classified as reactionist rejections of technology.
- **Accord.** The response mode most of us would like to think we use to confront new technologies is labeled *accord.*

This mode literally implies agreement and harmony. The behavior patterns, however, used to describe accord go much further. People who either accept and approve or reject and disapprove a technological proposal in this mode do so with a lot of thought. Their decisions and actions are based on understanding, awareness, accurate data and information, logic, and common sense. It takes more time to reach accord because all the pros and cons are weighed before an attitude is portrayed. The person who takes time to research an issue such as toxic-waste management before voting on a clean-water initiative is using this behavior to cope with change or to actually stimulate it. The cancer patient who seeks several opinions regarding his diagnosis and prognosis for being "cured" before accepting a recommended chemotherapy regimen is using this response mode before trusting one physician's theory.

Each of us has, at one time or another, used one of these six behaviors or a combination of them to deal with a crisis or cope with changes in our lives. One behavior cannot be identified as the best or most common for all situations. Social response to S & T is usually a reflection of perceived control or autonomy, literacy, and independence. Each of these social traits has something to do with society's persistent "love affair" with its technology.

Technology Traps

If we stop and take a good look at the network of technologies sustaining our daily routines, it is hard to deny our dependence on them. This is not to say reliance on technical systems is a bad thing—it is just reality. Some people openly admit their needs to surround themselves with technology's warm blanket of conveniences. Others feel trapped by technology.

In a literal sense, the word *trap* refers to confinement, or imprisonment, where escape is either difficult or impossible. Life in our contemporary society is replete with traps associated with technology. Just about every moving vehicle might be construed as a ***technology trap*** of sorts (for example, automobiles, airplanes, bullet trains, submarines, subway trains, and elevator cars). Can you think of others? Each time we step into one of these vehicles and watch the doors close behind us, we take the risk of not being able to escape its confinement. While most people do not stop and think about this possibility when they get into their cars or step into an elevator, many do feel this way when they board an airplane. In each of these transportation modes, users routinely illustrate their dependence on technology to get them to their final destination quickly and safely.

There are many other situations that can be cited to provide a literal translation for the technology-trap principle. Modern hospitals and their impressive surgery facilities reveal our reliance on technology to cure illnesses and save lives. A person who is hooked up to a life-support system certainly must experience the sense of being confined or trapped. Engineers who work inside government laboratories requiring them to pass through a series of security checks might also feel trapped by technology. Coal miners who descend to work in underground caverns are definitely aware of their dependence on technology to get them back out at the end of their shift. Identifying physical technology traps is not difficult, once you start the creative juices flowing.

On a more abstract level, a *technology trap* is defined as much more than physical confinement. A technology trap is yet another

profile characteristic of our modern society. The technology-trap concept refers to humankind's dependence on any technological system or device that either is not understood or cannot be controlled. More often than not, we tend to utilize or maintain technology in such a way that we seem to know what we are doing. Behind the facade, quite often, lies a vast amount of ignorance, inexperience, confusion, or even frustration regarding the technology being used. Technological systems and devices have advanced to such a state that they are regularly marketed as being "user-friendly." This means a person can use the device or monitor the system without possessing highly technical credentials. Today's automobiles are considerably more complicated than the ones manufactured in the 1930s. They are, however, much easier to operate. Contemporary automobile users do not need to be expert mechanics to drive their vehicles to work. Those who expected to drive the earlier models did not have the same luxury.

Abstract cases of technology traps exist all around you. For instance, unless you are an expert software engineer, the chances are pretty good that you do not fully understand why or how your word processing software works the way it does. As long as your term paper is submitted on time, why be concerned with the software's programming language? We also flip switches and press buttons throughout the day in order to execute a series of tasks. It is rare for most of us to stop and wonder about the location, let alone the internal mechanisms, of the power station providing the electricity we effortlessly use.

We casually pour all sorts of detergents into the water used to wash our clothing. The number of individuals who truly understand the chemical formulation of those products and why they work the way they do is quite small. Consider also the hourly worker at a chemical plant employed to monitor a number of gauges in the company's central control center. Let's say this person is instructed to engage switch "A," if the needle in gauge #201 reaches a certain measurement, or switch "B," if the reading on gauge #417 falls below 43°C. Unless the operator truly comprehends the outcome of these actions or the reasons they are being performed, the control panel might be considered a technology trap.

None of the examples mentioned is intended to make you feel inadequate or hopeless about the manner in which you depend on technology or make use of it without a second thought. They are simply and innocently presented to get you thinking about the kinds of ordinary instances in which every one of us is dependent on the artifacts of modern technology. Some technology educators believe these activities have something to do with one's level of technological or scientific literacy.

Technological and Scientific Literacy

Literacy has been a topic of concern in educational literature for decades. At all levels of instruction, teachers have tried a variety of motivational techniques to enable their students to become literate. In the broadest terms, literacy presupposes the ability to read and write. If an individual is *literate*, she is generally thought to be educated and well-informed. This generic term has been teamed up with several modifiers in recent years. We hear stories about adult literacy, literacy among minority ethnic groups, computer literacy, technical literacy, genetic literacy, and even nutritional literacy! Over the last decade or so, technology educators have espoused the need to design and implement curricular activities to improve our students' performance in the

international technological-literacy competition. In the year 2000, the International Technology Education Association published the results of its "Technology for All Americans Project" in a document titled *Standards for Technological Literacy*.

Technological literacy is an educational objective with widespread repercussions throughout the entire academic system. This objective is also an individual quest toward a meaningful existence in today's society. Technological literacy is rapidly becoming a desirable managerial trait. The saying "one doesn't need to understand the technology in order to manage it" is finally being disputed.

What makes a person technologically literate? Is there a standardized test one should take to determine his level of technological literacy? Responses to these inquiries are obviously contingent on the definition one accepts for technological literacy. Although no one definition for such a comprehensive topic is perfect, the following one is proposed for your consideration. Technological literacy involves an above-average level of the following elements:

- ❑ Knowledge of technical and scientific constructs and terminology.
- ❑ Awareness of the impacts (both negative and positive) S & T can have on society.
- ❑ Confidence and skill in the use of technology's tools, devices, and other artifacts.
- ❑ Control over the operations and functions of technical equipment.
- ❑ Insight into the potential future states of specific technologies, in order to project their social impacts.

Wow! This is some definition! The astute reader probably noted the use of the phrase *above-average level*. This phrase presents a problem of interpretation. One must ask for clarification as to the meaning of "average." What is considered average for one culture or social group might be either above average or below average for another group. Likewise, what is considered average for one scientific or technical discipline might not be true for other areas of study. With these facts on the table, it is safe to say everyone is technologically literate. It is equally truthful to conclude that no one possesses this literacy. This debate could go on forever!

Defining a socially relevant term such as *technological literacy* is always a challenge. Several years ago, the National Academy of Engineering assembled a Committee on Assessing Technological Literacy. The committee distinguished three dimensions within which the characteristics of a technologically literate person could be identified—knowledge, capabilities, and critical thinking and decision making. Measuring the extent to which a person or social group has acquired a prescribed level of technological literacy is impossible. Certain elements of the authors' lengthy definition can be assessed, but self-examination activities heavily influence the data recovered.

In a survey conducted by the NSF and reported by the National Science Board, a significant measure of disparity existed between the number of adults who indicated an interest in technology and those who felt well-informed (literate) about technology issues. In all cases, the levels of public interest in technological breakthroughs exceed levels of knowledge about these new findings. For example, while 65% of U.S. adults said they were very interested in new medical discoveries, only 21% felt very well-informed about these breakthroughs. Similarly, 43% expressed high levels of interest in new inventions and technologies, but only 12% felt well-informed about them. See **Figure 11-8.**

Over the years, the NSF has used three relatively straightforward survey items to assess the public's understanding of various

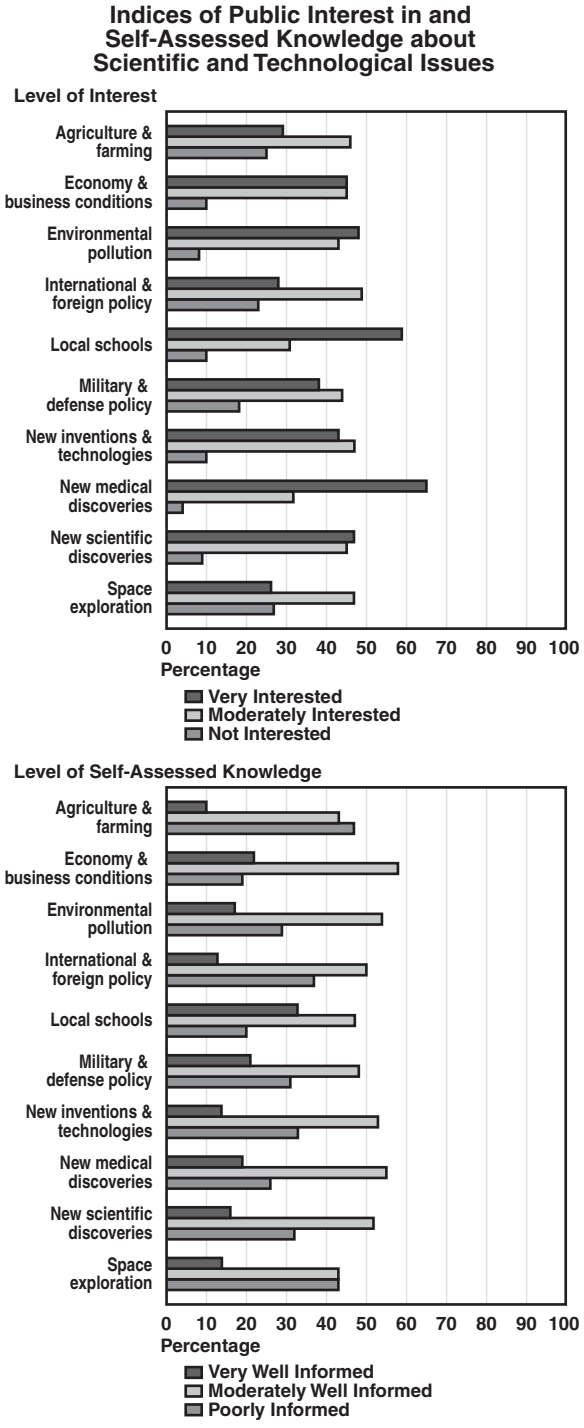


Figure 11-8.
These charts display indices of public interest in and knowledge about scientific and technological issues in selected disciplines. (Adapted from *Science and Engineering Indicators—2006*)

aspects of the scientific process. The NSF attests that a person's knowledge of basic facts and concepts about science, with an understanding of how science works, is a major indicator of scientific literacy. In its most recent administration of this survey, it found that less than 40% of U.S. adults could be considered scientifically literate. The table shown in **Figure 11-9** reports the NSF's findings, with reference to adults' responses to three questions about scientific study, experiments, and probability.

Studies of this nature serve to provide periodic reviews of cultural awareness of S & T. They might not actually measure technological or scientific literacy, but that is not their objective. Even if we cannot quantify the population's scores on a technological-literacy scale, it is enough to agree that such a construct exists. Any amount of attention or energy devoted to the enhancement of the level of technological literacy within society will not be futile, given our dependence on technology.

Recognition of Social Dependency on Technology

A series of titles has been proposed to describe our time in contemporary history. This time has been labeled the *information age*, *telecommunications age*, *postindustrial age*, *computer age*, and *biotech age*. Regardless of the descriptive term one endorses, we are living in an age of technological enthusiasm, laced with fantasy. Everyone from Hollywood producers to government officials has thrust technology on us. The stunning record of technical accomplishment during the last century lends support to their visions. For many citizens around the world, technology has become an article of almost-religious faith. Today's technology is uniquely seductive, since it appears to offer viable solutions to some of this planet's biggest problems. In

Public Understanding of Scientific Inquiry—2004				
Characteristic	**Inquiry**	**Scientific Study**	**Experiment**	**Probability**
All Adults	39	23	46	64
Males	43	25	49	57
Females	36	22	43	62

Inquiry: Levels of understanding of the nature of scientific inquiry estimated by combining each survey participant's responses to three questions. To be classified as understanding of the nature of scientific inquiry, all probability questions had to be answered correctly, "theory-testing" needed to be a part of the response to the scientific-study question, and the experiment-question response had to say something about the importance of using a control group.

Scientific Study Question: "When you read news stories, you see certain sets of words and terms. We are interested in how many people recognize certain kinds of terms. First, when you read or hear the term *scientific study,* do you have a clear understanding of what it means, a general sense of what it means, or little understanding of what it means? Second, if the response is either clear understanding or general sense, explain in your own words what it means to study something scientifically."

Experiment Question: "Two scientists want to know if a certain drug is effective in treating high blood pressure. The first scientist wants to give the drug to 1000 people with high blood pressure and see how many experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure and not give the drug to 500 people with high blood pressure and see how many in both groups experience lower blood pressure levels. Which is the better way to test the drug? Why is it better to test the drug this way?"

Probability Question: "A doctor tells a couple that their genetic makeup means that they have got one in four chances of having a child with an inherited illness. Does this mean that, if their first child has the illness, the next three will not? Does this mean that each of the couple's children will have the same risk of suffering from the disease?"

Figure 11-9.
Assessing scientific literacy in our society. (Adapted from *Science & Engineering Indicators—2006*)

some ways, it further encourages us to abdicate our personal responsibilities for these problems.

Social glorification of technology took off over a century ago with technology's cascade of curious inventions, including the steam engine, electric lights, farm machinery, the domestic sewing machine, and even running water. We next witnessed the arrival of the automobile, the telephone, the radio, the television, jet aircraft, miracle drugs, and nuclear energy. Along the way, a manufacturing and marketing infrastructure provided the necessary avenues leading to technology's penetration into all segments of society all around the globe.

Technology was revered during World War II for its potential to become the great equalizer on the battlefield. This technology helped the United States to purchase victory for its allies via U.S. superiority in industrial production and sophisticated weapons. Following the Soviet space surprise in the late 1950s (*Sputnik*, 1957), the United States adopted S & T as its chosen vehicles to regain global superiority.

At the beginning of the twenty-first century, we find ourselves inextricably addicted to technology. Technology underpins every aspect of our existence on this planet. Our affinity for technology and love for the conveniences it offers have led to our taking

much of it for granted. Take a moment to review the contemporary businessperson's typical working day. The individual under scrutiny awakes to a radio alarm clock; switches off the electric blanket; dresses in imported clothing made of synthetic fibers; defrosts the frozen orange juice and microwaves some type of breakfast treat with electricity a nuclear power plant generated; commutes to the office in a highly fashionable automobile, while listening to high-fidelity stereo or making a series of cellular-telephone calls; and travels up to the 26th floor by elevator, just in time to receive an important phone call that a satellite relayed from a time zone on the other side of the globe. This is just an example of a few of the machines sustaining our lives. Their influences do not cease with the close of the workday. The same person looks forward to the weekend to play with a host of high-tech toys (DVDs, power tools, video games, ski lifts, luxury yachts, and remote controlled model airplanes). This is the present.

The future outlook for technology is promising, but it will inevitably lead to an increased level of "social technohypnosis." In other words, more people will be caught up in the spell of technology. All of us are at least vaguely familiar with implants of electronic devices, such as heart pacemakers. We are witnessing an increasing use of these technologies to drive leg and arm muscles, to serve as implantable substitutes for hearing, and to monitor the metabolic reactions taking place inside the body. Some of the work being done in cryobiology (freezing tissue to store it indefinitely) permits complex organs, such as livers and kidneys, to be retained in a frozen state until needed. This will certainly lead to an expanded use of organ transplants to save more lives in the near future.

The fascinating world of computer electronics promises to continue its trek toward dazzling our imaginations. The GPS displays electronic maps on a small screen inside a delivery vehicle or your personal automobile to reveal details of local streets and landmarks. Users of these systems can also program them to suggest the best route to take to an intended final destination. Amateur and professional photographers alike can now use very affordable electronic digital cameras that record photographs on magnetic disks, instead of film. This feature enables users to preview the photos on a television or computer screen, in order to decide which ones to print. Bank credit cards are now actually quite smart. Some are imbedded with microchips to store checking, savings, and other financial balances, together with personal medical data and important telephone numbers. At the present, the smart Visa credit card enables its user to store cash in the account, permitting use of the card at previously cash-only merchants, such as newsstands and vending machines; have single-click access to account information 24 hours a day, seven days a week; request balance transfers, track purchases, and manage accounts on-line; and attach a smart-chip reader to a PC. See **Figure 11-10.** As you read in the *Dateline* segment of this chapter, smart cards have become part of everyday life for college students to manage and keep track of their lives on campus.

It was not long ago that automated bank-teller machines, PCs, high-speed facsimile machines, and on-line databases were figments of the technologist's imagination. When they first hit the market, they were luxuries. Today, they are common necessities. In the eyes of some, this type of technology has made the world increasingly incomprehensible. Computers now make loan decisions, diagnose



Figure 11-10.
The Apriva® X57 smart card reader is an aspect of contemporary credit card technology. A small 32K microprocessor chip is actually imbedded into the card, giving the card much greater information capacity than the magnetic strip does. This chip, therefore, coexists with other technologies to simplify on-line shopping and preserve security. (Apriva, Inc. "Wireless Business Solutions")

diseases, and represent a vital nerve center for the nation's defense system. The programs guiding these complex systems are the products of thousands of "person-years" of diligence. It is rare for one individual to fully comprehend their operations. We have become, in many ways, a world community dealing with abstractions and depending on the interpretation of wiggly marks on paper and digital pulses in machines. In an age of instant gratification, many young people are growing up with the belief that things "just happen," almost magically.

As with any romantic love affair, ours with technology has had its share of euphoric moments, interspersed with periodic states of deep depression. Repeated cycles of reality testing temper the highs and lows. The ingenious achievements scientists and technologists have made in recent years represent an expression of mankind's finest creative instincts. Society is dependent on the fruits of its technology. Also, society has the capacity to direct and control its technology to meet specific goals and objectives. The social management of technology will ultimately determine the extent to which contemporary civilizations can access technology's benefits without sacrificing their values and cultural ideals.

Living with Technology = Making Trade-Offs

Now and then, physicians have been known to remind their patients that "any pill strong enough to help you is also strong enough to hurt you." This warning seems to be applicable to many of the technologies discussed throughout this chapter. A concept labeled ***universalism***, which refers to a global technology community, further characterizes our modern society. For example, a powerful electromagnetic pulse that an adversarial superpower's defense system sends through the atmosphere could knock out this nation's entire electrical-power source in just a few minutes. This, of course, would totally immobilize us. Nevertheless, modern civilizations have become hostage to the forces of technological progress. There is no turning back because the benefits, both real and imagined, are enormous. The impending deficits are, likewise, greater than before and might turn out to be disastrous in the absence of a clear and prudent plan providing for a fallback system of survival.

Risk-Benefit Analyses

Several decades ago, risk analysis was an obscure concept. Beginning in the late 1970s and moving into the twenty-first century, risk analysis has become a major growth industry. Around the world, businesses, utilities, labor unions, insurance companies, hospitals, and government agencies are seeking the services of risk assessors. These institutions are requesting assistance in estimating and controlling risks from toxic chemicals, accidents, and other hazards. Some of these requests are a direct result of regulatory legislation. Regardless of the context, the risk assessor's central concern usually boils down to safety and the question "How safe is safe enough?"

When experts attempt to quantify risk estimates, they engage in a process of prolonged risk-benefit analysis studies. They try very hard to define actions that will result in an optimal balance between the benefits from an activity and the risks. In the late 1960s and into the early 1970s, an expert in this field distinguished between voluntary activities and involuntary activities to derive formulas related to ***risk-benefit analyses***. Studies revealed that individuals evaluate voluntary activities via their own value systems, whereas an external controlling entity determines the options and criteria for evaluating involuntary activities. Interestingly, the public seems willing to accept voluntary risks roughly 1000 times greater than involuntary risks, at a comparable level of benefit.[4]

The proliferation of technologies has expanded the scope of risk at an exponential rate. A century ago, if a maintenance worker failed to attach a carriage wheel properly, the lives of half a dozen people were threatened. In this day and age, when a manufacturer fails to install an O-ring properly in a Boeing 767 aircraft, more than 300 lives are at stake. The potential for disaster in mass transit, mass production, and mass destruction has grown geometrically. As our world becomes more interactive and centralized, it is easier to sabotage its technological life-support systems. Our survival on this planet depends on the personnel who tend the military computers and keep them running properly 24 hours each day. Somewhat closer to home, your safety is dependent on those people who manage local water-treatment plants. At any moment, it seems the lives of thousands are at the mercy of a few, who are just as human as we are. What if those few make a mistake? Many of us deal with our fears of being powerless by placing our faith in the competence of the people or the technology in control.

We ask what went wrong, when presented with the dark side of technologies. A partial list might include the following milestones along our precarious road toward progress: Bhopal, Chernobyl, Love Canal, Three Mile Island, Tylenol® medication, AIDS, toxic shock syndrome (TSS), the *Challenger*, asbestos, human-made pesticides, acid rain, PCBs, cancer, bovine spongiform encephalopathy (BSE, or mad cow disease), and Agent Orange. These examples imply we are living in an age of risk, but the human race has always lived at risk. How we react to and deal with risks might have changed, but we must continue to live with the sober truth that there is no such thing as zero risk. Perhaps it is humankind's realization of this caveat motivating us to press forward in the quest for greater safety, while simultaneously creating newer technologies, against which we must be protected. While these hallmarks of civilization seem to contradict each other, somehow we manage to keep the motors of social improvement running at full speed.

If one accepts the fact that safety is the absence of risk, but that risk cannot be totally abolished, a method to determine an acceptable

[4]Two studies are pertinent to this discussion: Star, C. 1969. Social benefit vs. technological risk. *Science* 165: 1232–1238 and Star, C. 1972. Benefit-cost studies in sociotechnical systems. In *Perspectives on benefit-risk decision making.* Report of the Committee on Public Engineering Policy, 17–42. Washington DC: National Academy of Engineering.

threshold level must be derived. Safety, expressed in terms of acceptable risk, is a social judgment call. Investigating the "how safe is safe" issue necessitates two central considerations. First, from a technical perspective, what are the probabilities of occurrence and the possible severity of harm? Second, from a social perspective, what sorts of cultural and ethical norms are established, with respect to the valuation of a single human life, personal property, or the natural environment? Stated in a different way, the technical experts often worry about the quantity of the risk, while the general public worries about the quality of the risk.

This leads into the question of disparities between perceived risk and actual risk. When the experts assess the risk of a technology, they are primarily concerned with how many people die from it in an average year. When laypeople evaluate the risks of technology, they focus on a much broader list of criteria: how well we understand the risk, whether or not the technology could wipe out an entire community, whether or not the technology will make a particular area uninhabitable for a long period of time (for example, only 30 people died of radiation exposure after the 1986 nuclear disaster at Chernobyl, but more than 1000 square miles of land have been rendered unsafe for human life for more than 100 years), and whether or not the technology might affect future generations or some members of society more than others. In answering each of these sensitive questions, experts offer the public a series of numbers and estimates to put technological risks into perspective, while public perceptions warn the experts against using sheer statistics to assess risks.

We assume the experts know a great deal about the technical aspects of nuclear power, space flight, biotechnology, food additives, and pesticides. This enables them to calculate very narrow definitions of *risk*, in terms of factors that can be reduced to numbers and then extrapolated to make probability statements. For instance, one Air Force report estimated that the chances of a fatal accident on the space shuttle were 1 in 35—compared with 1 in 10,000 for a nuclear disaster or a dam failure. When people read probability statistics, they are often less interested in the numbers and more anxious about whether a hazard is new or old, known or unknown, controllable or uncontrollable, and voluntary or involuntary and the degree to which it is potentially catastrophic. Fear of nuclear radiation is punctuated by each of these perceived threats.

Even though more people die in automobile accidents each year than have perished in accidents related to nuclear power, the public views nuclear accidents as being much more frightening. Much of this anxiety is due to a dreaded fear of the unknown. The risks of a nuclear accident are seen as unknown, uncontrollable, and most likely catastrophic. When people cannot be certain about the risks they are forced to confront, they at least want to have some measure of control over the activities and technologies producing them. Much to the chagrin of risk analysts, people tend to be more willing to accept higher risks in activities over which they have some individual control, such as driving, smoking, skiing, and consuming alcoholic beverages. They approve much lower risk thresholds for activities in which they have little control, such as industrial pollution, food additives, biotechnology, and commercial airlines. It is intriguing to review the differences between expert opinions and public perceptions regarding the risks of various activities and technologies. See **Figure 11-11.**

In order for society to judge "how safe is safe enough," there must be a widespread level of technology awareness. It is difficult

Public Perceptions versus Expert Opinions Regarding Risks Associated with Various Activities and Technologies			
Activity or Technology	**League of Women Voters**	**College Students**	**Experts**
Nuclear power	1	1	20
Motor vehicles	2	5	1
Handguns	3	2	4
Smoking	4	3	2
Motorcycles	5	6	6
Alcoholic beverages	6	7	3
General (private) aviation	7	15	12
Police work	8	8	17
Pesticides	9	4	8
Surgery	10	11	5
Fire fighting	11	10	18
Large construction	12	14	13
Hunting	13	18	23
Spray cans	14	13	26
Mountain climbing	15	22	29
Bicycles	16	24	15
Commercial aviation	17	16	16
Electric power (nonnuclear)	18	19	9
Swimming	19	30	10
Contraceptives	20	9	11
Skiing	21	25	30
X rays	22	17	7
High school and college football	23	26	27
Railroads	24	23	19
Food preservatives	25	12	14
Food coloring	26	20	21
Power mowers	27	28	28
Prescription antibiotics	28	21	24
Home appliances	29	27	22
Vaccinations	30	29	25

Do your worries match those of experts? Paul Slovic, President of Decision Research found significant differences among three different groups surveyed. Orderings are based on the geometric main risk ratings within each group. Rank 1 represents the most risky activity or technology.

Figure 11-11.
Public perceptions regarding risks of various activities and technologies, compared to expert opinions. (Paul Slovic, Decision Research)

to evaluate the potential for danger or disaster if one does not know what the risks are. Prior to the terrorist attacks in the United States in 2001, many Americans had perhaps never even heard of the spore-forming bacteria called *Bacillus anthracis*, or anthrax. In the last few months of that year, this reality quickly changed. *Newsweek*'s national poll at that time revealed that only 43% of Americans believed the administration was providing as much reliable information on anthrax attacks as they needed. Of those polled, 50% stated that the president's team was either not releasing information because it did not have the information itself or purposely holding back to avoid scaring the public. The American people have never been very skillful in knowing what risks they should worry about, and they become both anxious and angry when they feel uninformed. We are at a time in history, however, when getting the risk estimates correct has become linked to thousands of lives, billions of dollars, and the difference between chronic anxiety (***technophobia***) and realistic prudence (technology accordance).

Ostensibly, the purpose of government regulation of technology is to protect the public from a wide range of technological hazards. The U.S. government has the obligation to manage risk. Legislative initiatives over the past years have been enacted in an attempt to reduce uncertainty and surprise, enhance the visibility of possible cause-effect relationships, anticipate immediate and future impacts, and illuminate the alternatives that might spur prevention and delegate responsibility to all parties involved. Somewhere along the way, the word *trade-off* was invented to describe the process of deciding whether or not society has the dexterity or ability to contain the side effects of its technological feats. In an era of sharpened security and anxiety, our government leaders seem to be acknowledging that, while our country can never be made completely safe, it can certainly be made a good deal safer.

Technology Accordance

In the end, it appears that S & T are both good and bad. More than a quarter century ago, Samuel Florman referred to this state of reality as a "tragic view of technology." He believes people must be aware of the dangers without foolish illusions about what can be accomplished. This conviction is still relevant in today's world. Another view might suggest that science is neutral and is a process by which we attempt to form explanations of the natural environment. Technology then evolves as the use to which this understanding is applied: for good or bad.

Technological change is unavoidable. The method in which society chooses to manage it and respond to it is, however, quite flexible. ***Technology accordance*** is a label the authors use to refer to the extent to which a social group is able to recognize and take advantage of the potential benefits of a technological breakthrough and simultaneously control its negative side effects and risks. At the root of accordance, we find one of the response modes identified earlier—accord. As a greater proportion of society selects this coping behavior to decide the fates of new technologies, civilization will be a giant step closer to long-term sustenance.

Summary

Change is perhaps the only constant. Although society has convinced itself that most changes are revolutionary, it is far safer to suggest that changes tend to be evolutionary. This further implies people should take the time to stop and reflect on the changes taking place right now, in order to chart a course of active living for the future. This chapter examines the concept of social change from several points of view. *Science* and *technology* are defined from two perspectives: (1) S & T change our lives

on a regular basis, and (2) we, the people, routinely demand new S & T to meet our changing expectations. In the first view of reality, society lags behind technological change, whereas in the second, technology is perceived to lag behind social needs.

In order to cope with new and demanding scientific and technological breakthroughs, social groups rely on a number of behavioral response modes. Of the six presented in this chapter, accord is the one seeming to be aligned most closely with various aspects of both technological and scientific literacy. Accord is characterized by attentiveness to the risky side effects of S & T, coupled with well-informed decision making, regarding the exploitation of the many benefits we derive from S & T discoveries and innovations. A technologically advanced civilization must also be technologically conscious in order to preserve its survival. Technological change is often perceived to be linear, but in actuality, it is full of cyclical patterns of regression. Sustained progress mandates the design of fallback systems to protect us against our sciences and technologies that just might fail.

Discussion Questions

1. Explain the reason that the word *change* elicits emotional reactions from many people. What phrases are often used to tone down the use of the word *change* in various social settings?
2. Differentiate between the concepts labeled *system overload* and *information overload.* Provide contemporary examples to illustrate the similarities and differences between them.
3. With regard to the level of public confidence in the leadership of selected social sectors, speculate as to why Americans' faith and trust in the medical profession has trended downward, while their confidence in the military has increased in recent years.
4. Why do you think the American public continues to retain its belief that S & T make our lives healthier and easier? What types of situations might persuade people to disagree with this assertion? Why do you think so many people say they are interested in S & T, but so few feel well-informed about S & T issues?
5. Identify and describe the six behavioral response modes to illustrate the ways we cope with change. Provide your own examples symbolizing each behavior.
6. Define what the term *technology trap* means. Provide several examples to illustrate its literal meaning, as well as its abstract connotation.
7. If you were required to prepare a report responding to the question "How safe is safe enough?" with regard to an outdoor genetic engineering experiment, what type of information and data would you attempt to secure? Who would you rely on for expert advice and recommendations during the course of this exercise?

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Chapter 12

The Stability of Traditional Social Institutions

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DATELINE

San Jose, California

A disturbing phenomenon is evident in this city and numerous other metropolitan centers—the disappearance of the traditional family dinner. Social scientists report that the days of gathering around a huge dining room table for meals more than once or twice a week are certainly at risk in this country. Instead of eating evening meals with members of our families, we are eating out; taking out; ordering in to be able to eat at our desks well into the evening hours; and munching on the run, while driving on the interstate.

For decades, the evening family meal represented a time when children and parents could bridge the gap of their respective days. Eating at the table in the privacy of one's own home is one of the primary ways in which growing children learn about the conventional behaviors they will need to be in touch with as adults. Mealtime once was a time when parents taught values and social graces and children learned to communicate and express their feelings. Preschool children, in particular, benefit from mealtime conversations, in that their vocabulary skills can be enhanced quite significantly. Other studies show that teenage children who share dinners with family members at least five times per week are far less likely to be smoking cigarettes or drinking alcoholic beverages. The phrase *family dinner* has almost become a metaphor for a commitment to family.

Many of us seem to be forgoing this opportunity to teach and learn, in order to have time for fitness classes, jogging, pickup basketball, television, and dieting. Children themselves are torn from the dinner table to fulfill commitments related to their own after-school activities. It seems that spending time together is becoming less important than being busy.…

Introduction

Social institutions are the structural mainstay of civilization. Throughout history, human beings around the globe have recognized the need to establish a variety of social settings in order to most efficiently conduct the business of life. Beyond their ability to order living patterns, these social institutions provide a sense of hope and security, as well as a means for survival. People have a tendency to associate specific roles and responsibilities with each of the social institutions existing in their communities. Formal institutions provide the order and organization for a culture to sustain itself. Cultural anthropologists conduct systematic and scientific studies of the typical behavior patterns of people residing in each of the world's continents. A contemporary concern among these researchers is the extent to which modern technology might be influencing the stability and shape of traditional cultural morals, values, and customs.

It is always difficult to formulate a precise definition for a generic concept. Since *social institutions* are the primary focus of this chapter's discussion, it would be very helpful to understand what they are. In all probability, most of you already have a clear sense of

what this term means. You could probably provide a list of examples of these institutions evident in your hometown community quite easily. In fact, before reading on any further, take a moment to write down a few of the social institutions you believe to be currently operative in your life right now. For the purpose of our discussion, a social institution refers to a formal entity existing primarily to nurture and contain certain behavior patterns considered to be important in society. If one chooses to use either the word *traditional* or the word *contemporary* as a descriptive modifier, this explanation should still remain adequate.

Let's look at some of the social institutions we depend on to structure the manner in which we conduct our daily routines. If the list you just compiled includes such items as family, church, school, and government, you have identified some of the most commonly accepted social institutions throughout the world. These formal groups are readily viewed and categorized as "traditional," since they have been so widely respected for centuries. Some cultures revere their sanctity and believe in the importance of their preservation for the good of all humankind.

In recent years, a series of equally formal, but far less conventional, groups have evolved in our society. If your list identifies health and fitness clubs, corporate offices, research laboratories, golf leagues, and neighborhood taverns as social institutions, your perspective is significantly more modern. Although none of these entities has earned the level of recognition afforded to family, religion, and education, they are just as important to many career-minded individuals in today's social milieu. In the eyes of some researchers, the corporate office has achieved a higher position on the list of personal priorities than the family living room. Similarly, in many cases, individualized exercise programs have become a substitute for community involvement and civic duties. See **Figure 12-1.** Computer-software advancements and the availability of on-line courses at both the university and high school levels continue to threaten the integrity of real live teachers. The pervasive presence and power of computers seem to be influencing our religious beliefs. The corporate gymnasium is often comparable to the corporate boardroom, as a setting where powerful political decisions are often heatedly debated.

Are the traditional social institutions we have relied on for years being replaced with a host of alternatives? Furthermore, is modern technology having an adverse effect on their stability? Some researchers respond affirmatively to both inquiries. They seem convinced technology is the driving force behind the introduction of these new colored threads being woven into the tapestry we call our *society*. This chapter provides a synthesis of some of their opinions and theories, as they relate to both traditional and contemporary social settings. Although it is not possible to provide a thorough analysis of all the institutions mentioned so far, the following areas are discussed in some detail: family life, religious attitudes, educational programs, and recreational activities. These four topics are selected to depict a cross section of "contemporary" social activities and the persistence of "traditional" social institutions in a world of technological change. The following questions are addressed in this chapter:

- ❑ Is the traditional nuclear family becoming an endangered species in present-day society? What sorts of social groups do you think will come together to act as surrogate families?
- ❑ How has technology affected the way women structure their lives? Further, what sorts of influence has modern technology had on the socialization of the children of these women?

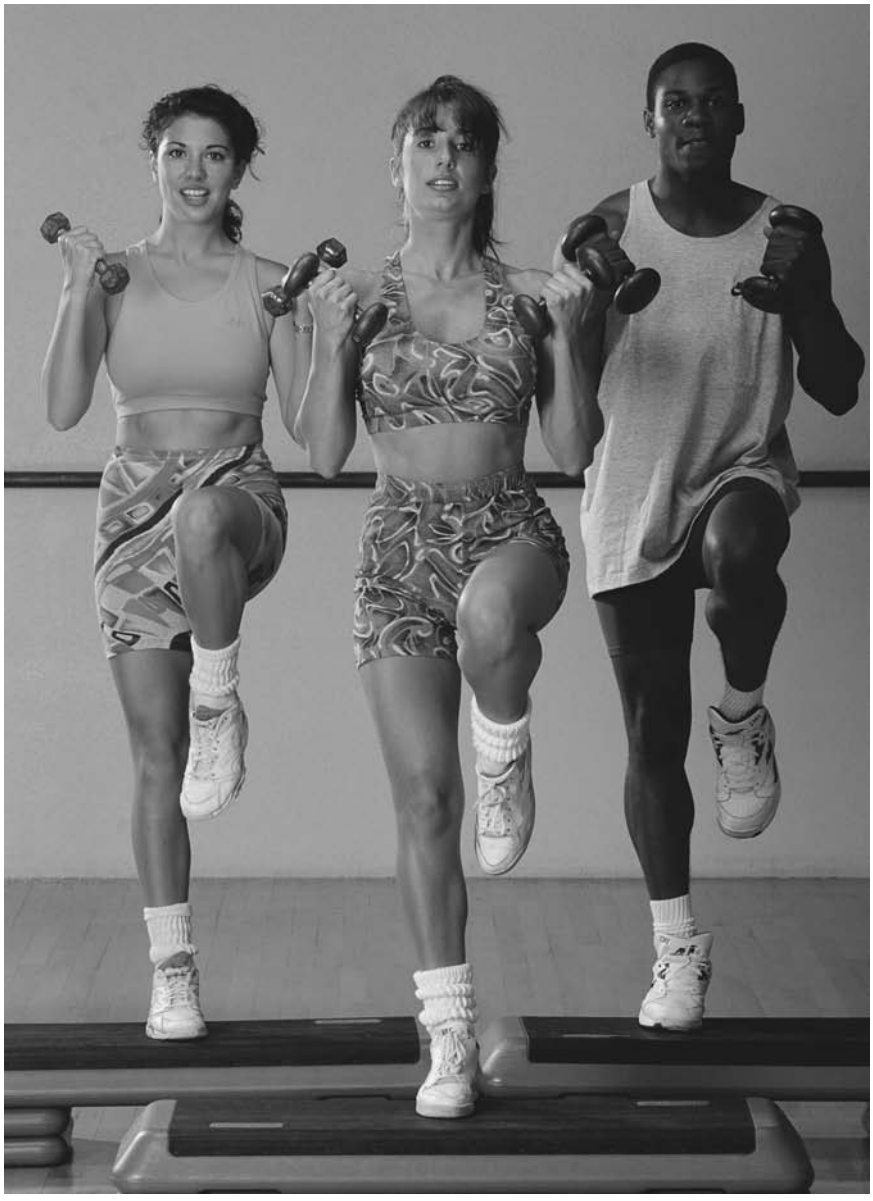


Figure 12-1.
Group fitness classes coordinated to popular music have become more common across the nation since the mid-1980s. Individuals who pursue this type of exercise program recognize the benefits of a complete-body workout and cardiovascular health. Some health clubs offer these classes throughout the day, but the evening classes enjoy the greatest attendance among the membership.

- ❑ What impacts have S & T had on the importance of religion in America? Are computers and the media changing our image of God?
- ❑ How have advancements in distance-education technologies begun to affect the ways educators and school administrators structure teaching and learning communities?
- ❑ In what ways has technological change affected the manner in which we spend our leisure time? What sorts of high-tech developments have changed the profile of the recreation industry?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

creationism
distance education
expert system
nuclear family
parental leave
social institution
zapping
zipping

The Family: Technology and Personal Relationships

In today's fast-paced world of technological and social change, it is unlikely that any other social institution elicits as much contentious debate as the family. One side argues that the movement away from marriage and traditional gender roles has seriously degraded family life across the board. On the other side of the field, the more optimistic group views family life as dynamic, resilient, and generally adaptive to new social circumstances.

The term *family* carries cultural meaning and has individualized significance for most people. For statistical purposes, the Bureau of the Census defines a *family* as two or more people living together who are related by blood, marriage, or adoption. At the onset of the twenty-first century, families maintain most households in the United States, but the percentage has declined since 1960. The U.S. Census Bureau further defines a *household* to be one or more people who occupy a house, an apartment, or another residential unit that is not "group quarters" (such as a dormitory). In 1960, *families*, as previously defined, occupied 85% of U.S. households. By 2000, this proportion had decreased to 69%. In the same time frame, the proportion of households run by just one person doubled from 13% to 26%.

For those satisfied with being single, the task of establishing friendships and alternative relationships (sometimes called *surrogate families*) is evident in contemporary social settings. Varying levels of intimacy are evident within these personal involvements. Men and women have expressed various forms of reverence for the institutions of marriage and the family throughout most of history. These age-old social institutions have been applauded and often referred to as the *lifeblood of society*. With specific regard for the family, we believe this institution will continue to adjust to dramatic social demands.

As we discussed in Chapter 11, some people are resistant to new ideas, but they remain willing to accept incremental changes in order to adapt to changing social circumstances. Economists commonly refer to the family as the *fundamental unit of society*. Some economists also claim to be able to assess the well-being of the whole nation on the basis of what they perceive as

the family's state of health. The traditionally accepted functions that the family unit serves in civilization include the following:

- ❑ The family unit is a provider of love and emotional support for its members.
- ❑ This unit is the principal agent of socialization for children.
- ❑ The family unit is a primary source of economic support for children, often throughout their postsecondary-school years and into early adulthood.

We have most certainly broadened our definition of *family* in this nation, amidst great shifts in demographics and accepted lifestyles. The profile of the contemporary family unit is quite a bit different than it was in the 1960s, or even the 1970s. The long-admired traditional image of the ***nuclear family***, consisting of a working husband and his stay-at-home wife, with two or more dependent children, now accounts for less than 25% of all U.S. households, according to Census 2000 data. Incredibly, however, this antiquated nuclear ideal persists in many well-publicized advertisements. For example, in a recent national campaign, Travelodge featured a little girl clutching a stuffed animal with her mother and father on either side. Chances are that suggestions to include grandparents or other adult figures in this ad were discounted in favor of tradition.

The look and feel of household arrangements continue to evolve with changes in religious, social, and legal directives. A significant change in the late twentieth century was the increase in the number of unmarried men and women living together. Also on the rise are the numbers of gay and lesbian households and multigenerational arrangements. Cohabitation and marriage have a lot in common, but they differ in critical ways. Marriage is a social institution resting on common values and shared cultural expectations regarding behavior. This institution adheres to legal, moral, and social rules. Cohabitation often serves as a precursor for marriage. We believe cohabitation is a contemporary social institution that will prevail in the coming decades. This institution does not boast a widely accepted social blueprint to guide appropriate behavior. If it ultimately helps couples strengthen their commitments to one another before marriage, however, cohabitation might gain higher approval ratings in the years ahead.

Individuals' reasons for marriage in the late 1990s were quite similar to those mentioned in the past: love, commitment to growth as a couple, security, social approval, and a desire for greater intimacy. Companionship represents a slightly revised variation on the older themes. Both men and women have found that they can be self-sufficient, but still have a desire for the closeness of a committed relationship. Other contemporary reasons for marriage that both sexes generally expressed are a growing disillusionment with the "singles' rat race" (short-term and often promiscuous dating with more than one person) and concern for physical health. Sexually or physically transmitted diseases, especially AIDS, have had an unequivocal impact on the interpersonal relationships between men and women. "Casual sex" is becoming less common in the early stages of a couple's interaction. Also, the frenetic pace of work in a technologically progressive society does not leave most people with a whole lot of energy or ingenuity to go out and search for companionship at the end of the day. The prevalence of on-line services for couples to meet is an emerging technological intervention in response to this, but many persons experience disappointment with a significant portion of these computerized matches. The comfort and quietude of a stable relationship within a marriage often seem quite appealing because of all this.

A previous perception of marriage commonly viewed the family as a business enterprise of sorts. The husband earned money and provided for the woman. In return, the wife agreed to do the housework and bear children. People who decide to get married these days are bringing a whole handful of new expectations into the marital contract. Prenuptial agreements have become much more common in recent years. Today's partners seem to be more aware of the need for their marriages to involve other dimensions, in order to be both fulfilling and successful. Women expect to be included in financial matters. Men expect to have direct involvement in the nurturing of their infant children. Not all people expect their marriages to be permanent, but most enter into the union intent on making it work.

Despite the changes taking place in family living arrangements, shared activities are still considered to be very important. Even though the family dinner might not be scheduled every night of the week, this activity is generally regarded as a significant, central time for all members (see *Dateline*). There is a move toward emphasizing the quality of time spent with family to compensate for the reduced quantity. In other words, the family dinner table might not be on its way out, but it might actually be experiencing a rebirth in some households. Families who consistently plan to have dinner together at least once or twice a week might find it to be a genuinely rewarding endeavor.

Without question, there has been a social revolution in family lifestyles. The extent to which technological changes have been a driving force behind this revolution is still somewhat vague. There are those who suggest that industrialization and technology have torn the family unit apart. Others predict that the advent of telecommuting as a work mode will draw families closer together. Some social observers insist this new method of going to work is straining traditional family roles and causing household conflicts. Continued advancements in household technology will stimulate further evaluation of men's and women's roles on the home front. For some people, life in today's technological world is too complicated, often scary, and unimaginable. This might ultimately cause contemporary families to pull closer together to make it through the hard times. Undeniably, the essence of family will survive as an important source of stability well into the future.

Modern Childhood

Career-focused adults spend a significant percentage of their days attending to work-related issues. Therefore, it is not uncommon for them to lament about how difficult it is to be a parent. Instead of worrying about polio vaccines, pneumonia, and ear infections, today's parents find themselves worrying about drugs, school-yard violence, teenage pregnancy, and threats of worldwide terrorism. If the truth were told, their children are probably having just as much difficulty trying to be kids! In some ways, there appears to be an overall merging of childhood and adulthood happening in our culture. Children growing up now are undergoing a host of psychological and social pressures. Too many children are being forced to grow up too quickly.

During the first half of the twentieth century, our culture revered childhood. The days of youth lasted into the teen years and were generally considered to be a time of innocence, amusement, and "best" friendships. Childhood was a time for young people to be sheltered from the demands and alarming realities of adult life. Kids were dressed differently from adults, and each group had its own language. Certain topics, such as birth, death, sex, and money problems,

were treated as off-limits for children's ears. Schools were structured within a strict grading system designating what a child of a given age should know and be able to do.

As the shape of family units has undergone change, remarkable changes have also occurred in the image and characteristics of children. Childhood is no longer viewed as a protected and sheltered period of life, and it seems to end before the chronological period called *adolescence* (often by age 10). Today's children seem less childlike in a number of ways. They speak, dress, and behave more similarly to adults than they did a couple of decades ago. The so-called "magic years of youth" do not always seem to be so magical anymore. Children are trying to cope with a world in which both parents are working, sex and drug abuse have permeated the elementary-school yard, and graphic violence is commonplace both on the television screen and in video games. See **Figure 12-2.** Mimicking adult behaviors, more children than ever before experiment with alcohol and other drugs at an earlier age, sometimes under 10 years old. Eating disorders and depression are also growing among preadolescents and early adolescents.

Overly status-conscious parents are inadvertently inflicting some of the stresses contemporary kids are confronting. Many of the pressures on children are directly related to America's new and novel lifestyles. The movement of women into the workplace created a need for a new assortment of child-care arrangements. In the mid-1960s, less than 10% of preschool children of working mothers were in a child-care center. By the mid-1990s, 29% of children under the age of five were registered in organized child-care centers across our nation. More recently, U.S. Census Bureau data reveal this figure remained almost unchanged, at about 25%. Child psychologists seem to be in agreement that sending children who are under three years old to day care is more stressful for the kids than having the children stay at home with a parent or a familiar baby-sitter. A child must comply with the environment at day care, and the daily program does not always respond to every child's individual needs or expectations.



Figure 12-2.
Numerous video game issues have been in the public eye over the years, with respect to the addictive nature of these games. Proponents of this form of youth activity suggest that video games can stimulate attention; exercise memory and reaction time; and develop fine motor skills, especially hand-eye coordination. Less enthusiastic are individuals who believe video game addiction among youths causes them to skip school and waste a significant amount of money on the machines. Video games seem to mesmerize youth (and some adults as well). The extent to which any components of this technotoy land are applicable to learning has yet to become an accepted fact among contemporary educators. (Jack Klasey)

There seems to be a growing concern that overworked parents will most likely beget harried children. Today's children have a higher degree of concern about time and meeting deadlines than those raised in an earlier, less hectic period. Unlike in previous generations, mom and dad's workload commonly dictates many children's daily

routines. The children's schedules for meals, bedtime, television privileges, and baths are no longer predictable. Even the traditional summer-vacation period has become incredibly structured, including many types of organized programs taking kids away from the home. It is unlikely that the intermittent parcels of substitute "quality time" parents devote to their young ones can adequately compensate for a lack of "quantity time."

Modern childhood is further plagued with a much greater amount of fear than in the past. Kids now face a dangerous world. The milk carton on the breakfast table is plastered with pictures of missing children. The evening news is filled with stories of child abductions. It is no longer clear what topics should or should not be discussed with children. In any event, children now seem to know about previously forbidden topics well before these topics are spoken about in their homes or schools. Birth control, abortion, alcoholism, and suicide have all become children's issues in recent years.

Young children today also seem to be expressing their fears of being at risk of nuclear or other terrorist attacks. Discussions centering on this topic commonly evoke feelings of confusion and helplessness. Adolescents seem to know there is something vastly dangerous and threatening in their world. Very few, however, have any real understanding of the technological information about this threat. One wonders how many of the problems today's youths are facing are actually tied to their underlying fears about weapons of mass destruction. Consciously or unconsciously, children know their future lives can be obliterated at any moment. Perhaps one reason today's kids are having difficulty working toward long-term goals is due to their lack of confidence in their own futures. It might be true that the age of innocence is shorter than ever before, but all hope is not lost.

Parents and educators alike can do a lot to minimize stress on kids and reduce their fears about technology and violence. Children need to be raised with a strong realization that there are many problems in the neighborhood, the nation, and the world. They are growing up, however, with the capabilities to help solve those problems. Instead of dealing with fear, adolescent students need to begin experiencing a sense of their own power, as citizens with a responsibility to help eradicate serious social dilemmas.

Parents need to communicate with their children and learn to respect each child's individuality. The recent emphasis on fierce competition and getting ahead has typically gotten out of hand. Preadolescents should not be pushed so much that they lose sight of the importance of cooperation, helpfulness, and good old-fashioned love in their daily adventures. We might eventually come full circle, as a result of the problems our young people are encountering. Parents might become more inclined to spend less time (when possible) on work and more time with their children, and the traditional family unit might find itself back in style.

Women's Roles: Change versus Constancy

Any discussion attempting to evaluate the stability of the family unit in our society would be considered deficient if it neglected to address the changing roles and responsibilities among women. Since the women's movements gained national momentum during the early to mid-twentieth century, numerous essayists, historians, and social scientists have published on a wide assortment of topics. Some universities also offer baccalaureate degree programs bearing the title "Women's Studies." Several prominent areas of discourse include women's rights; equality in the workplace; entrance into the

labor force; recognition in the nontraditional fields of science, engineering, and technology; the development of household technologies; and the use of reproduction technologies. If one makes a diligent effort to sift through all the material, one very general conclusion can be derived. While some of women's roles have changed dramatically during the past several decades, many roles have also remained constant.

Household technologies

In some circles, there is a commonly held belief that technology developed for the home can free women to participate in other nonhousework tasks. This might be true, if the technology could actually change the way in which household-maintenance tasks are divided among the family members who reside in the home. Regardless of whether or not women hold a wage-earning position, the most common practice in North American homes today is still for women to do the largest proportion of these tasks.

Utilities such as running water, electricity, gas, telephone, garbage service, and sewage systems represent the technological infrastructure in the home. These technologies probably changed the nature of household work more than other technical improvements, since they eliminated a series of burdensome tasks. On another level though, utilities such as gas and electricity might have fostered other technological changes by facilitating the introduction of many in-house appliances of all shapes and sizes.

Amazing as it might sound, some studies discovered that some of these so-called "laborsaving" devices actually make tasks more difficult, instead of easier! Cleaning some electrical kitchen appliances often takes more time than completing the task without the device. Two examples are the food processor and the electric can opener. See **Figure 12-3.** Appliance repair in one's home has become more difficult and mysterious. The service charge to fix some appliances often is as expensive as replacing them with new models. As household machinery becomes more specialized, the difficulty of understanding either the mechanical or the electrical operation has increased. Further, it often appears this computerized and electrified equipment is designed with planned obsolescence, in order to sustain demand for new sales.

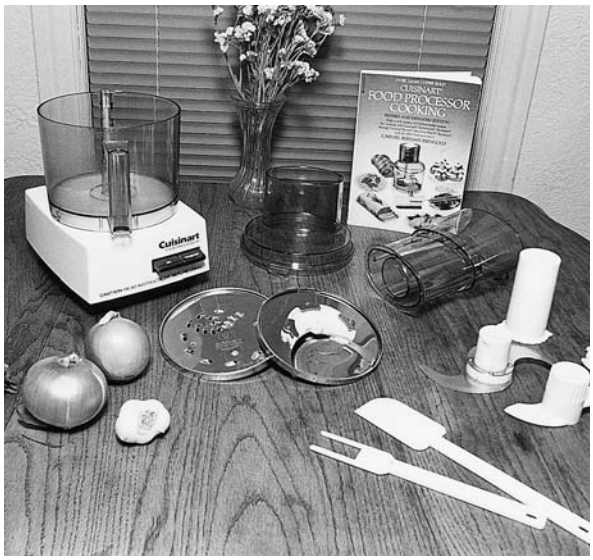


Figure 12-3.
Food processors were introduced into the American kitchen over three decades ago as an exciting laborsaving technology. This photo depicts a typical model, consisting of a base, housing the motor; a work bowl sitting on top of the base; and a series of disks and blades designed to chop, slice, grate, puree, shred, grind, and knead a wide assortment of foods. Since all the individual components must be cleaned separately, this processor's laborsaving profile is best observed when large quantities of ingredients must be prepared. (Michael Dafferner)

While technological innovations might have lessened the physical effort of housework, they have not significantly reduced the amount of time involved in keeping up with

it. The presence of technological gadgets and devices in the home has not lowered the psychological burdens on women, nor has the presence of technology changed the allocation of labor by gender. In fact, the greatest impacts on the manner in which contemporary housework is conducted emanate from nontechnological changes. Specifically, the pressures of inflation, along with the desire for additional goods and services, have drawn women into wage-earning positions. Households are smaller, and women are becoming less anxious about having their homes spotless. According to one report, during the 30-year period from 1965 to 1995, the total number of hours per week women spent doing housework tasks decreased from 30 hours to 17.5 hours. Even still, women were doing twice as much of it as their male partners were.[1] Later in the 1990s, research completed at the University of Michigan concluded that, on average, men spend 16 hours each week on housework (up from 12 hours per week in 1965), and women spend 27 hours doing housework tasks (down from 40 hours per week in 1965). In 2006, the Bureau of Labor Statistics found that women were still spending about 24 hours each week taking care of household activities, compared to men, who spent an average of 14 hours per week fulfilling these tasks.

Reproduction technologies

Birth control technology has played a critical role in stimulating and fueling women's movements throughout the twentieth century. This technology will most likely continue to do so into the twenty-first century. The early 1900s changed the primary role of women as mothers, with the help of barrier methods of birth control, and culminated with the passage of suffrage for women (1920). The later introduction and dissemination of the Pill and a variety of intrauterine devices (IUDs) further increased the ability of women to control procreation. These methods were more effective and much more convenient to use than previous solutions. More so than technological changes in the home, birth control developments led to the greatly increased rate of labor force participation among women.

Improved, safer, and more reliable birth control technologies will continue to increase the amount of control women have over their own bodies. Women can now better control both the total number and timing of the children they bear. Birth control has been a catalyst for a number of social changes, making the quest for long-term, intimate relationships for both males and females somewhat easier. On the other hand, many of the changes associated with these searches have made the maintenance of long-term relationships much more difficult. Even though birth control technology has altered and expanded the number and types of relationships available to men and women, most people still seem to desire a monogamous, long-term commitment at some point.

Reproduction technologies have increased the control women have over childbearing. For those couples wishing to have children, modern birth control usually makes it possible to achieve the desired number and timing of children. Birth control enables the woman to simultaneously pursue other career objectives. The ability to delay childbearing via birth control devices, however, does not always result in the desired, ideal family. Some couples who postpone childbirth decisions find themselves experiencing fertility problems. In yet another response to a social trend, new technologies to correct infertility are being tested and are becoming increasingly available.

The more important dilemma of who will rear the children remains. There is no technological fix for this responsibility. Not

[1]Bianchi, S. M. and L. M. Casper. 2000. American families. *Population Bulletin* 55 (4): 33.

all duties associated with child care can be purchased, regardless of how affluent the couple is. Kids are not robots, and they require a lot of parental attention and interaction for their mental and emotional stabilities. In the 20-year period between 1977 and 1997, the average workweek among salaried Americans working full-time increased from 43 hours to 47 hours. The U.S. Bureau of Labor Statistics data reveal that average working hours in the United States rose nearly 12% between 1973 and 2000. On average, in the early 2000s, employed Americans worked an astonishing nine weeks more per year than their Western European counterparts did. In Norway and Sweden, it is common for workers to receive four to six weeks of vacation and up to a full year of paid ***parental leave***. In other European countries, 35-hour maximum workweeks are enforced, partially to reduce unemployment. If male and female Americans alike continue to sustain this love affair with work, questions about child rearing will remain on the table (most likely not the family dinner table!).

The Church: Technology and Religion

For centuries, people from all ethnic and educational backgrounds, as well as all socioeconomic levels, have looked (and continue to look) to their religious institutions for comfort and guidance during times of sorrow or confusion. Aspects of modern technology, however, have caused some people to change their traditional views of church, their definitions of *God*, and other beliefs. As modern technology and science continue to provide cures for previously incurable illnesses, some might feel they no longer need a Supreme Being who is all-knowing and everlasting. Some actually look to their medical doctors as the new priesthood.

This reason and various others have led some sociologists to suggest that modern technology functions as a type of religion for some who have abandoned belief in God. At the same time, there are religious leaders who believe modern technology is causing a resurgence of humanity's quest for religion. There are no simple explanations for why the proliferation of scientific fact and technological know-how leads one person to question the existence of God, while it leads another to even greater belief in a deity. In a national study the National Science and Technology Medals Foundation commissioned in the mid-1990s, two-thirds of the adults polled in the United States said that new developments in S & T did not have much to do with their personal religious beliefs one way or the other.[2]

Many of the prevailing religious and ethical issues of the day are rooted in the world of scientific experimentation and technological innovation. The dilemmas of euthanasia, the wonderment associated with genetic engineering, the exciting new frontiers in stem cell research, the uncharted territory related to cloning, and the medical technologies of procreation are all legacies of a contemporary technoscientific culture. Vatican officials delivered one noteworthy response to several of these and other contributions technologists offered in the late 1980s. In a document titled "Instruction on Respect for Human Life in Its Origin and on the Dignity of Procreation—Replies to Certain Questions of the Day," the Vatican instructs governments around the world to ban artificial procreation, including sperm banks, embryo banks, postmortem insemination, and surrogate motherhood. The Vatican also recommends laws against embryo research and abortion. These strictures represent one of its most expansive public statements since the encyclical on birth control released in the late 1960s. See **Figure 12-4.**

[2]Ferree, G. D. 1996. American views on science and technology. *The Public Perspective* 7 (6): 60–63.

Procreation Policy Established by Vatican Congregation for the Doctrine of the Faith

Highlights of the Vatican Document

The Vatican document on artificial procreation expresses moral opposition to the following practices:

- Prenatal diagnosis, including the use of amniocentesis and ultrasonic techniques, for the purpose of eliminating fetuses that are affected by malformations or that are carriers of hereditary illnesses.
- Surrogate motherhood.
- Any artificial fertilization involving persons who are not married.
- Test-tube fertilization and embryo transfer involving a married couple.
- The artificial insemination of an unmarried woman or of a widow even if the sperm was donated by her husband.
- The collection of sperm through masturbation.
- Therapeutic interventions and methods of observation of an embryo that involve disproportionate risk to its health.
- All experimentation on living embryos not directly therapeutic.
- The keeping alive of human embryos for experimental or commercial purposes.
- Utilization of dead fetuses for commercial purposes and unnecessary mutilation of dead human embryos and fetuses.
- The voluntary destruction of human embryos obtained in vitro either for purposes of research or of procreation.
- Biological or genetic manipulation of embryos through practices like fertilization between human and animal gametes and gestation in the uterus of animals or an artificial womb.
- Efforts to obtain a human being without any connection with sexuality through methods like "twin fission," cloning, or parthenogenesis.
- The freezing of an embryo even when done to preserve its life.
- Efforts to influence chromosomic or genetic inheritance that are not therapeutic but which aim at producing human beings selected according to sex or other predetermined qualities.

The document expresses moral approval of the following practices:

- Prenatal diagnosis, including the use of ultrasonic techniques and amniocentesis, that aims at safeguarding or healing the embryo.
- Prenatal therapeutic efforts designed to heal an embryo of maladies including chromosomal defects.
- Prenatal research limited to the simple observation of an embryo.
- The use of experimental therapy on an embryo as a final effort to save its life.
- Artificial insemination within marriage when the technical means is not a substitute for the conjugal act but serves to help it achieve procreation.
- Fertility drugs.
- Medical interventions that facilitate the performance of the conjugal act.
- Medical intervention to remedy the causes of infertility.

Excerpted from the Vatican document entitled "Instruction on Respect for Human Life in Its Origin and on the Dignity of Procreation—Replies to Certain Questions of the Day" (San Jose Mercury News)

Figure 12-4.
Highlights of the Vatican statement regarding procreation and technology. This statement was released in the late 1980s.

These concerns about the impact of technology on procreation stem from the Catholic Church's view that human life is sacred from the instant of conception. A belief in that idea commands further opposition to in vitro procedures producing spare embryos to be destroyed or used later for research. Similarly, prenatal testing, sometimes viewed as genetic counseling, giving parents the chance to abort an abnormal fetus must be considered forbidden. The Vatican insists any technology separating the act of conception from the conjugal act is morally wrong. It is difficult to fully describe widespread public reaction to this ecumenical treatise. As with previous discussions regarding science, technology, and religion, the initial discourse might seem rhetorical. In other words, various groups make elaborate attempts to describe a complex social issue eluding specific characterization.

In its condemnation of artificial conception, the Vatican document is heavily reliant on its earlier restrictions against contraception. In the same way that contraceptives separate sexual union from procreation, the church argues that in vitro–fertilization techniques separate procreation from sexual union. Many Catholics do not agree with their Church's opposition to birth control. Many have been inclined to question this directive. In fact, some theological observers believe the Vatican's response to the technology of fertility might cause the Catholic Church's present congregations to disregard some of its other teachings. On the other hand, society might ultimately view this document as a timely warning against a growing scientific indifference to the origin and vulnerability of human life.

The Debate between Science and Religion

It seems that whenever the word *Christianity* surfaces in the scientific press, its readers tend to prepare themselves for yet another round of a creationism debate. Stated differently, spectators expect the fundamentalist Christians to insist on the validity of Genesis and refute any scientific diatribes concerning the evolution of the human species. Indeed, there are a number of variations on the creationist theme, and each group is trying to reconcile Genesis with science in some particular manner. There are also many Christian scientists who regard the creationism debate as irrelevant to the essence of contemporary science policy. Their basic tenet is that faith needs science and science needs a firm grounding in Western religious heritage. Both parties seem to have a great deal to gain from one another, if the primary objective is a deeper humanization of science, technology, and society.

Today's scientists should be reluctant to live out their scientific lives in a research laboratory devoid of any spiritual foundation. Likewise, religious leaders who aspire to have a voice in determining the future uses of technical information and technology in general should have at least a rudimentary understanding of the scientific method. The core of the debate between science and religion rests on the following precepts:

- ❏ Scientists believe religion skews objective reasoning, fuels repressive movements, and stifles freedom of thought.
- ❏ Religious leaders are convinced that science pursued from an agnostic or atheistic base will continue to feed the ever-growing materialism in society and contribute to the violence of the modern age.

Fortunately, there seems to be an emergent group of humanists who support the goals and convictions of both camps. According to a recent poll that the Pew Forum on Religion and Public Life sponsored, 42% of the American public essentially reject evolution, believing that life on this planet has always been the way it is and has not evolved. Among the 51% who do accept evolution, 21% still think a Supreme Being or creator guided evolution. Pew studies also demonstrate that about 62% of Americans support teaching ***creationism*** alongside evolution in public schools. Essentially, respondents say evolution should be taught as scientific theory, and creationism should be discussed as a religious theory. Although people might differentiate science and religion as two distinctly separate areas of human life, they also identify ways in which the two share common points of contact in our society.

One example of a commonality is related to mankind's relentless quest for understanding and intelligibility. Many believe the essence of science is experimentation, which produces data observable to the senses. Empirical methods of research usually yield empirical data, but the true objective of scientific inquiry is the attainment of intelligibility, not the generation of data. Scientists search for patterns isolating relationships between one bit of sensory data and another. These patterns constitute an understanding of reality, rather than an unrefined list of facts and figures.

Understanding science as the search for intelligibility suggests science and religion share the same ultimate goal. Namely, they both envision the capacity to provide tangible meaning to the world and human existence. Theologians do not use empirical methods with a great amount of scientific rigor, but they do seek to make our unique human experiences significantly more lucid. Journalists once asked Albert Einstein what he thought about the existence of God. He replied he thought it obvious there was an intelligent force in nature that put the universe in organized motion. He had no problem with science and God residing in the same space. (See http://www.einsteinandreligion.com.)

Both religion and science provide ways of obtaining intelligibility in contemporary society. Neither institution can speak with absolute precision. Both are constantly trying to use language to demystify realities often beyond the capacity of language to explain. Many of us look to religion for personal guidance, support, a sense of belonging, and hope for the future. At the same time, we look to S & T for an enhanced quality of life, a sense of progress, and a hope for the future. Religion does not try to explain nature the way science does. Science, with all its limitations, cannot give intelligibility to all we experience as human beings.

Computers and God's Image

The traditional view of God deeply integrated into our culture is inherited from Judeo-Christianity. Specifically, God is out there, enduring beyond time and space in a state of permanency, and not susceptible to change. God is the creator of all that exists and is the unifying force allowing the continuation of life as we know it. In addition, God determines and represents the nucleus of life after death.

Social scientists speculate as to whether or not computer technology will have a far-reaching impact on these traditional images we have of God as our creator, who is all-knowing and all-powerful. For instance, computers have become integrally involved with the medical field. They appear to be changing and improving the manner in which we are able to sustain human life. Is the view of God, as the one who creates, nurtures, and extends human life, rendered less precise, when humans and their machines are allowed to interfere with the process?

On another front, through the aid of computers, members of the general population are able to tap into vast resources of knowledge from their own homes and offices. The average citizen living in the industrialized world of the early twenty-first century has access to an immense bank of information. Precomputer scholars were known to spend their entire academic careers in the pursuit of wisdom now available to the common man. Perhaps an omniscient God does not seem as awesome to the individual who can find out a great deal through a directed, computerized search of literature. Instant communication on a global scale via computer technology might also change our perceptions of omnipresence. Corporate executives in Chicago who are engaged in a real-time videoconference with engineers in Bangkok might feel they are, in some ways, approaching being everywhere at once.

Further, the field of AI has developed such refined ways of emulating human reasoning that it might not always be possible to distinguish between humans and machines. We are bombarded with interactive programs to diagnose diseases and make suggestions regarding ways we can improve our sense of self-esteem. Will people who have difficulty differentiating between minds and machines have just as much trouble seeing the difference between humans and God? Avowedly, this last inquiry is rhetorical, but it is intriguing just the same.

Computers might truly be changing our traditional views of God. To suggest that computers have the power to either replace God or diminish a person's religious beliefs seems fatuous. In fact, astute cognitive scientists would probably be the group least likely to make this sort of testimonial. They are quite in touch with the reality that a modern computer capable of processing the amount of information stored in the human brain would need to be thousands of times larger in volume than the human brain. From this vantage point, computer technology provides a new mode of comparison without affecting our traditional images of God. Computers are our newest and most sophisticated tools to make further attempts to comprehend the true meaning of life and human existence.

The School: Technology and Education

Computers and education have become inextricably linked. Parents worry about whether or not their children are computer literate. Educators fret about tracking the latest trends in technology for the classroom. Students are anxious to gain experience with computers, in order to launch a successful career.

The days of the little red schoolhouse constructed on the prairies of this great nation are truly ancient history as we enter the first decade of the twenty-first century. Nevertheless, the stalwart school building has retained its role as one of the most influential social institutions we encounter throughout childhood, adolescence, and early adulthood. The profile of the curriculum and the salient features of the building and its classrooms are different, but the primary objective is alive and well. However comforting this might sound, there is something a bit scary and slightly unsettling about this statement. Think for a moment about all you have learned about change as you have read through the other chapters of this textbook. Undoubtedly, a physician trained in the 1850s would be terrified if asked to perform a surgical procedure in a modern hospital operating room. The average American farmer of the 1920s would hardly

recognize anything besides the cows on a twenty-first-century technology-dependent dairy farm. Astronomers who studied the skies in the sixteenth century would be clueless during a tour of a contemporary space observatory, but a seventeenth-century schoolteacher would most likely feel right at home in one of your current university classrooms.

Schools exist to educate and socialize the residents of a community, state, nation, or continent. One of the most significant goals of education is to challenge learners to think critically about issues, generate new solutions to both old and new problems, and develop top-notch written and oral communication skills. Schools house the industry we call *education*. Their productivity and quality are measured via the success of the students who traverse their hallways and learning centers. Technological advancement is certainly challenging the face of this traditional social institution, but is this institution's stability also being threatened? How are the fruits of our technology impacting educational delivery systems in an ever-changing world?

Educational commissions, task forces, and ad hoc committees regularly issue reports warning us about the demise of our nation's educational system. These editorials indicate that the quality, value, and relevance of a major segment of our educational services have been declining over the past several years. Projections of this nature have made it clear that this country's future leaders will be at risk unless more attention is devoted to our schools. Education has never been more essential to the survival of humankind than it is today.

A major responsibility of schools is to prepare students to enter a rapidly changing and constantly evolving job market and political environment. Schools are expected to mold students who are adaptable and able to respond quickly to the changing requirements of new technologies. Gone forever are the days when a high school education could get a person through life pretty well. In our society, it is expected that workers' job descriptions and task definitions will change significantly every four to eight years. This means our schools will train both youths and adults. Adult workers will require additional education and retraining each time business and industrial operations are updated. Schools will continue to be commissioned to provide a greater number of services to the local community, to area businesses, and to very young students. Educational institutions might become the primary mechanism to mitigate skills and knowledge obsolescence in a society in which lifelong learning is the accepted norm.

Technology in the Classroom

Education is one of just a handful of major American industries yet to be thoroughly computerized. This industry's turn is on the visible horizon, as computer-hardware manufacturers and software developers have already identified education as a huge gold mine. An intriguing assortment of high-tech wares already exists for classroom teachers. Products in the forms of computers, software packages, databases, interactive electronic media, and far-reaching telecommunications linkages all cost money. Obtaining classroom equipment is certainly an integral part of curriculum development and modification, but it should not be the first step. The two most essential questions prospective buyers should ask are "Will the new technology improve productivity and quality in teaching and learning?" and "Is the technology relevant to specific instructional goals?"

As we enter the twenty-first century, nearly all full-time regular-classroom, public school teachers in this nation have access to

computers or the Internet (usually both) in their schools. Although a majority of them use technology for classroom instruction, a few years ago, many said they were not as well prepared for the task as they would have liked. Not surprisingly, the National Center for Education Statistics (NCES) reports that teachers who have more than 32 hours of professional development related to instructional technology are twice as likely to use computers effectively than their colleagues who have not been trained. The National Science Board reports that schools have made tremendous progress in providing Internet access—only 3% of instructional rooms had on-line connectivity in 1994, compared to 93% in 2003. In public schools with Internet access, during the same time period, broadband connections increased from 26% to 95%.

Education Week, in a joint project with Public Agenda, found that more students today report using computers at school on a regular basis and they are using them for serious learning.[3] In contrast to earlier findings by the NCES, most teachers interviewed here said they receive the technological support and equipment they need and they feel comfortable using computers in the classroom. Not only are students' use and instructors' use of technology increasing during the school day, but the ways computers are being used are also more sophisticated. In this same study, 63% of the kindergarten through high school students questioned stated they use computers in school to gain assistance in learning new things, as opposed to using them just for typing or playing games. This represents an increase of 21% in just a bit over two years. Many students use the Internet to do schoolwork or homework several times a week. Computer-aided instruction (CAI) has forever changed the way teaching and learning activities unfold both inside and outside the walls of today's school buildings.

Reduced costs, improved performance, and access to incredible amounts of information are among the most compelling reasons for increasing the use of computers in instruction. In CAI, computers are used as supplements to conventional teacher-led instruction and can be used over a wide range of subjects. The price of computers has fallen dramatically. Along the way, a tremendous surge in the development of educational software has occurred. Complementing the earlier drill-and-practice programs designed to supplement the teacher's presentation are a wide variety of software packages. See **Figure 12-5.** These instructional aids consist of tool software, problem software, and simulation software designed for use in courses such as programming, logic, music, science, social studies, language arts, graphics, and mathematics. Computer-programming specialists have demonstrated their adeptness at devising expert systems for use in our schools. This concept finds its origin in the field of AI. An ***expert system*** for educational use is a computer program condensing a huge amount of accumulated knowledge on a given subject into a form of question-and-answer routine to lead the learner through a logical progression to the correct response.

While software improvements are being made regularly, some professionals believe that the resultant learning modules will soon replace some kinds of textbooks. Software can be tailored to meet individual student needs and updated more efficiently and inexpensively than textbooks can be. Computers can also be linked with videos to provide sight, sound, and movement. These features promise to provide a new dimension to lessons in subjects such as history, art, and political science. The one drawback to this form of delivery system is that younger students might have a tendency to view these lessons as they would a television program. In the absence of direction and instructional

[3]Public agenda reality check 2001. 2001. *Education Week* 20 (23): S1–S8.



Figure 12-5.
The presence of networked computers in elementary and secondary classrooms is commonplace today. These students are working together.

cues, less studious learners might not absorb a lot of the information presented.

As computers and educational software become increasingly available in contemporary classrooms, teachers are finding it necessary to figure out how to best manage these resources. The first step toward effective management is to view the computer as a tool. The acronym *CAI* itself implies that the computer aids, rather than crafts, instruction. Educators who approach CAI with specific problems in mind and then ask how the computer can be used as a tool to solve these problems are more likely to synthesize sensible and successful applications for their computers. For instance, it might not be necessary to house a large number of computers in the classroom. Strategic planning might reveal that a ratio of one computer station per 5 or 10 students is adequate. In selecting software for the class, the teacher must be careful to identify those units that will ultimately promote the effective use of the computer as a tool to meet her curricular objectives. It is especially critical to develop a management strategy that can facilitate the smooth rotation and recycling of students through the CAI package.

In the rush to join the computer revolution, school district administrators should not lose sight of the importance of careful evaluation and planning. CAI is just one of many instructional approaches. The cost-effectiveness of CAI should be assessed by the extent to which this approach can provide instruction more efficiently than other alternatives.

Distance Education and Distance Learning

If we closed this segment of the chapter without a brief discussion of various distance-education and distance-learning options, we would be remiss in our analysis of technology's impact on today's schools and universities. Across the nation, a vast assortment of classes is being taught in virtual classrooms. A commonly agreed-on definition of *distance learning* is a formal educational process occurring with the teacher and learner separated by either time or distance (often both). In the realm of instructional technology, ***distance education*** is a subset of what might be viewed as a larger world of technology-enabled teaching and learning. Despite all the hype and media attention devoted to this industry, distance learning is really not a new or novel phenomenon. Every one of you who is reading our textbook has, at some time, engaged in distance learning.

When you ponder the definition above, the most common, and perhaps oldest, form of distance learning is your daily homework. When you complete a homework assignment, you accomplish a learning activity that your instructor constructed. You achieve this without the presence of the instructor (at a distance from your instructor). Correspondence courses represent another form of not-so-new distance-learning options. A person's cumulative, acceptable completion of an entire set of assignments constitutes a course, for which credit can be earned. If one strings many of these courses together, a degree might be the ultimate result. The unassuming independent-study course is yet a third example of distance learning, in which students rarely meet face-to-face with their professor.

Nevertheless, when administrators talk dollars about distance in contemporary educational institutions, they are not generally envisioning these three examples. In most instances, distance-education courses are identified as those being delivered to remote (off-campus) locations via audio, video, and computer technologies. Advancements in fiber-optic, microwave, compressed-video, and satellite technologies allow many of our traditional face-to-face real-time classrooms to be simulated for distance learners who are separated from their teachers.

The two major types of interactive television delivery systems are satellite and nonsatellite. Most satellite delivery systems allow for one-way video and two-way audio transmission, while those that are nonsatellite dependent allow for two-way audio and video transmission. Synchronous two-way, interactive video systems caught the attention of and excited many faculty members in the late 1980s and early 1990s. Some states invested in widely dispersed interactive video communication systems, with the expectation that one faculty member could be counted on to teach many students at multiple sites across the state. Unfortunately, the interactive nature of the systems was not as promising as they had hoped. A recent study revealed that professors asked to deliver courses via interactive television must be informed ahead of time about the following differences from traditional teaching:

- ❏ The professors will have less control over the delivery of their courses.
- ❏ It might be impossible to replicate the responsiveness found in their more familiar face-to-face classrooms.
- ❏ The professors must be extremely keen listeners.
- ❏ The lack of students' nonverbal cues might adversely affect the professors' teaching and the quality of their teacher-student, interpersonal relationships.

The use of the PC and associated networked communication technologies represents the latest, and perhaps most convenient, form of distance education. At the close of the twentieth century, nearly every two- and four-year college and university in the United States had developed (or was developing) courses and complete degree programs to be delivered and completed using the Internet as the primary vehicle for communication. Distance-learning courses are designed to replicate face-to-face classroom and laboratories through the use of WWW-based e-mail, bulletin boards, listservs, and chat rooms. When these technologies are combined with other Web site–based information sites, videotaped materials, audio recordings, on-line testing applications, and the old-fashioned telephone, many instructional objectives can be accomplished through distance-education courses.

In a recent *New York Times* report, it was estimated that more than a million people were enrolled in on-line courses for credit during just one academic year. This did not include the numerous adults who enrolled in and completed noncredit courses. Avowedly, on-line distance education is still in its infancy, and the debates about how to best blend technology and pedagogy have only just begun. In 2006, just a few examples of cyberspace instruction included the University of Illinois's master's program in library and information science, a master's degree in nursing from the University of Phoenix, Stanford University's on-line engineering program, and degrees in vocational-education teacher preparation at SUNY at Oswego. See **Figure 12-6.** Perhaps you are using this textbook for a course you are taking on-line.

Will distance education and distance learning totally supplant school- and university campus–based teaching and learning? We believe it is safe to say this will not occur in the immediate future. In each of the on-line programs just mentioned, some amount of on-campus instruction or another form of face-to-face dialogue between students and the instructor was apparent. We must continually reexamine educational priorities and directions and not lose sight of the fact that the learning goals of education are diverse and complex. Likewise, the array of instructional strategies and assessment approaches we use to accomplish those goals must be equally diverse and complex. Technology can either enhance our educational programs or undermine their long-evident stability. People who profess to be educational leaders have an obligation to keep their curricular goals just as current as the technology-laden classrooms being designed to achieve these goals. In other words, curricular relevance will more directly influence the stability of educational institutions in our society than technical modernity will. Further, educators must not lose sight of the fact that teaching is not enough. Contemporary educational professionals must provide numerous opportunities for authentic learning to occur.

The Playground: Technology and Recreation

Few people would have difficulty accepting the fundamental fact that play is an essential part of the human condition. The concept of a playground, however, is usually more recognizable among the residents of the world's industrialized nations. Play is central in children's lives. Children make their world into a play world at every possible opportunity. The urban movement, born of the industrial revolution, has progressively and drastically reduced the opportunities to create safe play worlds. Busy streets pose

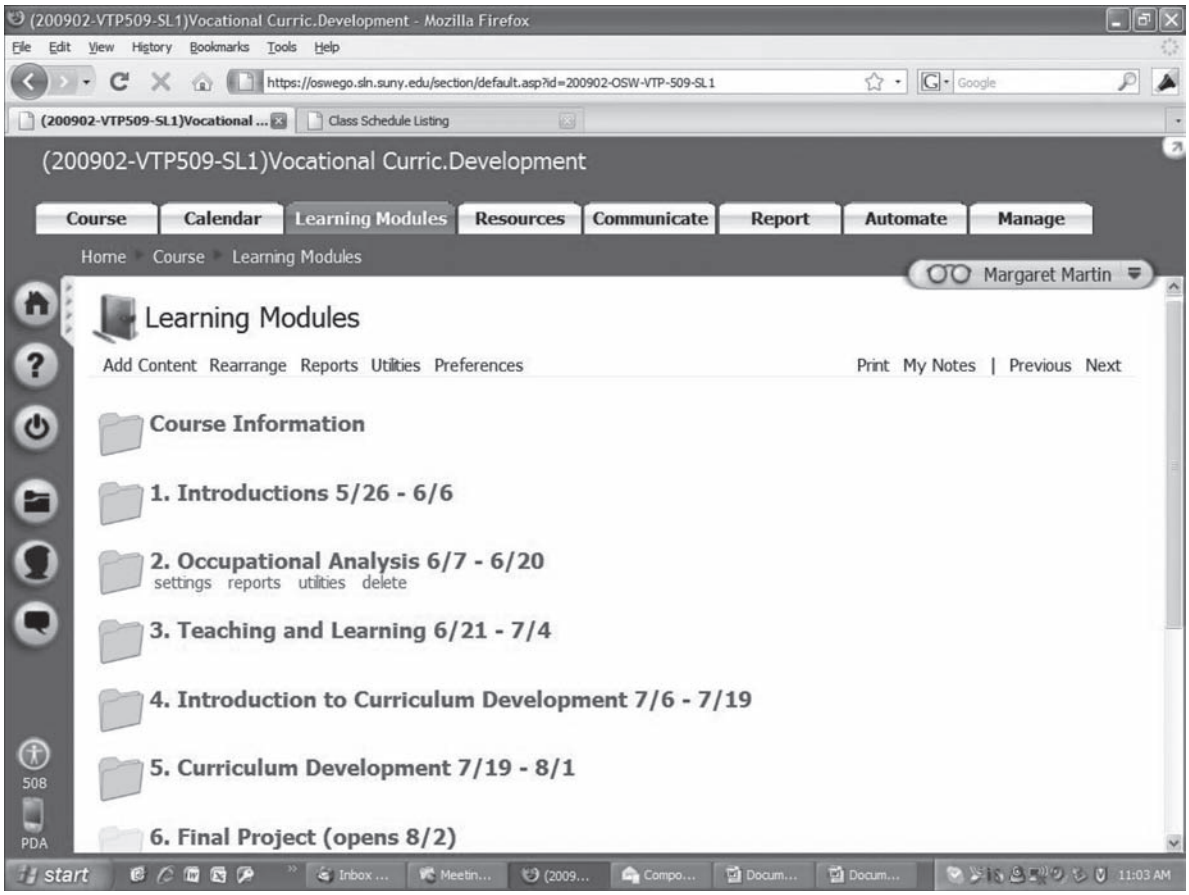


Figure 12-6.
One example of a distance-education course. (Margaret Hill Martin)

serious hazards, vacant lots have disappeared, and high-rise living arrangements eliminate backyards. The need to set aside special spaces where children can find at least a minimal opportunity for growth and development through play first became evident in the technology-oriented sector of the world. See **Figure 12-7.**

The playground movement in the United States was initiated during the late nineteenth century with the sand gardens in Boston. This movement's proponents asserted that city life was ill suited for the normal growth of children. Crowded cities stimulated a basic social concern for the provision of adequate play space for children. This became a catalyst to spearhead the formation of a new national organization. Around the turn of the century, the Playground Association of America was established to collect and distribute information concerning playgrounds and to promote interest in their development across the country. The provision of adequate open space for recreation has become one of several public policies that originated with and grew out of the early playground movement. This movement's primary advocate today is the National Recreation and Park Association (NRPA).

While not everyone envisions recreation and playgrounds as social institutions, few deny the importance of leisure in contemporary



Figure 12-7.
From sand gardens to high-tech facilities, we have witnessed dramatic changes in the design and construction of playground equipment during the past century. Playground manufacturers report the number one trend shaping the design of equipment is a concern for safety. There is also a growing demand for durability and an interest in the modular concept. While there are still many examples of traditional playground equipment, such as swings, slides, and climbers, in use, there is a trend away from purchasing one-use-only pieces. Recreational planners have the option of buying several components that can stand alone or fit together to form a variety of shapes serving to enhance and stimulate more creative play activity. (Michael Dafferner)

society. Questions concerning how individuals spend their leisure time have led to new fields of study, formal degree programs, and a whole new technological discipline devoted to playthings. How does leisure look in a technological era? It is unlikely that the early playground pioneers, who initiated an organized response to a critical social concern, could ever have imagined the magnitude and diversity of organized recreation in today's society.

Throughout the twentieth century, Americans witnessed significant changes in their leisure patterns. In the early 1900s, workers put in, on the average, a 56-hour week. By the late 1970s, that number had decreased to 43 hours per week. As was noted earlier in this chapter, however, the trend back upward was apparent at the dawn of the twenty-first century. Also, noted in Chapter 11, many of us seem to be busy with work-related tasks, even away from our places of employment. As we all work harder, the need for leisure is even more compelling. As you will read in the following section, this translates to opportunities for leisure time for employees during their workdays.

Technology has influenced the types of leisure activities we enjoy. The term *sports* is used to describe some of the universal leisure pastimes. Developments in technology have shaped the manner in which everyone, from the serious athlete to the hobbyist, is able to participate in sports.

Free time is sometimes used to describe leisure. Nevertheless, the word *leisure* somehow conveys the idea that time is being used constructively. In some instances, it even implies the individual is engaged in upper-class, cultural activities, such as attending the ballet, seeing the opera, going to the theater, or reading the classics. When a person uses his free time to watch football on television while "slugging down" a few beverages with friends, the word *idleness* is sometimes substituted for *leisure*. This degrading expression indicates to some that the person is not doing anything worthwhile, but he is simply wasting the free time available. Of course, there are arguments for both definitions, and neither leisure pattern is necessarily desirable for everyone. If anything definite can be said about our leisure time, it is that this time is individualistic. What some people consider leisure, such as washing the car, others consider work.

What other people consider leisure, such as watching televised football games, their friends might consider a boring waste of time. See **Figure 12-8.**

Besides giving us more time to enjoy leisure activities, our high-tech society has also provided a number of new ways to use technology, including electronic games, DVRs, DVD players, affordable air travel, large-screen televisions housed in local neighborhood taverns, demolition derbies, recreational vehicles, and lots of high-tech athletic equipment. Of these, the electronic media, which absorb staggering amounts of free time in contemporary American households, offer the most seductive leisure format. Some writers have actually compared the television screen to the more traditional fireplace hearth. Analogous as they might seem, the latter example promotes conversation and romance, while the former seems to stifle both.



Figure 12-8.
People devote time to leisure activities for many reasons. Some people find it worthwhile to spend time with their families, even while doing necessary tasks, such as washing the car. Others use modern athletic equipment to stay in top physical shape. Other activities, such as reading a good novel and horseback riding, offer therapeutic value and relaxation.

Survey statistics indicate that watching television is perhaps the most common form of leisure today. The proliferation of VCRs during the 1980s and DVD players in the late 1990s provided the television-viewing pastime with even more room to multiply. Television has been credited as the primary source of accessible newsworthy information and as an educational tool to aid in the socialization of children. More often, television tends to be chastised as a technological intruder that has destroyed the personal interaction among family members and stimulated the growth of violence in our society.

Regardless of the label ascribed to it, television demands very little from our minds and bodies. Television's mesmerizing presence allows us to absorb as much or as little as we desire. The availability of remote control devices makes it possible to change channels, adjust the volume, advance the tape in the VCR, or cue a spot on the DVD, without even getting out of the chair. As with other technogadgets, the remote control feature has created new terms associated with its use. Two such terms were coined in the mid-1980s, and while the use of these words might no longer be apparent, the behaviors remain prevalent. ***Zapping*** refers to the practice of switching back and forth between channels, generally to avoid being exposed to product advertisements and commercial interruptions. ***Zipping*** describes the use of the remote control buttons to fast-forward a prerecorded tape to watch a one-hour show in about 53 minutes. This zipping strategy pertains also to cuing a particular place on the DVD. Both the zipping and zapping behaviors yield the same result—zero commercials or trailers for other programs or movies. As you might well imagine, large corporations are becoming more reticent to spend huge sums of money on television ads that people zip over or zap out as they are being broadcast. Some companies have taken to imbedding advertisements directly in network programs to counteract these consumer tendencies. Think about this the next time you see a favorite actor drinking a can of Pepsi® soft drink.

As an increasing number of Americans retreat to their electronic cocoons for their leisure, some appear to becoming psychologically dependent on the television set. In all likelihood, you probably know people whose free time is almost completely engrossed by video in its various forms. Meanwhile, another electronic device has become quite common in American homes. Even though the PC might be considered to be more intellectually demanding than the television, it still fits the electronic-cocoon scenario of leisure patterns. As a type of leisure device, a PC provides all sorts of electronic games. PCs also allow users to converse with other people via bulletin boards, chat rooms, and IM. Household computers, combined with televised home shopping networks, have already made it easier for us to do our shopping, banking, and even our work, without ever leaving the house. Do you think this trend will lead to the resurgence of the long-lost delivery boy of the early twentieth century?

In a previous section of this chapter, it is stated that there appears to be an overall merging of childhood and adulthood in our society. As children try to act more similarly to adults, adults often behave very similarly to kids. This behavioral tendency is most obvious in the recreational interests among a growing population of middle-aged baby boomers who refuse to slow down as they approach retirement age. In fact, the Sporting Goods Manufacturing Association reported that its largest growth market is coming from 50- to 74-year olds. An interesting social trend that not only supports this adult need for play, but also recognizes the

importance of organized leisure activities, might easily be found in corporate wellness and fitness centers. Sometimes listed under the discipline heading "Industrial Recreation," these programs have surfaced around the country, and many have been in existence for more than 30 years.

Employee Recreation Programs

It is difficult to accurately pinpoint a time period when industrial recreation really got started. Perhaps the roots of this discipline can be found at the first company picnic given for the employees of Johnson Wax in Cincinnati, Ohio in the late 1800s, or maybe the catalyst was formed during an employee baseball game between the Equitable Life Assurance Company and the Metropolitan Fire Insurance Company in New York City in the mid-1800s. Some recreation professionals make reference to the World War II era, when the nation called for increased productivity. The need arose to relieve the tensions of war and enhance employee unity in the midst of family separation and loss. In any case, employee recreation, services, and fitness (ERSF) programs have experienced tremendous growth in the United States over the past several decades.

With each passing fiscal year, the number of companies offering some type of recreation program as a component of their employee-benefits package increases significantly. Many corporations have installed exercise facilities in their office complexes. Others have turned to private health spas and fitness centers as places for their employees to exercise. In other words, while some firms have actually built an on-site facility, others have found it more convenient to purchase corporate memberships from nearby health clubs. Some of the predominant features both types of programs offer are basketball, racquetball, tennis, weight lifting equipment, stationary bicycles, fitness classes, and volleyball. Also available, on a less regular basis, are amenities such as golf course access, company swimming pools, softball fields, massage parlors, and suntanning salons. The awareness of the importance of recreational facilities convenient for employees to use during the workday has spread beyond corporate executives. Concern for a holistic business environment seems to prevail among forward-thinking architects and developers who are designing contemporary office and industrial parks. In a bona fide attempt to attract corporate tenants, builders have included jogging trails, lakes, bicycle paths, fitness centers, and diversified landscaping in their plans.

If you study the construction documents for one of these industrial parks, you might wonder when anyone would find time to get any work done. On the contrary, since that first company picnic years ago, the philosophy has remained the same. Many executive officers firmly believe that recreation services can cement employee loyalty to the company, reduce tensions, lower absenteeism, and promote employee camaraderie and morale. As you probably already guessed, numerous studies have been engineered to determine the validity of these sorts of convictions.

Most of the research results on this topic have been quite positive so far. It seems safe to conclude that many important organizational advantages can be gained through employee recreation programs. For example, NASA corroborated the findings of the Heart Disease and Stroke Control Program. NASA and the Heart Disease and Stroke Control Program both concluded that a program of regular exercise reduces absences, improves stamina and work

performance, and enhances powers of concentration and decision making. Along the way, they also found that the average office worker's efficiency decreases 50% during the final two hours of the workday. By comparison, those who exercised on a daily basis were found to work at full efficiency all day long.

The most fascinating thing about recreational activities is their dichotomous ability to either arouse and stimulate participants or relax them and calm their nerves. Essentially, most recreational activities act to optimize and equalize a person's stress level. A certain amount of stress can actually increase productivity and creativity. In sum, ERSF programs have a lot to do with reduced absenteeism and turnover, increased job satisfaction, increased performance, improved general health, and reduced cost of care. Quite simply, in this day and age of complex technology and change, employee recreation programs can really increase profits.

High-Tech Recreation Equipment

The profile of athletics, in an era when technology can ostensibly fix anything, seems to go through one transition after the next. Today's athletes come better equipped than the chariot riders in ancient Greece. More interesting, however, is the extent to which contemporary athletes, professionals and amateurs alike, are dependent on a whole array of paraphernalia. We have almost reached a point when it is not enough to say you lack the necessary coordination to be a good skier or halfway-decent tennis player. The chances are strong that your ski instructor or a tennis pro will recommend that you go out and purchase a new "whatever" to improve your performance.

Sports equipment has always been a crucial link between the athlete and the game. Now, more than ever, a host of technical refinements are introducing a whole new line of "improved" basketballs, tennis rackets, aerobic shoes, golf balls, golf clubs, baseball gloves, bicycle gears, and safety helmets. The improvements in sports equipment are being made so fast that, in some cases, they are actually revolutionizing the sport itself. On the teaching side of the games, technology is changing the look of the lesson. Two excellent examples are found in Florida.

The Grand Cypress Academy of Golf in Orlando and the IMG Bollettieri Tennis Academy in Bradenton both use computers, high-speed video cameras, and heart monitors to diagnose the problems and improve the performance of duffers, hackers, and tournament players alike.[4] Instructors at the former institution aim to develop the perfect golf swing for every registrant. Within various program formats, the students receive daily 45-minute lessons in front of video cameras. While the tapes are played back, a computer-generated stick figure is superimposed over the image of the learner to illuminate deviations from the ideal movements. See **Figure 12-9.** At the tennis school, the heart monitor is one of the chief teaching aids designed to train players to perform competitively on a consistent basis. These professionals believe players function at their best skill level within a narrow range of heart rates.

The manufacture of leisure equipment is a major industry. One of the most common sales-promotion gimmicks that sporting-goods firms use is to sign well-known athletes on to use certain products exclusively. Sporting-goods companies are subsequently under tremendous pressure to constantly improve product lines so their sponsored athletes maintain an edge over the competition. Also

[4]At the time of this writing, these agencies were found at the following Internet addresses, respectively: www.grandcypress.com/Academy and www.imgacademies.com/tennis/jump.sps.



Figure 12-9.
Dr. Ralph Mann, former Olympic medallist and now President of CompuSport, uses Model Golf® teaching-system software to view a computer-generated model golf swing. He researched this model swing from the performance of over 50 top Professional Golfers'Association golfers on the professional tour. Dr. Mann tailors the model to a student's body dimensions and overlays the model on the student's actual golf swing. (CompuSport)

adding fuel to the fire are governments, national athletic organizations, coaches, and athletes who are usually clamoring for better equipment. Consumer tastes and a slight increase in the amount of discretionary income people have to spend on their leisure have also altered the shape of some traditional products.

Manufacturers use the latest in space-age materials and computer-aided techniques to improve the life, power, and controllability of tennis rackets. Shoe designers boast that their particular aerobic models represent the latest technology in attire for the feet. The adult segment of the bicycle market has grown considerably. This has motivated manufacturers to develop an elite line of bicycles aimed at the quality-conscious, adult buyer. For the backpacking devotee, the formulation of advanced fibers and fabrics is starting to eliminate some of the discomforts inadequate clothing design and construction cause. DuPont's fiber, Thermax® fabric, combines the softness of cotton with a wicking ability that pulls moisture away from the body for evaporation. The wearer stays drier and is much more comfortable. The list of examples to portray the use of technological genius to build new toys or improve the ones we already possess goes on much further. Regardless of your favorite sport or recreational hobby, in one way or another, technology will surely modify the sport's or hobby's profile in the near future.

Summary

Social institutions exist in all cultures around the world. Some are highly respected, due to their longevity and coincidental ability to preserve tradition and nurture local customs. Others are recognized as more contemporary social groups, serving as a type of substitute for conventional institutions. In either case, people tend to compartmentalize their lifelong objectives and aspirations into specific activity areas. A few of these compartments are discussed in this chapter, including family, religion, education, and recreation.

Technological developments have certainly affected the general profiles of these social institutions. Each institution continues to be operative in our society at varying degrees of stability. One group of sociologists reports that the family unit is existing only on shaky ground, technology is replacing religion, real live teachers are becoming obsolete, and serious adults believe buying more toys might be the answer to their loneliness. On the other side of the fence, a more optimistic group of social scientists contends that marriage

and family life are both quite healthy, the strength of religious affiliations is on the incline, and technology in the classroom can assuredly enhance curricular goals. A lot of adults believe recreational activities should be a productive, rather than a passive, financial investment. Regardless of which group you can most readily agree with, social institutions remain the structural mainstay of our civilization.

Discussion Questions

1. Identify and describe several characteristics of a nuclear family, an extended family, and a surrogate family. Explain how they are similar to each other in contemporary society.
2. What are some of the personal expectations you might list for your prospective spouse to peruse at the onset of your marital agreement? How are these expected outcomes different from the ones your parents might have had when they got married?
3. Which, if any, contemporary medical procedures do you believe to be acceptable for couples who find they are unable to conceive a child to use?
4. This chapter reviews Western religious beliefs and customs and their alignment with S & T. Select another religion and investigate its views about modern technology.
5. Explain how the responsibilities of teachers in our society are being modified, as a result of the rampant pace of technological change.
6. Identify several ways the toys manufactured for the adult population in this country seem to perpetuate the adults' visions of childhood. Give specific examples. Conversely, what sorts of toys are marketed for children to enhance the process of socialization?

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Chapter 13

The Technologist's Responsibility for the Future of Society

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DATELINE

Atlanta, Georgia

The Influenza Division of the CDC conducts surveillances for influenza in the United States each year from October through May. This work is designed to determine when influenza viruses are circulating, identify strains, and detect changes. Health officials are also attempting to monitor influenza-related illness in the United States and measure the impact of influenza on deaths in the United States. The CDC's Influenza Division collects and reports information on influenza activity across the country. Researchers here report the total number of respiratory specimens tested and the number that are positive for influenza by type and subtype each week.

For most of the year, immunization experts around the world work similarly to sleuths stalking a shifty opponent. Circulating influenza strains and disease-trend information are gathered by 118 national influenza centers in 84 countries. Four WHO collaborative agencies, one of which is the CDC, further test and analyze the viruses and other data. By the time spring arrives, they should be more or less in agreement on their forecasts. Full-scale vaccine production must get underway by early April in the northern hemisphere, if they expect the serum to be available by the end of autumn and the start of the flu season. Their predictive forecasts involve a certain measure of guesswork, since the process of isolating a flu virus is very similar to hitting a moving target.

Even still, these labs form the world's cornerstone of the surveillance and forecasting effort. The influenza virus is a formidable foe. There are two major types, known as *A* and *B*, and numerous subtypes, or strains. Flu viruses travel quickly and change radically in a span of a few short weeks or months. The present surveillance system is adequate to guard the world against a disaster such as the 1918–1919 epidemic, which killed 20 million people, but it is far from perfect.…

Introduction

Speculation about the future has been a favorite social pastime throughout all human history. Greek and Roman myths are full of tales of supernatural beings who could foretell the future. The early biblical prophets are believed to have possessed divine inspiration and the God-given ability to predict the future. Tribal cultures around the world have been ever trusting of their local witch doctors when there was a need to forecast future events. Most everybody, at one time or another, has taken a stab at making a prediction concerning her own destiny. Think about this for a moment. Have you ever had your fortune told at a local carnival or county fair? Have you ever noticed roadside advertisements for palm readers in small tourist towns? Have you ever scanned the Yellow Pages® directory for a listing that might put you in touch with a spiritual consultant? See **Figure 13-1.** Have you ever read your daily or annual horoscope? Have you ever asked your own physician how long it might take for you to

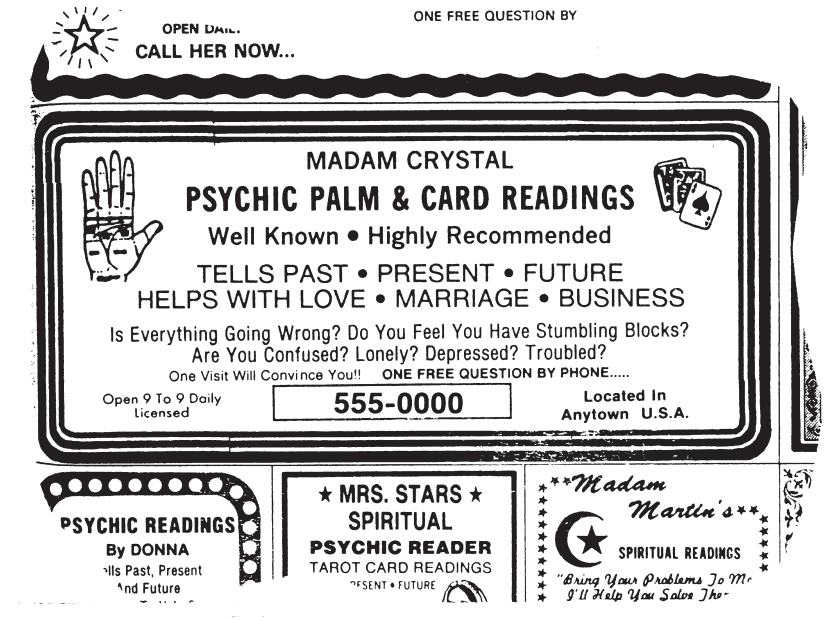


Figure 13-1.
The Yellow Pages directory might use the heading "Spiritual Consultants" to advertise for a wide assortment of businesses professing to predict, or forecast, future events in your life.

heal after a surgery? Do you know someone who has a terminal illness and has been given an estimate about how much time he has left? Have you or has someone you know ever consulted a stockbroker to determine which financial investments would be most lucrative? Each of these simple examples presents a case of curiosity about one's life at some point in the future, and each of these inquiries requires some method of forecasting.

Prior to the mid-twentieth century, forecasting activities were seemingly left to prophets and philosophers who were thought to enjoy special powers of insight. Today, however, when business organizations and government agencies need an image of tomorrow or a projection about next year, they submit their request to a whole new breed of intellectuals. Although several titles have been used to describe these individuals, they are highly respected as professional futurists. Unlike the old-fashioned soothsayers, these consultants are respected for their intuitive abilities to analyze recent events and study the laws governing social, political, and economic trends, in order to provide future forecasts.

Futures studies and research did not really have an organized existence much before the mid-1940s. The birth of professional futurology coincided with the realization that history itself did not follow any ironclad laws, and therefore, the future must belong to humankind. This birth also seemed to occur at about the same time that our destructive capacity created a new source of anxiety about the future—nuclear weapons—and the later evolution of the cold war. The Air Force and Douglas Aircraft established one of our nation's first major think tanks, the RAND Corporation in Santa Monica, California, in the mid-1940s.

(*RAND* is actually a pronounceable contraction of the term *research and development*, or *R&D*). This corporation's initial mission was to do a more creative job of dreaming up military technology than the Soviets did. Today, RAND's work is more diversified. This corporation now assists all branches of the U.S. military community, and it applies its expertise to a wide range of social and international issues (for example, education, the arts, public safety, the environment, energy, population, and regional studies).

Since the birth of RAND as a nonprofit entity, hundreds of private research institutions and laboratories have been launched into operation. Think tanks have essentially become an American phenomenon. It is unlikely that any other country awards such a great amount of significance to private institutions that are, in many cases, in business to stimulate creative thinking and influence public decision making. These future-oriented firms are responsive to the needs of industrial corporations, as well as government agencies, and regularly pull in multimillion-dollar contracts.

Regardless of the future time frame (six months, 2 years, 5 years, or 20 years down the road), the land of the future has become the home of futurology. A large and still-growing group of future inspectors has been keeping its watchful eyes on the nation and the world over the past several decades. These inspectors routinely observe and report on the significant trends they have detected in society, industry, technology, and international relations. In the process, they use a variety of observational forecasting techniques, including futures wheels, content analyses, growth curves, environmental scanning, trend-impact analyses, and Delphi studies. Their ongoing investigations have transformed the study of the future into a profession with its own specialist institutions and several widely circulated journals.

More has been written, discussed, debated, and revealed about coming events over the past few decades than has been even mentioned in the entire brief history of futures thinking. The future has been a central topic of a great many books and articles, television programs, feature films, journals, societies, congressional committees, institutes, and government commissions. By the end of the 1960s, the various permutations had caught the interest of a wide range of readers, while a network of communicators spread the latest predictions about tomorrow's world. One major source of information in the United States was, and continues to be, the World Future Society and its journal titled *The Futurist*. Chartered in the mid-1960s, this community of future-minded citizens came from a diversified lot of professions. This still-active organization is headquartered in Washington DC. Nearly 50 years after being chartered, its membership exceeds 25,000 people residing in more than 80 countries.

Shortly after the publication of Alvin Toffler's notorious *Future Shock*, the U.S. Congress passed the Technology Assessment Act of 1972. This legislative decision established the Office of Technology Assessment (OTA) as a congressional support agency. Over OTA's 23-year history (1972–1995), its staff analysts provided congressional committees with nearly 750 objective analyses of the emerging and often highly technical issues of the late twentieth century. Prior to the congressional decision to defund the agency, OTA's activities were based on the need for the social consequences of technological applications to be anticipated before public policies were enacted. Technology assessment is sometimes viewed as a branch of futurology. This assessment, along with several other forecasting strategies, is discussed in this chapter, with reference to future prospects for various technologies.

Studies and investigations are constantly being set up to project or predict the future state of a particular technology so the technology's impact on society can be assessed. Data these researchers accumulate is also being used to determine ways in which the United States can maintain and continually strengthen its edge in technology development. Futures studies are invaluable to contemporary corporations requiring reliable estimates of where their industries will fit in a changing global economy. Strategic technology management seems to be an essential feature in the personality profiles of scientists and technologists who aspire to assume responsibility for the future of humanity. The following questions are addressed in this chapter:

- ❑ As other nations continue to build up their scientific and technical skills, will American dominance in S & T be significantly threatened?
- ❑ How can government agencies and private citizens most effectively utilize the disciplines of technology assessment and risk assessment?
- ❑ Should those who manage technology inside a plant also be responsible to oversee its successful implementation in the external social environment?
- ❑ What types of forecasting techniques should "responsible" scientists and technologists rely on for critical moves and decisive actions regarding specific, and possibly controversial, technologies?

Key Concepts

As you review the material contained in this chapter, you should learn the meanings of the following terms:

applied research
basic research
content analysis
data mining
Delphi study
development
epidemiology
futures wheel
heuristics
microphotonics
natural language processing (NLP)
optoelectronics
risk assessment
technological imperative (TI)
technology assessment

Technology Research: On the Leading Edge

Few economists would be willing to deny that technical innovativeness and scientific curiosity stimulated a large portion of the growth in the U.S. GNP during the final third of the twentieth century. These are the main ingredients in the formula responsible for the amazing surge in the U.S. standard of living since the end of World War II. Technological innovation, combined with capital and an abundant supply of natural resources, made a significant contribution to this nation's overall level of productivity throughout the last half of the twentieth century. The power of American ingenuity is legendary, but the rest of the world seems to be ready and determined to catch up. Our international trading partners are always challenging American dominance in S & T. Our government officials must

remain cognizant of the fact that a significant weakening of our lead position could threaten the future prosperity and well-being of all U.S. citizens.

Technological change is exciting, but it worries a lot of companies who fear they will not be alert to react quickly enough to stay in the race. These days, they seem to be scrambling even more diligently in anticipation of the accelerating twists and turns of novel technologies. Large multinational corporations are streamlining their internal research projects. Smaller companies, wary of the huge financial commitment that technology ***development*** requires, are joining research consortiums or hiring outside consultants to keep them on track. Firms not even involved with the manufacture of high-tech products have started to set up internal technology units to keep abreast of computer refinements and software enhancements that might affect their own industrial vitality.

Technology advances and changes so quickly that companies find themselves aiming at a series of elusive moving targets. They no longer have the luxury of planning years in advance and assuming that the rules of the technology contest will remain unaltered. As product life cycles become shorter, businesses continue to become obsolete. A few corporations have indicated their belief in decentralization as a key to long-range technology planning. For example, back in the early 1980s, 3M Company decided to establish separate product divisions. One division handles short-term research. Another layer of laboratories oversees research that might produce benefits 5 to 10 years hence. A third research team watches for developments even further in the future. Flexible planning for technology change is crucial to staying ahead in the global high-tech race. 3M's growth through the 1990s and into the twenty-first century evolved through a desire to participate in many markets in which the company can make a significant contribution from core technologies. This company has resisted the urge to be dominant in just a few markets. 3M's current Web site has the following quote from the CEO: "To the outside world, what we do looks a little like magic. We create entirely new product categories and breathe new life into markets crying for reinvention. It's been called the 3M effect. Harnessing innovation for your benefit—that's the practical magic behind 3M's success."

Whatever form of crystal ball a company, or even a nation, uses to plan for the future, it cannot anticipate every technological twist of fate. Aggressive technology-development programs can be quite risky. Corporate executives are often fearful of making hasty decisions leading to heavy financial losses. On the other hand, the price of advice to help guide their long-term speculations is no cheap investment either. One example of a technology-focused research and consulting firm, to which more than 11,000 organizations worldwide have subscribed for assistance, is Gartner, Inc. Founded in the late 1970s and headquartered in Stamford, Connecticut, Gartner works with its clients to help them understand and capitalize on regional-market opportunities within a global-business context, with an eye for future entrepreneurial success. Gartner consultants serve as independent advisors to a majority of the Fortune 500 and Global 500 firms—supporting these firms' key decisions regarding technology assessment and procurement, project development, technology management, and spending recommendations. Boasting revenues of $1.06 billion in fiscal year 2006, this firm's services are cost intensive.

Technological prowess is a direct result of a long chain of efforts ending with new and useful products able to compete successfully in international markets.

During the early years of the twenty-first century, the United States will either remain close to the leading edge of technology development, or it will fall behind its competitors to become a technologically stagnant nation. U.S. residents will either continue to be the beneficiaries of economic prosperity or become the victims of dependency on foreign nations for advanced products and services. In order to prevent the latter situation, tomorrow's technologists and industrial leaders should already be thinking about and learning how to sharpen the country's competitive edge.

National Science and Technology (S & T) Policy

The quality and diversity of U.S. research in S & T is quite impressive. The major contributors to the U.S. R&D efforts are industrial firms, the federal government, colleges and universities, federally funded R&D centers (FFRDCs), and other nonprofit institutions. The U.S. industrial sector funds and performs a significant portion (64% and 70%, respectively) of the R&D projects in S & T. The federal government accounts for the next largest share, in terms of funding (30%). With regard solely to the performance of ***basic research*** in the early 2000s, universities and colleges accounted for the largest portion of this type of work (55%). More than two-thirds of their funding, however, was procured from the federal government. See **Figure 13-2.**

Trends in our nation's support for technological and scientific research are traditionally analyzed by examining the amount (or percentage) of funds devoted to three categories of activity, which are more or less chronological in nature: basic research, applied research, and development. The table and graphs shown in **Figure 13-3** present a profile of our R&D expenditures in the middle of the first decade of the twenty-first century. Research projects are often classified as being basic or applied, and development activities follow.

National R & D Expenditures, by Source of Funds, Performing Sector, and Character of Work: 2004

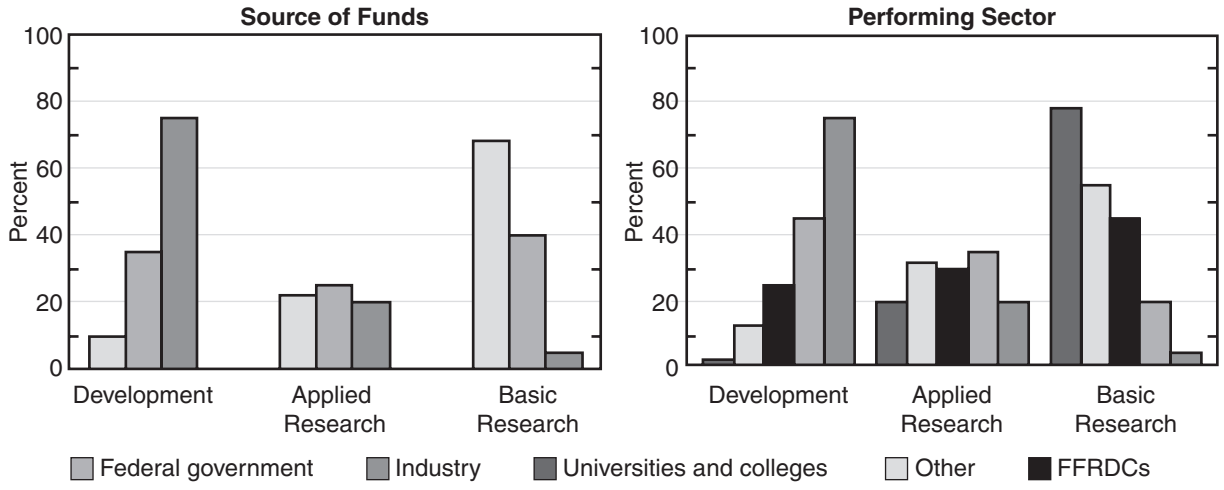


Figure 13-2.
National R&D expenditures by source of funds, performing sector, and character of work, as a percentage of total R&D expenditures. (Adapted from *Science and Technology Indicators—2006*)

U.S. R&D Expenditures, by Character of Work Shown as Percentage of Total R&D Expenditures and Amount of Funding							
	1960	**1976**	**1980**	**1985**	**1989**	**1998**	**2004**
				(Percent)			
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Basic Research	8.9	12.8	13.9	12.5	17.3	16.7	18.7
Applied Research	22.3	23.2	21.7	21.5	16.6	22.5	21.3
Development	68.8	64.1	64.3	64.6	66.1	60.8	60.0

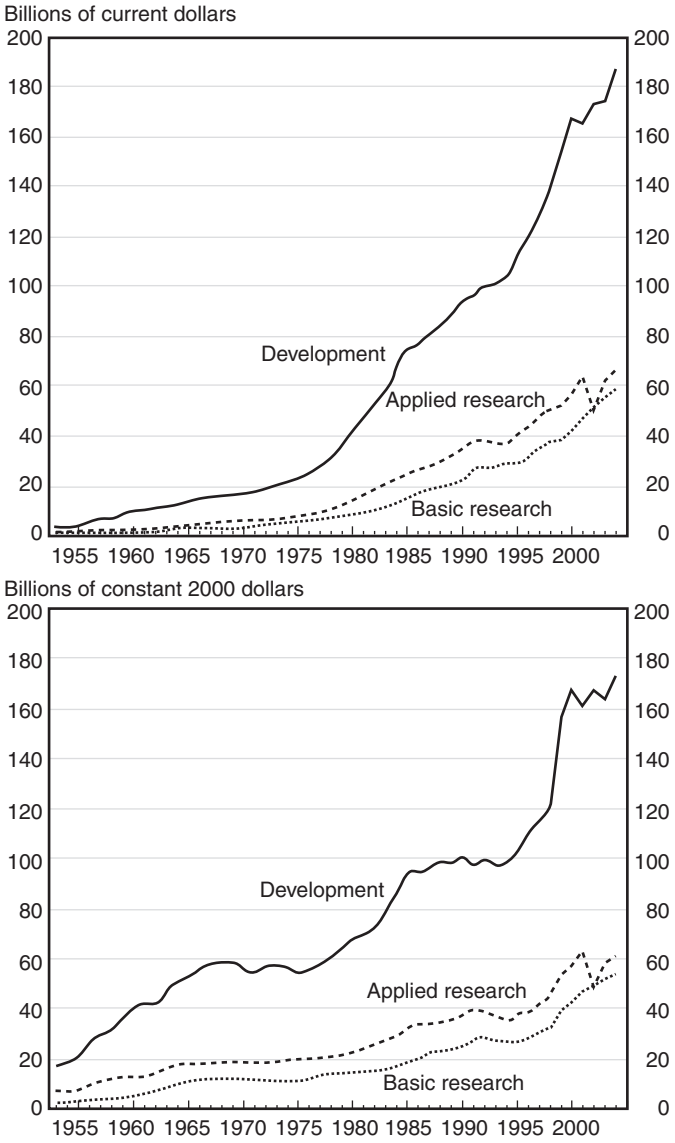


Figure 13-3.
National R&D expenditures by character of work, as a percentage of total R&D expenditures. These graphs illustrate national R&D funding by character of work. (Adapted from *Science and Engineering Indicators—2006*)

Basic research is fundamental and often stems from a desire to fill gaps in the existing knowledge base, rather than a desire for a practical application. In industrial settings, basic research is viewed as research that advances scientific knowledge, but does not have specific or immediate commercial objectives. On the other hand, it might very well exist in a field or an area of study in which the company already has a current or potential commercial investment.

Applied research is directed to gain knowledge or understanding to meet a specific, well-recognized need. In industry, applied research is generally aimed at the discovery of new scientific knowledge that can be used to achieve the corporation's commercial objectives—both immediate and long-range. In contemporary venues, the line of distinction between basic and applied research is actually quite porous. Academic scientists whose promotions in rank are often contingent on new discoveries tend to describe their research endeavors as basic. A government agency or industrial firm might label similar, and occasionally identical, projects *applied*, in order to justify their credibility to a funding source or its own board members.

Development, in which the results of earlier studies and investigations are molded to fit a particular application, is the next step beyond applied research. This step represents the systematic use of the new knowledge gained from previous research. Development projects are usually directed toward the full-scale production of useful materials, devices, systems, or methods. The initial design and development of prototypes and processing techniques also fit beneath this heading.

National investment in R&D has been increasing incrementally in constant dollars (correcting for inflation) over the past four decades, despite a brief period of stagnation in the early 1990s (following the Persian Gulf War). The federal government's share of all U.S. R&D dropped to a low of 25% in 2000, at which point the declining trend reversed. Since that time, federal spending on R&D has increased, particularly in the areas of defense, health, and counterterrorism. The federal share of U.S. R&D in the middle of the first decade of the twenty-first century was about 30%. In 1990, defense accounted for 63% of government R&D spending in the United States. Less than 10 years later, however, this proportion had fallen to 54% of the government's investment in national R&D initiatives. In the years subsequent to the terrorist attacks in 2001, defense once again became the largest federal R&D budget function (nearly 60%). By comparison, at the opening of the twenty-first century, government allocations to defense-related projects were considerably lower in the UK (34%); France (23%); and Japan, Canada, Italy, and Germany (each with 6% or less).

The United States also places a much more pronounced emphasis on health-related research than any of these other nations. In the early 2000s, 24% of the U.S. government's R&D investment was devoted to health, especially to the support of life sciences in academic and similar nonprofit institutions, making this discipline second only to defense. The NIH is presently our country's largest source of federal funds for university research, followed by the NSF. Nevertheless, it is complicated to make direct comparisons between health and defense R&D because most health-related projects are research, and nearly 90% of defense projects today are development. (This was not always the case. During the Manhattan Project, when atomic weapons were still new, academic scientists held a near monopoly on knowledge of nuclear physics.)

Nevertheless, we seem to have reached a point where it is critical to examine the nation's S & T research priorities. In some ways, the terrorist attacks on our nation

in 2001 might have actually shocked the nation into rethinking its assumptions about our scientific superiority and technological invincibility. The challenges of wartime have certainly given birth to numerous scientific advancements in the past. Defense, health, energy, and counterterrorism will continue to occupy prominent positions when it comes to distributing federal research dollars. In recent years, the U.S. government has identified a number of R&D priority areas that tend to involve the expertise of several federal agencies. Collaboratively, these groups will move among projects dealing with combating terrorism, climate change, nanotechnology, and developing hydrogen fuel cells. The authors are optimistic that these emphasis areas will be balanced with other well-organized research projects in areas such as genetics, civil engineering, fiber optics, materials science, magnetic transportation, and intelligence.

Since the traditional boundary lines between scientific disciplines have become much less distinct, attention and energy must be focused on multidisciplinary pursuits for knowledge and understanding. For example, breakthroughs in computer science continue to inform the biotechnology discipline. Similarly, R&D in manufacturing to improve robotic assemblies have the potential to improve our work onboard the *International Space Station*.

The complexion of research methodology is also undergoing significant change. Disciplines that sole investigators in self-contained laboratories, insulated from the outside world, have long dominated now often require larger, more elaborate, and more expensive instrumentation. The cost factor alone makes it necessary for several researchers working as a team on a variety of (perhaps even competitive) projects to share these pieces of equipment.

Research efforts around the world are producing new knowledge and information at an accelerating pace. The time lag between basic research and applied technology seems to shrink substantially as the years go by. Subsequently, cooperation between universities and industries is expanding to perform work in areas such as biotechnology, biometrics, microelectronics, microphotonics, computer hardware and software, natural language processing (NLP), materials science, and data mining. Cooperative arrangements such as these are highly beneficial to both parties, but they are not often executed without a certain amount of strain. Essentially, private industry's concern over proprietary rights or the government's concern over the confidentiality of its projects must be balanced against the importance of unobstructed communication within the academic sector.

We must continue to nurture working relationships among universities, industries, and governments to enhance the flow of personnel and research findings. This assertion prompted the NSF to implement several creative programs permeating traditional institutional and disciplinary boundaries. A number of U.S. universities have been able to establish engineering and technology research centers as a result of federal funding through the NSF and monies from groups of company sponsors.

Two other federal technology partnership programs were initiated in the early 1990s. Their purpose was to accelerate the development and deployment of innovative, often risky, technologies for broad national benefit through cost-sharing, collaborative partnerships between government agencies and industrial firms. The DOD's Technology Reinvestment Project (TRP) lasted only a few years. At its time, it was one of the largest commercial investment programs the DOD ever undertook. Over the course

of three solicitations (1993–1995), the TRP elected to sponsor more than 130 dual-use technology projects. The Department of Commerce's Advanced Technology Program (ATP) was set up to assist U.S. businesses and industry to invest in longer-term, high-risk research that would stimulate many payoffs beyond private profit. ATP's legislation also authorized it to aid industry-led, joint R&D ventures, which enabled U.S. universities and independent research organizations to be included in promising projects.

Since ATP's inception in 1990, a little less than 10% of the $2.3 billion in ATP funding has been awarded to more than 170 different universities across the country. Leading the list of top-10 universities that have received the most support via ATP projects are Stanford, University of Michigan—Ann Arbor, Carnegie Mellon, UC San Diego, and MIT. During the 1997–2007 time period, these nonprofit organizations recognized that ATP can provide critical funding for state-of-the-art laboratory equipment and the risky development of innovative technologies for commercial gain. ATP also exposes university faculty and students to the ways industry carries out its cutting edge R&D. Collaboration via an ATP award further extends and deepens the relationships nonprofit organizations have with competitive companies, which can lead to future sponsored projects. With the signing of the America Creating Opportunities to Meaningfully Promote Excellence in Technology, Education, and Science (COMPETES) Act (HR 2272), ATP was terminated. Continued support was authorized for all existing projects, and more than 50 new proposals were funded in 2007.

Despite these efforts in the right direction, a gap still remains between the universities and industry in this nation's R&D arena. The parties are learning how to work together, but neither has yet been able to completely master the exercise. Universities need industry because the nation's economic future depends on industry. Academic scientists and technologists need to be informed about industrial problems, in order to more succinctly design their own research projects and assignments for their students.

On the flip side, industry needs both the graduates the universities produce and access to the talent and creative ideas flourishing in universities' free and open climates. It is certainly not enough for corporations to recruit universities' graduates each year and tempt away their professors with larger salaries. Industrial leaders must assume an active and ongoing advisory role in shaping both educational curricula and applied-research programs.

Furthermore, the extent to which scientists and technologists are able to articulate their expertise to inform national policy is questionable. It is alarming to note that, for the past three decades, academic scientists have mostly remained on the sidelines, while the White House and Congress have ignored them. In some cases, our legislators have seemingly made decisions running counter to scientific advice. For example, many scientists argued that the *International Space Station* will never produce enough valuable research to justify its exorbitant cost. They have argued since the mid-1980s that this huge project had more to do with foreign relations and national pride than with scientific discovery. As you might recall from Chapter 4, this cost-intensive space-exploration project does have its share of dissenters.

As was mentioned earlier, Congress abolished its own OTA in the mid-1990s. Since then, members of Congress have directed numerous appropriations to specific universities in their home districts for research projects. Academic scientists have reasoned to no avail that, since such funds are not subjected to merit-based scrutiny via

scholarly competitions, the dollars might very well be supporting science projects of dubious quality. As a result, many scientists and even some lawmakers believe Congress needs to re-create a regular source of bipartisan advice about all policy issues involving advanced S & T.

Similar to the compelling national R&D objectives driven by World War II, the resultant cold war, *Sputnik*, and the resultant Apollo Program, our nation's contemporary aspiration to eradicate global terrorism might become a primary unifying issue that will guide future S & T policy. Prevailing social problems, including water shortages, malnutrition, tropical deforestation, global warming, public health, and the side effects of ITs, must also receive significant and justified attention. Given these realities, it might be even more difficult in the coming years to reach a national consensus, with reference to our future research priorities. Future strength, success, and trust in science, technology, and engineering endeavors will be accomplished to the extent that our nation's research community can create and sustain partnerships. Along the way, let's hope this community's responsiveness to public concerns will be fortified and the integrity and excellence of standards in its research will be heightened.

Leading Edge Technologies

Attempting to predict which technologies will be front-runners in the years ahead, versus those that will simply plod along in the middle of the pack, is not an easy task. In fact, if you were to travel around to interview scientists at work in a variety of research labs across the country, each of them would easily contend that her efforts are on the leading edge. Who would say the people working on isolating a cure for various forms of cancer are more important than those trying to devise a stream of new space-age materials? Who would argue that research related to desalinization processes is more critical than designing more energy-efficient motor vehicles? No one should, of course. Labeling one technology as being any more useful or significant than any other is second-guessing reality. Such second-guessing might lead to the curtailment of lifesaving breakthroughs. In any case, there are those scientific experts among us who insist on identifying which groups of sciences and technologies are moving forward into the twenty-first century and are the ones to be viewed as most critical or leading edge.

Advances being made in the fields of energy systems, medicine, IT, materials science, and genetics are totally recharting the course of human history and transforming the way human beings live on this planet. As you have read throughout the previous 12 chapters of this textbook, some of the consequences associated with these technological changes are not always pleasant. Regardless, scientific breakthroughs will continue to take place in the abstract world of theory, as well as in the concrete achievements of sophisticated machines. Several emerging technologies having the potential to transform the world as we know it today are briefly described in the following list:

- Neurobiologists are pioneering the use of neural implants to study the human brain. These hybrid brain-machine interfaces might allow human brains to control artificial devices designed to restore lost sensory and motor functions. Paraplegics who are confined to wheelchairs might actually regain partial control over their own limbs.
- Flexible transistors based on organic (carbon-based) molecules or polymers will have advantages over silicon-based electronics. New hybrid materials that

can be dissolved and printed onto paper, plastic, or fabric might pave the way for digitized newspapers, product labels, and clothing. Materials scientists at the University of Illinois at Urbana-Champaign are testing the applications for stretchable silicon. Their work adds significant findings to this discipline we call *microelectronics.*

- The emerging field of ***data mining,*** also labeled *knowledge discovery in databases (KDD),* is based on elaborate pattern-recognition algorithms. Exciting applications are projected in many fields, including automobile maintenance, astronomy, geology, medicine, quality assurance, and military intelligence.
- The world of intellectual-property protection will never be the same as it was in pre-Internet years. The nascent discipline calling itself *digital-rights management (DRM)* might be a prime catalyst for electronic-content protection. Encryption schemes, combined with methods to collect payment for use, might be the solution corporate officers are seeking, through which they can protect their property.
- The field of biometrics has already emerged such that it is obvious to us as laypeople, and it involves technologies allowing specific biological traits to identify us. Under development and in early stages of use are capacities for face recognition, iris recognition, fingerprint recognition, voice recognition, and dynamic signature recognition. (You might recall the *Dateline* entry back in Chapter 1.)
- Advancements in robot design might lead to more affordable robots that can be efficiently deployed in hospitals, households, and grocery stores. Leading robotic researchers are devising ways to fully automate the design and manufacture of robots by programming computers to conceive, test, and even build configurations of robotic systems. In actuality, robots will be building robots.
- Those of you who have seen the now-classic (then-futuristic) 1968 film titled *2001: A Space Odyssey* will surely remember HAL 9000—the friendly (and later crazy) computer that conversed quite easily with human astronauts. The world of ***natural language processing (NLP)*** might be taking us several steps closer to HAL and making it possible for us to verbally interact with our computers. (On a more trivial note, the label *HAL* consists of the three letters before *IBM* in the alphabet!)
- The exciting field of ***microphotonics*** reveals an array of technologies for directing light on a microscopic scale, which will significantly impact the future of telecommunications. Researchers are studying the utility of photonic crystals, which might lead to the creation of the world's smallest laser and electromagnetic chamber—both of which are essential components for integrated optical circuits.
- Actor Robert DeNiro, in the 2001 action film titled *The Score,* used the statement "It's just simple physics" to describe his strategy for breaking into a heavily guarded, indestructible safe. The forces of physics move ocean tides, geological formations, and entire galaxies. Applied physicists are investigating ways to manipulate tiny volumes of fluids thousands of times smaller than a raindrop. *Microfluidics* is the name of this promising new branch of biotechnology, which might enable us to perform instant diagnostic tests and build implantable drug-delivery devices.

- The days of wireless transactions are upon us in full force, but the pervasive wireless world remains a future reality. Hundreds of scientists and engineers are at work to make computing truly pervasive. They envision a day when RFID tags will be imbedded in merchandise, enable blood pressure monitors to signal for help in an emergency, and enable automobiles to talk to each other to avoid collisions. Finding a common protocol to link all our wireless gadgets together is at the center of this new field of experimentation.
- Amidst the controversial arguments permeating the embryonic–stem cell research debate, biologists are investigating cellular-reprogramming possibilities. Work is underway to find alternative methods to create cells with the versatility of embryonic stem cells. Researchers at Harvard anticipate it might be possible to create stem cells whose DNA matches a specific patient's by using existing stem cells, stripped of their DNA, to reprogram adult cells. At the Oregon Stem Cell Center in Portland, efforts are ongoing to use proteins that can directly reprogram skin cells to behave similarly to stem cells.
- Peer-to-peer (P2P) file-distribution technology might emerge to be the Internet's savior in coming years. This "outcast" technology, commonly known for its links to piracy of copyrighted materials, might find legitimate uses as video applications account for increasingly greater percentages of Internet traffic. With conventional architecture, video, audio, and other digital content reaches users along treelike pathways—the content owners' centralized servers form the trunks, while the multiple distribution servers form the branches, and the consumers' computers resemble the leaves. If the branch is cut off, the leaves fall off as well. Data flows in one direction, so individual computer users cannot upload data. In P2P networks, there are no trunks or central servers—all users exchange data with others in an ever-fluid mesh. Researchers at Cornell University are testing a P2P system called *Chunkyspread,* which they believe combines the best features of trees and meshes. Their discoveries might allow the Internet to remain unclogged for several more years.

As scientists and technologists throughout the world decipher the few remaining mysteries of the atom and the gene, considerable advances are being made in the fields of physics and molecular biology. Ongoing and often interdisciplinary research in the dozen fields identified on the previous list of emerging technologies could have appeared in one of the *Dateline* entries throughout the book. We believe they have great potential to make lasting and far-reaching contributions to the well-being of humanity. The authors describe three of these emerging technologies in the following paragraphs.

Data mining

Most of you, at this point in your academic careers, are quite familiar with the term *information overload*. In today's world, few of us can say we suffer from a lack of information. We are deluged with facts, opinions, news releases, formulas, statistics, and lengthy reports on a daily basis. The problem is that information does not equal knowledge. In order to understand and fully grasp more complex issues in contemporary society, especially those related to S & T, we need more than bare facts and figures or brief news bits. With access to so much information, we yearn for a mechanism that can sort, integrate, and analyze information in a way that makes sense and allows us to extract useful knowledge and insight.

The emerging discipline of data mining might ultimately be the answer to our prayers. Data mining is the process of finding patterns and correlations in large amounts of data. This technology combines pattern recognition with statistical and mathematical techniques to sort through millions of data values in search of discernable patterns. Take a moment to think about the last time you launched an Internet search in order to complete a research paper—perhaps even for this class. Using conventional software, let's say you typed in the following key words: *laboratory*, *animal*, and *research*. Once you entered the "search" command, millions of documents were reviewed in a few seconds. The "results" line states that 275,172 hits were located during the search. Where do you start? The problem here is that, without more specific pattern-recognition algorithms, conventional databases are limited.

Several promising applications for emerging data-mining technologies are found in genetics, medicine, quality assurance, and customer service. Biological research has become very database driven, due to large-scale functional genomics experiments measuring gene expression. New challenges in the field called *bioinformatics* call for integrated databases connecting disparate information and performing complex studies to collectively analyze many different data sets. In practice, data mining normally takes the form of statistical surveys, similar to demographic censuses. When studying different populations of genes and proteins, the goal is to identify certain outstanding features a given population possesses. Some of the exciting breakthroughs discussed in Chapter 2 and Chapter 5 are largely dependent on integrative data mining.

A peripheral area of development is called *text data mining*, which entails the extraction of unexpected relationships from huge collections of free-form text documents. Textual formats provide a very flexible way to store large amounts and various types of information. Analyzing huge amounts of textual data, however, takes a tremendous amount of time and energy, since we must read and organize the content. Text–data mining investigators are experimenting with NLP, statistical word counts, concept extraction, and the creation of semantic dictionaries. These researchers hope to develop technologies that can analyze more detailed information in the content of individual documents and extract information that only multiple documents viewed as a whole set can provide (for example, a stack of customer service–call documents can be analyzed to reveal trends and isolate areas of concern and complaints). Many organizations around the world are presently engaged in work related to data mining.

Natural language processing (NLP)

Information scientists have been experimenting with retrieval programs simulating natural human-language queries for several decades. Work in natural language years ago took notice of the fact that human language is not an abstract code. Language is a very complex and subtle form of communication. Getting computers to understand ordinary language, when it is either written or spoken, has been a long-time goal of computer scientists and is at the core of NLP research.

Language cannot be understood without a perception of context and an extensive knowledge of beliefs and expectations. In the 1980s, AI research utilized ***heuristics*** to engineer programs that could understand simple sentences with limited vocabulary. The term *understand* was used loosely, since the machines could not really understand ordinary language as humans do. A smart machine can electronically translate the sound of a human voice into symbolic patterns.

Such a machine can, next, identify individual words and phrases, analyze syntax, and contextualize the words and phrases in its memory. Finally, it can make thousands of logical inferences and respond in the user's native language.

In the three decades since these earlier natural language–processor applications were introduced, a new generation of interfaces has emerged from research laboratories. This breakthrough presents a complex integration of speech recognition, natural-language understanding, discourse analysis, world knowledge, reasoning ability, and speech generation—the sum total of which will enable those of us who are so inclined to engage our computers in extended conversations. Applications for coherent, interactive human-to-machine communication are endless. A few areas in which these technologies have value include machine translation (for example, English-Spanish), automated medical coding, cultural tourism, and monitoring stock transactions and other financial indices.

The NLP group at Microsoft Research is currently at work on a number of software-design projects that will ultimately enable human beings to converse with and address their computers similarly to the way they speak with their friends. One of these unique systems is called *MindNet*, and it has been under development since the early 2000s. This applied-technology work is developing a system that will automatically extract a massively hyperlinked web of concepts from something similar to a standard dictionary. If, for example, the dictionary defines *cyclist* as a person who rides or races a bicycle, MindNet software is designed to use its parsing technology to decipher the underlying logical structure for that definition. The software next identifies a *cyclist* as a type of person, and then *rides* and *races* are seen as verbs, thus taking *cyclist* as a subject and *bicycle* as an object. The eventual result is a conceptual network linking human understanding together with words. The subsequent act of placing this type of conceptual network into a computer takes the machine many steps closer toward understanding natural human language. **Figure 13-4** provides an illustrative depiction of a natural-language processor.

Microphotonics

Photonic crystals made of a few ultrathin layers of nonconducting material represent a new discovery in materials science. On the cutting edge of microphotonics, photonic crystals are able to reflect various wavelengths of light almost perfectly. The capacity to direct light on a microscopic scale will have a major impact on telecommunications. Years ago, a technology labeled ***optoelectronics*** emerged to become a marriage between electronics and optics. Researchers learned in the 1980s that photons could be employed as more compact carriers than electrons, to achieve greater efficiency in data processing and transmission. Photons are discrete units of electromagnetic energy having zero mass and no electric charge, and they are essential to optical-communication networks.

In our contemporary world, where it is now a challenge to keep pace with the Internet's increasing need for more bandwidth, microphotonics shows potential for being able to break up the logjam that the somewhat-difficult marriage between fiber optics and electronics (optoelectronics) creates. At present, photons go whizzing through the network's optical core, only to run smack into bottlenecks, at which time they must be converted into a much slower stream of electrons that electronic switches and routers handle. When these electronic switches can be replaced with faster, miniature optical devices (photonic crystals), an incredibly fast, all-optical Internet could be the huge payoff.

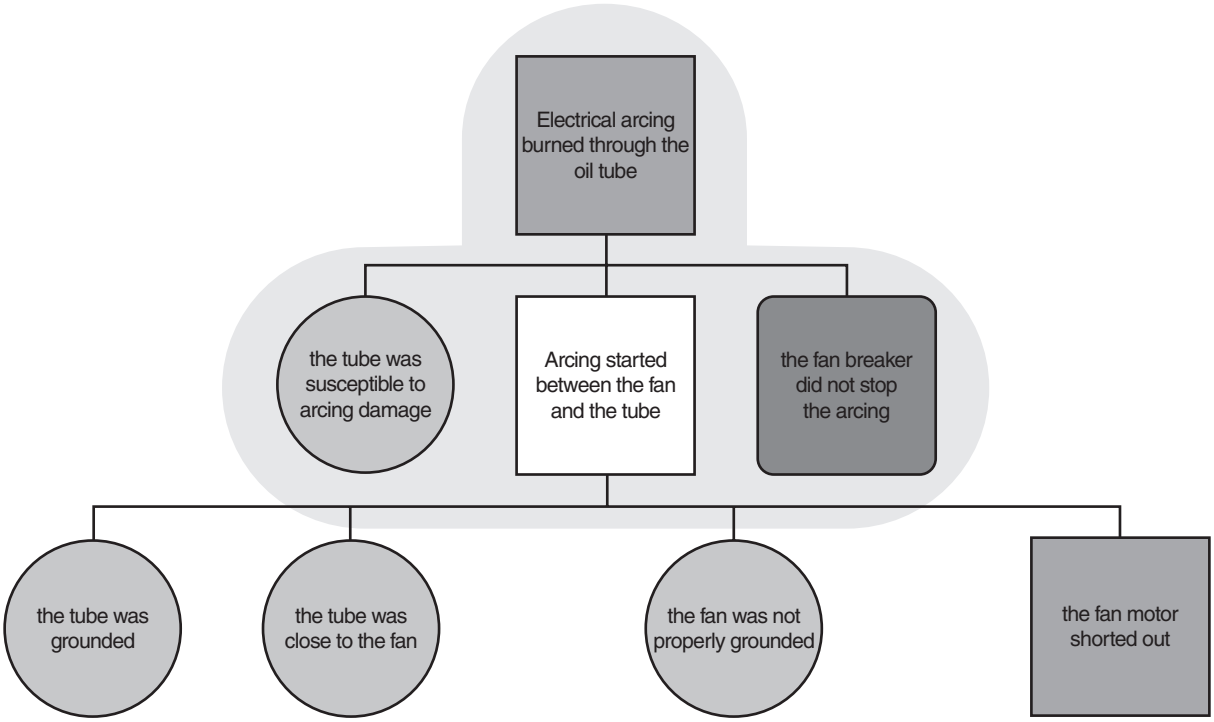


Figure 13-4.
A natural language processor. (Adapted from http://www.rootcause.com/R6NLP.htm)

Several large telecommunications-equipment manufacturers, including Lucent Technologies, Corning, Agilent Technologies, and Nortel Networks, are already at work developing new optical switches and other miniature devices. Regardless, some of the most provocative and promising work so far in this field is taking place at MIT, under the direction of physics professor John Joannopoulos. In his laboratory, photonic crystals are providing the mechanism to create optical circuits and other small, inexpensive, low-power devices that can carry, route, and process large quantities of data at the speed of light. As Joannopoulos continues to improve his "perfect mirrors" and press the theoretical limits of photonic crystal, this leading edge research merits careful scrutiny over the next several years—especially as we become more enamored with audio and video messages on demand, via the omnipresent Internet.

Life on the Edge

The above three still-emerging disciplines of data mining, NLP, and microphotonics are highlighted to illustrate the competitive nature of scientific research and technological advancement. Although being at the cutting edge of a discovery sounds rather exciting, scientists' lives are often full of stress and anxiety, and sometimes even guilt, over their projects. Scientists might actually describe life at the edge as long periods of demanding, exhausting, and commonly frustrating labor, interspersed with occasional moments of euphoria.

Once an individual earns elementary status as a scientist by completing the doctor of philosophy (PhD) degree with a creative dissertation, he is likely to enter some type of research laboratory or academic institution. The world of research is characterized by a constant search for funding, in which scientists

submit a number of proposals each year. The funding opportunities might come from agencies having specific guidelines and expectations. Rarely does a research grant come with no strings attached. Research specialists must then make choices as to whether to pursue unknown areas out of curiosity (basic research) or to construct their research designs toward the money sources (more applied research). These types of choices are especially objectionable when researchers, who are personally committed to research for human progress, discover that funding for their specialty is available primarily from an agency primarily representing defense projects that ultimately lead to a loss of human life. Unfortunately, in order to be a successful scientist these days, one must possess a certain amount of entrepreneurial drive.

Other sources of anxiety at the front line come from the realization that your colleagues might get there first. The relentless pace of the entire research enterprise makes it almost impossible to even keep up with the new literature. Since there are often no prizes for second place, scientists usually live with the pressure to succeed quickly—in order to gain the rewards of precedence. Some people feel this frenetic race to win first prize might diminish the quality of the research being conducted.

Life at the edge is filled with criticism and peer evaluations. New discoveries must stand up to professional confirmation first and public scrutiny later. There is always the chance your newfound theory is incorrect, incomplete, or invalid. For whatever reason, society seems to take a certain amount of pleasure in witnessing scientists "scrape the egg off their faces." In fact, issues concerning the moral responsibility of scientists have received considerable attention in recent years. Media coverage of scientific-misconduct cases has moved some members of the general public to regard science as fallible, evil, and often dangerous. Perhaps this is one justification for the existence of an insulated scientific community, in which scientists and technologists can occasionally lose touch with scientists in other disciplines and also get away from the general public.

Scientists determined to stay with it until they witness a breakthrough might find life on the edge to be quite stimulating. For others, the work schedule might lead to insomnia and deep periods of depression. The struggles of the solitary scientist go largely unnoticed by the rest of the world. Even though collaborative research teams execute and monitor a large portion of the S & T projects, the individual scientist still plays a central role in the process of inquiry leading to benchmark findings. Although there is no magic formula for creating or becoming an outstanding scientist, one thing seems clear: to survive on the edge, these individuals must be competitive, curious, and brilliant. Furthermore, they must take extreme satisfaction in being able to solve one of nature's riddles before anyone else does, via high-caliber research, whatever the discipline.

Technology Management

Embarrassment is an experience most of us prefer to avoid. Many people fear they will be humiliated if they do not know the answer to a question or, worse yet, give an incorrect response to a question. Well, when it comes to our contemporary world of S & T, even the most highly trained, well-educated experts among us must accept the fact that what they do not know is many times greater than what they do know. Ironically, a high state of ignorance seems to be a universal condition in today's society. While this state of affairs might sound rather bleak on the surface, the balance of knowledge and understanding seems to average out

favorably among the individual technical disciplines in our midst. To a great extent also, interdisciplinary breakthroughs have led to lower levels of ignorance among the experts, who are often called on to work outside their immediate areas of specialization.

Somewhat related to the dialogue surrounding technological ignorance versus scientific specialization is a discipline known loosely as *technology management*. Over the years, American business students have been taught that a good manager can manage anything and it is not necessary to have a technological understanding of the process one is attempting to manage. In some settings, we seem to have reached a point where American managers have lost contact with the technologies they are supposed to be directing and monitoring for productivity. In comparison with the rest of the world, a higher percentage of American managers come up through nonproduction jobs in business, law, accounting, and marketing. The number of managers in the United States who have an applied-technology background is much lower than found among management personnel in both Europe and Japan.

Nontechnically oriented managers might very well understand the technologies their own firms are using and developing, but they generally lack the intuitive capacity to determine which of the possible technologies out on the horizon should be further developed and which should be ignored or discarded. They are challenged to plan for progress in an intelligent and a strategic fashion. This level of intuition and type of insight comes only from firsthand experience. Engineers, technologists, and scientists are often reprimanded for believing too strongly in untried technologies and hastily plunging ahead where caution is warranted. Sometimes this charge is true, but it seems that managers who possess a technological background might end up with a more successful betting record than those who lack an understanding of technology.

Does the field of technology management say that every master-of–business administration graduate should also possess an undergraduate degree in science, technology, or engineering? Not exactly, but it does suggest that effective managers should be able to do the following:

- ❏ Understand scientific arguments.
- ❏ Interpret computer-generated documents.
- ❏ Synthesize complex statistical information.
- ❏ Understand the dynamics of technological change in the global economy.
- ❏ Articulate an understanding of the chronology of events from scientific discovery to technology applications to engineering development.

The art and science of technology management encompass a long list of responsibilities, including risk assessment, environmental scanning, measurement and control, competitive analysis, strategy formulation, technological forecasting, organizational climate, and corporate structure and culture. Corporate managers who are well versed in technological issues represent an essential profile characteristic in successful institutions and the necessary human element long overdue in this country's business environment.

Technology Assessment

Managerial shortsightedness, with reference to technological decision making, is generally a result of working within a very narrow perspective of one's own business or industry. One form of the problem surfaces when industrial leaders fail to broaden their visions to analyze how technological progress in their own or related industries will affect their future status. Another type of crisis situation might occur when a company or an

industry actually has advanced technology available to it, but it does not recognize how to apply this technology in a strategic manner. The first example illustrates the failure, or even reluctance, to stay informed about emerging technology. The second example amounts to failing to utilize technology in a timely manner, with regard to market expectations and economic conditions. In either case, the managers in question are somewhat shortsighted in their approaches to ***technology assessment***.

TECHNOLOGY ASSESSMENT

The process of making projections about the future state of specific technologies, so we can assess and plan for their impacts on society.

The former U.S. OTA defines this concept as it relates to a projection of the possible future state of a technology and an assessment of the technology's potential impact on society. Over OTA's 23-year history, the bulk of OTA's work focused on comprehensive assessments, each taking 1 to 2 years to complete. They dealt with all sorts of technology issues that congressional members earmarked as areas of concern or controversy. The OTA staff consisted of skilled professionals who had advanced training in physical science, life science, engineering, and social science. Throughout each project, OTA made use of advisory panels of experts on the particular topic being investigated.

OTA's library of some 750 reports runs the gamut of urban ozone reduction, the safety of medical devices, IT, the reliability of polygraph tests, and ethics of engineering.[1] Essentially, the advisory panels helped to formulate OTA studies by defining them initially, critiquing them while in progress, and reviewing the reports before they were released. OTA assessments were subsequently published by the Government Printing Office and were frequently reprinted by commercial publishers. Interestingly, even though OTA's official function was to do analysis for congressional committees, the office's reports were widely disseminated and ultimately used by interest groups, academics, and the general public.

In today's world, Congress finds itself living with its 1995 decision to eliminate OTA and grappling with highly controversial issues, such as stem cell research, energy policy, anthrax, Internet monitoring, human cloning, air-traffic security, and greenhouse-gas emissions. Several legislators have been vocal, with regard for the need for a new organization to fill the huge void left behind when OTA's doors were closed. Representative Rush Hold (D-NJ) introduced legislation (HR 2148) in 2001 to actually revive OTA. Despite its bipartisan support for several years, the bill has not been given a hearing or floor consideration in the House of Representatives.

A major criticism of the former OTA was that it took too long to complete its studies. Therefore, a newly constituted organization must consider making improvements in its design and operation. Lessons can be learned from the success of several European technology-analysis units, many of which the U.S. OTA inspired. In the early 2000s, M. Granger Morgan, head of the Department of Engineering and Public Policy at Carnegie Mellon University, even suggested a new name for this U.S. agency—the Office of Science and Technology Analysis. He insisted that this new enterprise should be set up to provide advice to individual members or small groups of congressional members within a time frame of three to six months for most studies. His ideas have yet to gain legislative support.

Technology-assessment reports might be respected as documents guiding public

[1]OTA was closed in 1995 due to the passage of a congressional-reform plan that resulted in its funding being eliminated. As of 2008, OTA's electronic archive (1972–1996) is available at http://jya.com/otapub.htm.

policy–making decisions. In an industrial setting, however, technology assessment is an important component of managing current, as well as emergent, technology developments. Strategic decisions to establish a national telemarketing center, require 40% of your employees to become telecommuters, switch over to a more efficient bottling line, or totally change the container specifications for your company's product should not be made without a comprehensive assessment of the potential consequences of these actions. For instance, failure to recognize that the price of glass bottles might soon become prohibitive, compared to plastic containers, would make the investment in a brand-new glass bottling line somewhat faulty and very costly for the firm. The word *strategic* implies foresight, logic, statistical analysis, and an awareness of trends in the making. When this word is used as a modifier for the activity known as *decision making*, technology assessment becomes part of the equation.

Technological forces have begun to play a much greater role in corporate strategic planning. Within a company's annual strategic formula, emerging technologies can present seemingly endless opportunities for a whole range of new products. On the downside, new technology is also a gamble that eats up precious research time and money without any real assurance of success. Fierce global competition in many industries has led to a new zeal to optimize the return on investment in new or modified technology.

In an effort to reduce the percentage of bad risks, corporate executive officers are increasingly recognizing the value of technology assessment. Business managers view technology assessment as a management discipline allowing for the systematic determination of which technologies are most appropriate for their companies' long-term objectives. The process further identifies the avenues best suited for exploiting the technologies ultimately selected. Each potential technology shift receives a rigorous appraisal, and the projected margin of profit over a specific period of time estimates the technology's probable degree of success.

One large corporation that has made very effective use of technology-assessment procedures over its 200-year history is the Delaware-based DuPont Company. DuPont was primarily an explosives company 200 years ago. This company's focus turned to global chemicals, materials science, and energy 100 years ago. Today, as it moves ahead into its third century of existence, DuPont continues to deliver S & T–based solutions affecting businesses such as agriculture and nutrition, nylon, performance coatings and polymers, pigments and chemicals, polyester, specialty fibers, specialty polymers and electronics, bio-based materials, and safety resources.

Over the years, DuPont made wise investments in its R&D, and it was quite selective as it moved into new product directions. DuPont has successfully adapted to changes along the way and was able to establish a long-term leadership position by choosing new product venues in which there was still a considerable amount of technology to be perfected. This company has become, via clear and careful technology-assessment strategies, one of the world's most innovative companies. Throughout its long history, DuPont's technology game plan has adhered to several core values, including commitment to safety, health, and the environment; integrity and high ethical standards; rapidity of response; sensitivity to customers; service to the marketplace; quality; and treating people with fairness and respect.

The range of new technologies is so expansive that no single company currently in existence can hope to master them all. Technology transfer and the rapid (often immediate) exchange of information make it

evermore difficult for a company to protect its trade secrets and other intellectual property. Technological development is expensive, and the gains it produces can often prove to be quite short-lived. Technology-assessment strategies are critical across the entire range of product design and development. Today's companies do not have the luxury to say, "We have invented a wonderful new composite material. Now where is an optimal market for it?" R&D teams must be savvy in their attention to market demands and expectations. They must also realize that, without strong patent protection, and even with it, the most sophisticated technology can be outmoded quickly, almost overnight. The technology race has no finish line—its contenders just need to keep on running if they want to stay in the black, ahead of the pack. DuPont now operates in more than 70 countries and employs more than 60,000 persons worldwide. This company maintains 40 R&D and customer-service labs in the United States and operates more than 35 labs in 11 other nations. Undoubtedly, you will find a DuPont imprint somewhere in your household. (Some examples of products that were initially developed and registered by DuPont are Teflon® coating, SilverStone® cutlery, Lycra® spandex fiber, Stainmaster® carpet, Kevlar® synthetic fiber, and Tyvek® fabric.) See **Figure 13-5.**

Technology assessment entails making projections about the future states of specific technologies, in order that the technologies' impacts can be projected and planned.



Figure 13-5.
The versatility of the DuPont Company's S & T solutions is ever-present in our lives. A building-construction site shown here features Tyvek fabric, a widely used weatherization system made by DuPont.

Technology-assessment studies, if they are done well, take time and money, but they can result in much more efficient technology management. Even if the decision is to scrap the innovation, the company might save hundreds of thousands of dollars by not developing a product that does not sell. When corporate managers who are in charge of technology start to think about entering a new research area, they truly must make an honest evaluation of how their company stacks up against the competition. Further, even if a company has targeted specific areas of technology to focus on, it does not hurt to know what is happening in adjoining areas. Technology management entails technology assessment via an external environmental-scanning system to permit timely decisions toward effective implementation of the new technology.

Ethical Dilemmas in Technology

You might recall our discussion of ethics, as it relates to quality of life, in Chapter 5. We made it a point to give examples in which certain medical interventions might actually sustain life, but the quality of life might not be deemed acceptable to the patient who is suffering. In other words, just because we can prolong life does not necessarily mean we should do so. Ethicist Richard DeGeorge makes reference to the ***technological imperative (TI)***. In his mind, TI describes our tendency to believe that, if it is possible to develop a technology, we should (and most likely will) develop it. When TI hypnotizes the proponents of science, technology, and engineering, they might fail to consider the range of ethical ramifications of moving forward with a proposed technological solution.

In the previous segment, we provided a listing of DuPont's core values, and you might have noticed this company's commitment to "integrity and high ethical standards." It is difficult to ignore the importance of ethics and responsible research in today's science, technology, and engineering community. Unfortunately, many of the discussions in the literature written about science, technology, and engineering ethics tend to focus on negligence, wrongdoing, mistakes, and oversights—and then the dialogue turns to how these events could have been avoided or prevented. In discussions related to ethics, much less coverage is devoted to the good work and responsible contributions that scientists, technologists, and engineers make. Perhaps this is because we generally take for granted the good and reliable work of these professionals (for example, we assume the bridge will bear the weight of our personal automobile plus several others if we are stopped in traffic over a waterway, we trust the brakes and various other stopping devices to work as the pilot lands the Boeing 737 aircraft and we arrive as passengers in Chicago, and we believe the elevator car will lift us safely to the 75th floor of our office building). All too often, it seems we take special note only when these feats of science, technology, and engineering fail to do what we expect them to do. These types of failures commonly receive more media coverage as well, making it difficult for them to be ignored. Perhaps the phrase "no news is good news" has relevance here.

Even though many of us have limited understanding of the highly complex work going into the design and construction of today's technology and engineering artifacts and even less knowledge about specialized efforts that might have prevented failures or improved reliability, we still trust the experts. On the other hand, we also find comfort in the belief that these professionals take their responsibilities seriously to ultimately protect public safety, health, and welfare. We

depend heavily on the expertise of scientists, technologists, and engineers, but a significant portion of their collective work is anonymous. Few of us ever actually meet the people who design, develop, and build the tools and devices we routinely use each day. Somewhere in our minds, however, we discover a sense of faith and trust that these people are professionally competent and, further, they possess an intrinsic belief in a set of strong professional ethics.

Many universities offering degrees in engineering include courses in engineering ethics in their curricula. The Accreditation Board of Engineering and Technology (ABET) requires its accredited engineering programs to provide opportunities for students to gain an understanding of the engineering profession and practice. The ABET 2000 standards require programs to ensure that students have a major design experience, including ethical, as well as economic, environmental, social, and political, factors. Similar expectations exist within the professional associations aligned with science education and technology studies.

Throughout this textbook, the authors have strived to give both the good news and the not-so-good news about a wide range of established and emerging technologies, including genetics, medicine, manufacturing, and the military. S & T are dominant in our lives. Decisions being made across the country in research labs, university facilities, government centers, and industrial firms are replete with ethical dilemmas. Each day, scientists, technologists, and engineers are making choices about which way to go next in their research investigations. Large corporate entities or nonprofit foundations, with whom the people doing the actual research might never have met face-to-face, often sponsor these investigations. You might be in a position similar to this one day in the future. For those of us who will be depending on you to make the right choice and to be ethically and morally responsible, never forget the importance of character and virtue as you proceed in your career. A recent study among practicing engineers and engineering managers revealed their opinions about responsible engineering and exemplary engineering practice. The results of this study clearly apply to S & T professions. See **Figure 13-6.**[2]

Technology Risk Assessment

As mentioned earlier, another responsibility falling under the jurisdiction of the technology manager is related to a procedure labeled ***risk assessment***. At least one facet of a technology-assessment study should examine the potential risks to humans, if the technology is allowed to enter full-scale development and production. Risk implies uncertainty. Risk assessment, then, is largely concerned with uncertainty. The related concept of probability is often hard to grasp. The effective illumination and subsequent minimization of risks requires knowing what the risks are and how big they are. Knowledge of this sort is commonly gained through experience over a sustained period of time. The essence of risk assessment features the application of this knowledge of both previous mistakes and deliberate actions, in an effort to prevent new mistakes in new situations.

RISK ASSESSMENT

A method of studying the risks of a new technology, material, or device so they can be better avoided, reduced, or otherwise managed.

[2]Pritchard, M. S. 2001. Responsible engineering: The importance of character and imagination. *Science and Engineering Ethics* 7 (3): 394–395.

Dispositions	
Engineering Ethics	**Engineering Practice**
• Integrity • Honesty • Candor • Civic-mindedness • Courage (to speak up) • Courage (to stick to one's guns) • Willingness to make self-sacrifices • Willingness to assume some personal risk	• Competence • Ability to communicate clearly and informatively • Cooperativeness, teamwork skills • Habit of documenting work clearly and thoroughly • Commitment to objectivity • Openness to correction and admitting mistakes • Commitment to quality • Imagination • Seeing the big picture, as well as the details of the smaller domains

Figure 13-6.
In a survey of engineers and managers, researchers at Western Michigan University assembled a list of commonly mentioned dispositions. These dispositions reflect ethics and behaviors associated with successful engineers. (Pritchard, M. 2001. Responsible engineering: The importance of character and imagination. *Science & Engineering Ethics*.)

The results of risk assessments are most commonly presented in the form of an estimate of probabilities for various events that are usually injurious or dangerous. (For example, for women over 35 years old, there is less than 1 chance in 200 that an amniocentesis procedure will result in any pregnancy complication.) Although the goal of conducting a risk assessment is to obtain this type of estimate, the major value in performing a risk assessment might actually be the exercise itself. Ideally, the people who are executing the study will explore all aspects of the action or technology under scrutiny. Refined knowledge about all angles and ramifications of the technologies will serve to make their estimates considerably less subjective.

The manner in which various risks are calculated strongly influences the way we perceive them. When risk estimates are based on historical data, they are fairly easy to understand and tend to be perceived as reliable reports. Historical data provides the estimators with the frequency of events over a certain period of time. This facilitates the derivation of trends.

In order to make further predictions about the future probability of risks, researchers must employ some type of statistical model. The historical approach to estimating risks is useful only when the particular hazard has been around for a while, the risk is apparent, and the risk is large enough to be empirically measured (for example, cigarette smoking). If there is no historical database for an individual hazard in question, risk assessors might choose to consider the hazard in separate parts. In doing so, they calculate the risks from each segment and add them together to estimate the risk for the whole system. A well-known instance in which this risk-assessment technique has been employed is in the calculation of the probability of a severe accident at a nuclear power plant. Some carcinogenic risks might be estimated from historical data. The time delay between initial exposure and the final incidence of a cancer, however, complicates this process. This is the difficult field of ***epidemiology***, in which causality is very hard to prove when the risk is small or seemingly insignificant.

Cause-and-Effect Relationships

Risk assessment, with regard to new technologies, is a relatively youthful discipline. While many agencies, consulting firms, and technology managers have been performing these assessments over the past 20 or more years, there still does not seem to be a consensus on which basic rules and procedures to follow, in order to solve problems involving risk. The process of evaluating an environmental hazard to predict how many people might be at risk is, indeed, a challenge. As time goes on and we continue to develop more sophisticated detection technologies, scientists are able to measure the effect of toxic substances in smaller quantities. These assessments produce results that might actually contradict, rather than reinforce, the results of earlier studies. Risk analysts must take the time to follow the hazard through whatever twists, turns, and shifts it makes in the real world. (Refer to the *Dateline* segment of this chapter. Flu experts are constantly attempting to do this in order to formulate an effective vaccine.) Risk assessors must be able to determine how potential threats are released into and move through the ever-changing environment. Next, they have to figure out how much of the substance people might eat, breathe, or swallow and then estimate how much of it people can ultimately absorb. Knowing all this, they finally make an effort to determine the severity of the hazard associated with the absorbed level of the substance.

Risk analysts rely heavily on computer modeling to get a handle on typical risk estimates, but it is extremely difficult to incorporate all the important information into these models to make their findings reliable for the population at large. Consider the previous exercise. Even if the analysts knew exactly how much of a substance is in the environment (phase one), they cannot necessarily predict how much of it people will absorb (phase two). People breathe at different rates, depending on their levels of health. Individuals possess widely disparate breathing rates and dietary habits. Each of these factors affects the dose of specific substances taken in from food and air. People also absorb substances in varying amounts, depending on the thickness of their skin and the properties of their nasal mucus. These are just a few of the discrepancies making it difficult to complete phase two of the risk assessment.

Phase three entails a determination of how much of a hazard the absorbed substance poses (whether or not the substance will cause symptoms such as acute nausea or chronic loss of hearing). This is another complicated problem. Epidemiological studies are frequently insensitive in detecting health hazards from relatively low levels of exposure. In other words, the rates of specific illnesses from a given substance must often be several times above average before analysts can conclude they are not simply random fluctuations. By definition, *risk assessments* are officiated to reduce the amount of risk a particular technology might cause, but if causation is so tricky to infer, one must wonder about the extent to which the whole activity is an exercise in futility.

Analogous Relationships—Animal Studies

In cases in which the epidemiological evidence is either tentative or ambiguous, risk assessors might choose to use animal studies to make their projections. Studies done by analogy suffer from their own uncertainties. Laboratory animals are commonly exposed to high concentrations of chemicals to ensure that, if there are any toxic effects, they will be evident at statistically significant levels. The use of a mathematical

model called a *dose-response curve* must be fitted to the resulting data to assess the probability that humans will get cancer at much lower levels than they might realistically encounter. Still, serious limitations plague the process of interpreting animal studies and extrapolating them to humans.

The initial use of high doses of toxic substances might actually interrupt the recipient's internal metabolic reactions toward the initiation of carcinogenesis. Molecular biologists have discovered the existence of certain enzymes in cells that convert chemicals to more toxic metabolites—starting the march toward cancer. When the toxic chemical agent is introduced in large quantities, the enzymes are fully occupied and cannot generate the toxic by-products at a greater rate. When risk assessors extrapolate downward to realistic levels of human exposure, they might not take this saturation effect into account. Therefore, they might actually underestimate the risk to human beings.

Another limitation is that animals and humans metabolize substances differently. For this reason, the level of the test chemical reaching various organs in the animal and the human body can differ a great deal. Subsequently, the animal might suffer from different health afflictions from the human, or none at all. For instance, a laboratory chemical called *bis(chlormethyl)ether* has been found to produce nasal tumors in rats, but lung tumors in people. In other cases, dogs and humans have developed bladder cancer from some aromatic amines, such as benzidine (used to make various dyes), while rodents displayed cancer of the liver. Correcting for these differences is not easy because scientists still lack critical information regarding human and animal systems across the board. A significant portion of risk-assessment studies relies on data accumulated through tests conducted among various animal species.

Risk Communication

Technology risks are not only found in large industrial plants and hazardous-waste facilities. They are also present in the air in your homes, the chemicals your neighborhood dry cleaner uses, and the woodstoves found in many kitchens. Since these risks have the potential to seriously disrupt individual lives and livelihoods, people insist on being more fully informed about them. People also expect to have a voice in the methods of control. Risk communication is therefore becoming more necessary, but not any easier, than it has ever been in the past.

Risk analysts should not attempt to overstate or understate threats. Rather, they should attempt to give their best estimate of possible occurrence and the specific range of uncertainty. It also seems important for the various federal regulating agencies we rely on for our information to coordinate and standardize their risk-assessment procedures so they will arrive at similar estimates for given technological activities.

Progress in the discipline called *risk assessment* has been commendable. If technology managers are to be expected to make enlightened decisions about whether or not to go with a new or modified technology, they must be able to operate with a reliable set of data. This expectation is predicated on improving our contemporary forecasting techniques.

Forecasting for a Responsible Future

When does the future begin? Who is or should be responsible for the way it turns out? Both of these questions are central to the ongoing debates among scholars who study the future. As noted previously in the

introduction segment of this chapter, the field of futures studies, or futurology, has grown considerably over the past several decades. The pictures these professionals paint of tomorrow's world illustrate a wide selection of scenarios. Some views are exciting, others are hopeful, and still others are rather grim. These images are not so much predictions of the future as they are reflections of society's contemporary concerns about the quality of life on Earth—both now, as we know it, and tomorrow, as we hope it will be for our children and grandchildren.

Advertising agencies play an interesting role in future forecasting these days. They are not directly involved in the futurology profession, per se. Their futuristic slogans are really created to convince people to support their clients' products or services. They, however, also seem to be making a business out of defining the future. The manner in which the essence of time is used tells consumers about the product's image, with reference to the past, present, and future. Consider some of the following expressions found in a variety of contemporary advertisements:

"The future is now."
"The future is right around the corner."
"We've been working on the future for 200 years."
"We represent tradition with a future."
"Tomorrow's technology, available at today's prices."
"The future is already here."
"Our products let you experience the future before its time."
"This is the wave of the future."
"Don't let the future pass you by!"
"New pathways to the future, where creativity knows no bounds."

Each of these slogans implies the future is something to look forward to with a smile on your face and a positive attitude. See **Figure 13-7.** The statements define the future via a clear linkage with the past. They are meant to be comforting, from the perspective that the future is not only going to be better, but it will also be familiar.

Present-day advertisers might be described as marketing soothsayers. Their primary objective, however, is to sell goods. The business of technology forecasting is much more comprehensive, with regard to its justification for existence.

Forecasting Techniques

The rise of the predicting profession of futurology has simultaneously popularized several forecasting tricks of the trade. Three techniques that have earned respect among the futures-studies community include the futures wheel, content analysis, and the Delphi study. The futures-wheel projection technique is a small-group brainstorming session in which the participants examine the consequences of a particular social trend or a technological event. This type of activity might precede important policy-making decisions. Brainstorming might also be used to format the early discussions within a technology-assessment exercise. In developing a ***futures wheel***, the group members physically prepare a visual diagram of their opinions and hypotheses about the event or trend being evaluated. Refer to **Figure 13-8.**

In the first phase of this procedure, the group leader is required to identify and describe the technology action, event, or social trend the group members are supposed to discuss. This event becomes the hub of the wheel in the diagram. Participants are asked to describe the immediate probable consequences of the trend, with the proviso that any member of the group can veto any consequence perceived to be unlikely. The search is for a lineup of first-order consequences the group can agree on unanimously. Each of these first-order



Figure 13-7.
Founded in the early 1900s, this youth organization proudly displays its belief in the future course of its social agenda. Still very active in community projects, the Girl Scouts of Santa Clara County used a slogan about the future, denoting an alliance with the past. Even though this photo was taken a while ago, the Girl Scouts' current Web site states "Driven by the new realities of our ever-changing world, Girl Scouts is undergoing unprecedented movement-wide changes that will help us align our operation with our vision of meeting the needs and challenges of the girls of today and beyond." (Michael Dafferner)

consequences next becomes the center of its own wheel, as the group continues to make projections about second-order consequences, while the veto rule remains in effect. The exercise proceeds until the wheel has expanded out to include a list of third- and fourth-order consequences. This type of discussion activity enables the experts to review a vast selection of cause-and-effect relationships in a relatively short period of time. The entire list of consequences of an action, an event, or a trend can be further analyzed to make an educated forecast about future possibilities.

Content analysis is a forecasting method in which reviewers keep track of events as they occur, in order to make an accurate projection of major trends one to two years down the road. Although it had its initial use by military strategists during World War II,

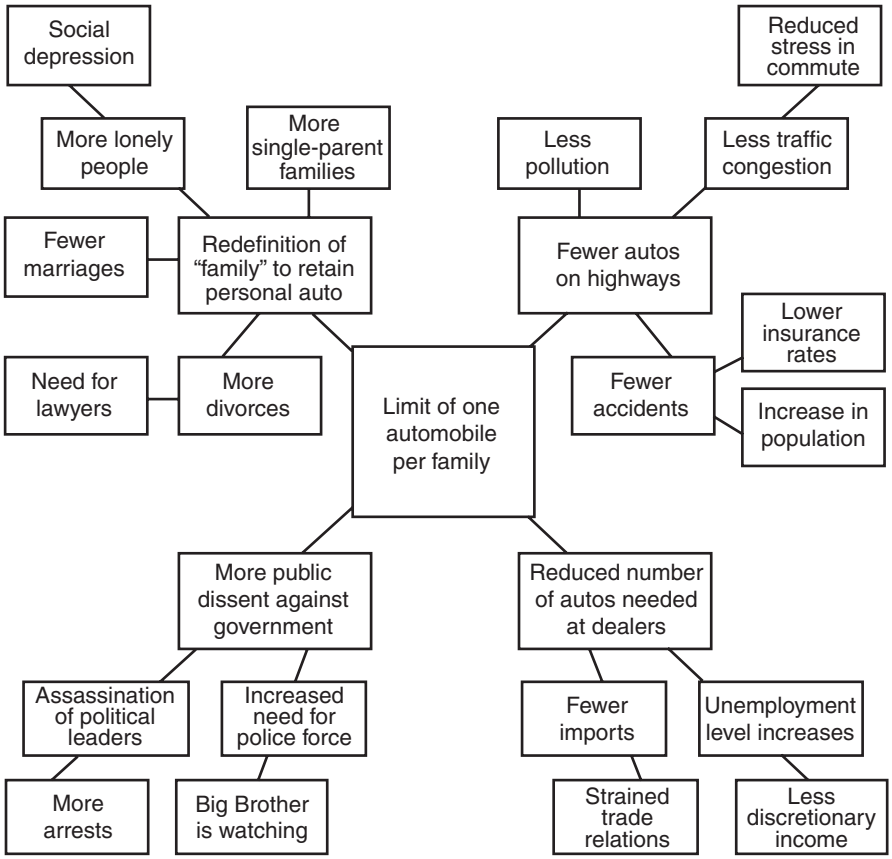


Figure 13-8.
An example of a futures wheel. This is a brainstorming technique used to project probable consequences of a particular social trend, legal action, technological development, or other such topic. (Prepared by students in Technology and Civilization, offered through the Department of Aviation and Technology at San Jose State University)

content analysis gained popularity during the 1980s and into the 1990s by John Naisbitt's group. This group published a triannual newsletter called *The Trend Report*, which compiled much of its information through an in-depth analysis of daily newspapers printed in some 200 U.S. cities. The premise behind content analysis is this: All you need to obtain a preview of the future is an awareness of the changes taking place right now. Companies endorsing this technology-forecasting strategy are able to reconceptualize the nature of their own businesses, in anticipation of changes taking place in the external business environment. In other words, they are not forced into quick fixes, bailouts, or crisis reactions to changes for which they were not prepared.

Another analyst who used what might be called a *synoptic approach* to future studies is Joseph Coates, who founded his Washington DC–based consulting firm of Coates & Jarratt in the late 1970s. His approach, similar to content analysis, was to study the current trends and developments in S & T and project them into future scenarios. The scenarios his firm forecasted for more than two decades included economic trends,

political agendas, and social issues. Coates began his futures work professionally at the NSF, and he later moved to OTA. Scenarios development became a major component of the futures research he took on at Coates & Jarratt, and the firm's studies generally looked ahead 5 to 50 years. Around the time Coates retired, one of his skilled futurists, Tom Conger, founded Social Technologies (ST), which is also headquartered in Washington DC. In less than a decade, ST grew into an international consulting firm that helps its clients to prepare for the future with an informed and empowered perspective. Conger's company provides strategic conversations, technology assessment, scenario development, and trend interpretation.

The Delphi-study process involves an anonymous exchange of opinions through an intermediary, who controls the feedback of opinions in sequential rounds of interchange. ***Delphi studies*** have proven to be useful for long-range forecasting of technological and societal developments. Corporations and government agencies have conducted future-oriented Delphi studies dealing with topics such as political affiliations, technological advancements, technology transfer, environmental degradation, medical developments, military strategy, and economic indices. When reasonable consensus has been reached, the potential events described provide a basis for subsequent planning and action. The Delphi study is essentially designed to overcome some of the difficulties encountered when experts try to arrive at a consensus during face-to-face interaction in a committee meeting.

In a typical Delphi study, the participants are initially selected on the basis of their expertise or interest in a particular subject area (such as nuclear physics, meteorology, religion, education, or futurology). They are sent a series of questionnaires through the mail. In the first round, for example, they might be asked to provide their judgment as to the probable dates of occurrence of a group of events, technological developments, or scientific discoveries (2010, 2015, 2020, after 2050, or never). The intermediary collates the responses to reveal the spread of opinions. This data is sent back to the participants in a second questionnaire. In round two, the respondents are given the opportunity to revise their estimates in view of the overall group response. Respondents whose answers are either above or below the responses the majority gave are asked to provide reasons for their opinions. These narratives, along with the new figures of the group as a whole are collated and presented to the participants in a third questionnaire. In the third round, the participants are again asked to reassess their earlier estimates, in light of the new group-response profile and the reasons the deviants gave. As the study progresses to a possible fourth and fifth round, there is a convergent tendency toward a total-group consensus.

Each of these forecasting techniques is reliant on the judgment and opinions of the people involved with the exercise. The credibility of the results achieved is, therefore, contingent on both the imagination and technical competency of the forecasters employed. You might one day be asked to participate in a forecasting activity as part of a technological assessment, an environmental-impact analysis, or even a Defense Department planning session. Your input into such a forecast, based on careful judgment, might serve to provide a coherent structure for testing alternative actions being contemplated, warning that certain actions are too risky and should be avoided, or defining the scope of reasonable expectations in the technological world of tomorrow. If this appears to be a tremendous responsibility, your perception is right on target.

The Technologist's Responsibility

As time passes, S & T are becoming less a matter of hardware and more affixed to the structure of our social network. Scientists and technologists are, therefore, enjoined to be responsible to the social groups in which they operate. Where are we headed with our S & T? Where should we be headed? Where do we go from here? Where is here? We are in the midst of a host of technological evolutions that generate much to hope for and much to fear. Tomorrow's world will present more advancements and just as many setbacks. Many of our current speculations will have become clear to us 10 years from now, but they will be replaced with a whole new set of unknowns as we move further ahead into the twenty-first century.

Technology has mesmerized a significant portion of contemporary society. In search of answers regarding what to do about the future course of events on their planet, social groups often look to the experts for guidance. In other instances, they place their trust in computerized expert systems for immediate solutions to long-term social and political problems. In many ways, the technologists and scientists have come to the rescue. Their contributions to humanity, however, present many paradoxes:

- ❏ We have more knowledge and information than ever before, but not always with increased understanding.
- ❏ Humanity has more comforts and conveniences, and we also have more risks.
- ❏ We have more arms and military prowess, but no greater sense of security.
- ❏ Humanity has more communications technology, but less community cohesion.
- ❏ We have more education, but less appreciation of the efforts needed to secure the degrees affiliated with it.
- ❏ Many of us have hundreds more choices about how to spend our time than ever before, but less time to choose among these choices.

These realities of the day seem to make us want to ask two questions:

- ❏ To whom do we owe our appreciation for these miraculous achievements?
- ❏ Who should we hold responsible for these ominous threats to our general well-being and survival?

The obvious first response to both questions is to say that the people in charge of science, technology, and engineering should be both thanked and blamed for their numerous innovations. If one delves a bit deeper, however, it should become apparent that every person in society operates in more than one social circle and is no less responsible for the profile of the future than any other person. The social management of technological change is enmeshed in a complex network of objectives, including international cooperation, political stability, economic growth, renewed community vitality, scientific vision, technological responsibility, and a social conscience regarding the future of civilization on this planet. Regardless of educational training or technical background, every person has the unique capacity to make a contribution toward at least one of these objectives.

You have certainly had the experience, at one time or another, of being called on to make an important decision affecting the

lives of other people around you. Perhaps you found it necessary to step away from the situation to collect your thoughts on more objective footing before taking any action. This mental relaxation strategy illustrates the human awareness of the need to use caution when other people's lives are involved. Nearly 25 years ago, Joseph Weizenbaum, an esteemed pioneer in the field of AI and Emeritus Professor of Computer Science at MIT, was quoted with the following sentiment:

> What's needed more than anything else, I believe, is an energetic program of technological detoxification. We must admit that we are intoxicated with our science and technology and that we are deeply committed to a Faustian bargain that is rapidly killing us spiritually and may eventually kill us all physically.[3]

In response to the question "where do we go from here?," even though this recommendation was made some time ago, it still makes a whole lot of sense in today's world of uncertainties. Human beings have the responsibility to each other to act as leaders in society's technological R&D pursuits. Each of us must make a contribution toward the improvement of humanity's existence to bring it into accordance with both the natural environment and the technological environment. As each of the chapters in this book has shown, responsible citizens must keep abreast of new and emerging technologies, in order to intelligently determine whether or not the benefits outweigh the risks of their development. In other words, decisions made under the influence of an overdose of faith in technology might not always be the ones most responsive to the needs and expectations of the populace.

End Line

If this seems a rather ambiguous ending to an otherwise concrete presentation, you are, once again, quite correct in your perception. The fact is that we can always pick up from wherever we leave off, as long as we can still find that end point… and here we are! Most of the preceding chapters, and this one as well, open with a *Dateline* entry related to S & T. These selections reveal that there might or might not be a recognizable starting point for a particular breakthrough discovery, but that progress emerges incrementally over time. At the end of each chapter, you are given a list of suggested readings for further study. In fact, the list of suggested readings for this final chapter is especially lengthy, given the diverse nature of the topics discussed. These readings provide an excellent starting point if you are interested in increasing your understanding of technology. Perhaps they will also pique your curiosity enough that you will become personally committed to the construction of a responsible technological future. Stay with it!

Discussion Questions

1. Explain what the terms *basic research, applied research,* and *development* mean within our country's national S & T arena. Provide examples of each within the fields of transportation, medicine, and defense. Why do you think the percentage of basic research being conducted in the United States has been trending upward over the past couple of decades?
2. Where do you believe the most significant advances in leading edge technologies will take place in the next decade? Provide your rationale.

[3]Long, M. 1986. The West Interview with Joseph Weizenbaum. *West Magazine* (19 January): 4–5.

3. Identify and describe the roles and functions the former OTA served. Generate a list of 5 to 10 contemporary topics or issues in technology you believe warrant investigation by a replacement agency, should our government establish one. Explain why you included these topics on your list.
4. Work with two or three members of your class and study several current newspapers to locate an incident related to science, technology, or engineering ethics. As a group, do an analysis of the case to determine how ethical and moral values did or did not play a role in the event.
5. Explain what the term *risk assessment* means. Why do people attribute a greater amount of credibility to historical risk assessments than to those based on computer models? Provide examples to highlight your answer.
6. Develop a futures wheel illustrating a variety of first-, second-, and third-order consequences related to an issue or event in contemporary S & T.

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Glossary

acid rain: A serious environmental problem resulting from the presence of sulfur oxides and nitrogen oxides in the atmosphere. (9)

advance directive: A written statement made by a competent person that gives directions about his wishes and expectations, with regard to medical treatment. This statement also identifies who should be able to make medical decisions on his behalf. (5)

aerobraking: A technique NASA scientists use to slow down a spacecraft by taking advantage of a planet's atmosphere. (4)

agile manufacturing: An industrial construct that focuses on being fastest to market, with the lowest total cost and greatest ability to meet varied customer requirements. (6)

agroecology: An approach to agriculture promoting sustainability and linking ecology, socioeconomics, and culture to the design of agricultural systems. (8)

Air Quality Index (AQI): The updated version of the PSI. This index includes data on several commonly occurring pollutants and enables comparisons to be made among different regions of the country. (9)

amniocentesis: A medical test normally performed during a woman's 16th week of pregnancy to determine if the unborn child has certain birth defects. (5)

applied research: Research that has the objective of gaining the knowledge or understanding required to meet a specific and well-recognized need. Applied-research investigations are typically structured to discover new scientific knowledge that has commercial end points, with respect to products, processes, or services. (13)

appropriate technology (AT): An intermediate level of technology development, as opposed to one too sophisticated or complex for the problem in question. AT is also an attitude regarding an overreliance on high technology. This technology fits the cultural situation for which it is proposed without causing more problems than it solves. (7)

artificial satellite: An artificial object, such as a telecommunications satellite, orbiting a larger astronomical object, usually a planet. (4)

balloon angioplasty: Formally referred to as *balloon dilation therapy*. Angioplasty is a medical procedure that can replace coronary bypass surgery for clearing clogged arteries in a person's heart. (5)

bar coding: A primary component of automatic ID systems in industry. (6)

basic research: Research that has the objective of gaining more understanding or comprehensive knowledge of the subject being studied, without a specific application or immediate commercial objective in mind. (13)

bioastronautics: The study of how living organisms adapt to conditions of weightlessness and then readapt to life on Earth. (4)

biological weapon (BW): A weapon using a living organism, usually a pathogenic microorganism, for hostile purposes. (10)

biomass: Organic material used to supply energy. (8)
biometrics: Technology that identifies humans based on unique characteristics, including fingerprints and iris scans. (3)
biomining: A technique in mining that uses bacteria to eat away any unwanted iron and minerals, leaving the valuable mineral behind. (2)
biotechnology: The manipulation of biological organisms to make products benefiting human beings. (2)
bioterrorism: The use of biological organisms by terrorists to attack a country and its people. (10)
blastocyst: The hollow sphere of cells resulting from the division of the single cell that the union of a sperm cell and an egg forms. (2)
blog: An on-line journal with descriptions and commentary of events. (3)
busyness syndrome: A concept suggesting it is almost a status symbol in our society to be constantly busy. (11)
cell fusion: A union involving the artificial joining of cells to combine the desirable characteristics of different types of cells into one cell, known as a *hybridoma*. (2)
chaff: A penetration aid included in the deployment of nuclear missiles. This aid consists of thin, confetti-like metallic strips released to confuse the opponent's radar system. (10)
chemical weapon (CW): A weapon using poisonous, asphyxiating, or other gases affecting humans when they are either inhaled or absorbed through the skin. (10)
clone: An exact genetic copy. This copy is an individual grown from a single somatic cell of its parent. Clones are genetically identical to their parents. (2)
cluster bomb unit (CBU): A common work-horse weapon that can deliver lethal explosives to personnel over expansive areas. Instead of having one large explosion, these bombs contain dozens, hundreds, or even thousands of BLUs. (10)
command, control, communications, and intelligence (C^3I): A network that provides information about communications, counterintelligence, security, information surveillance, and reconnaissance to the military forces so they can succeed in every mission. (10)
command, control, communications, computers, intelligence, surveillance, and reconnaissance (C^4ISR): The military's research and information plan that uses improved ITs to enhance military operations. (10)
common space: A region of the world entirely or partially considered to be international territory. These areas are beyond national jurisdiction. (9)
compellance: The deployment of military power in order to convince another country to change its behavior, to make the behavior more satisfactory to the aggressor. (10)
computer-aided design (CAD): The use of a computerized drafting and design program to design a new product to be manufactured. (6)
computer-aided manufacturing (CAM): A manufacturing strategy using computers and ITs to control, manage, operate, and monitor manufacturing processes. (6)
computer blacklist: A database containing the names and ID codes for individuals who should not be given credit, automobile-insurance policies, or such, due to some legal problems in their past. These lists are regularly compiled and updated by financial institutions and government agencies. This form of electronic record keeping has caused many people to question their rights to privacy. (3)
computer-integrated manufacturing (CIM): A host of automation technologies in the manufacturing environment. CIM does

not refer to one specific technology, but to the integrated use of computers in all sections of enterprise, from the planning of production, through the design and manufacture of a product, up to the assurance of good quality. (6)

computer-mediated communication (CMC): An area of study including the use of computers and telecommunications technology to enable people to communicate with one another over real or perceptual distances. (3)

concurrent engineering (CE): This type of engineering requires a systematic and collaborated effort to simultaneously design and develop a product and its manufacturing processes. (6)

content analysis: A forecasting technique in which reviewers keep close track of events as they happen, in order to make an accurate projection of major trends one to two years down the line. Content analysis often makes use of daily newspapers as its primary source of reference material. This technique had its roots among military strategists during World War II. (13)

cookies: Files placed on users' computers when the users visit a specific Web site. They generally store personal information about the users, such as passwords and screen names, and are stored on the hard drive of a user's computer. (3)

Cooperative Threat Reduction (CTR) Program: A Defense Department initiative that has the primary goal of preventing the widespread acquisition of NBC weapons. (10)

coronary angioplasty: A medical intervention known as *balloon angioplasty*. (5)

counterforce targeting: A defensive strategy in which weapons are aimed at the military forces of the opponent, particularly at strategic or theater nuclear forces. (10)

countervalue targeting: A defensive strategy in which weapons are aimed at soft targets, such as urban-population centers, industrial areas, and economic enterprises. (10)

creationism: A theological doctrine ascribing the origin of all matter and living forms as they now exist to distinct acts of creation by God. (12)

cybercrime: A criminal offense with the use of Internet data or resources. Cybercrime includes identity theft, phishing, pirating, and child pornography. (3)

cybermedicine: The widespread availability of medical information (including diagnoses and services) on the Internet. (5)

cyberterrorism: The electronic disruption of military information or information in our homeland. (10)

data mining: This emerging field is also labeled *KDD*. Data mining is the process of finding patterns and correlations in large amounts of data. This field lies behind the future of a fully personalized WWW on the Internet and much more. (13)

decoy: A penetration aid included in the deployment of nuclear missiles. This aid is a dummy warhead that looks similar to the real thing, but carries no explosive power. (10)

Deep Space Network (DSN): An international network of antennas that keep in constant touch with spacecraft. NASA's current DSN has three antenna facilities 120° apart around the world—at Goldstone, in California's Mojave Desert; near Madrid, Spain; and near Canberra, Australia. (4)

Defense Advanced Research Projects Agency (DARPA): A research organization for the U.S. DOD that develops both risky and revolutionary military technology. (3)

Delphi study: A forecasting strategy in which a group of preselected experts engage in an anonymous exchange of opinions through an intermediary, who controls the feedback of ideas in sequential rounds of interchange. (13)

demand lag: The time it takes for a technology to gain acceptance in foreign markets after it is first introduced into the innovating country's domestic markets. (7)

deoxyribonucleic acid (DNA) chip: A wafer of silicon, glass, or plastic, onto which DNA strands are arrayed, or placed. (2)

design for manufacture and assembly (DFMA): An engineering tool for product simplification conveying an evaluation of the product's complexity and subsequent development of design alternatives to simplify product features and improve the firm's capacity for defect-free manufacturing. (6)

deterrence: The deployment of military power to threaten an adversary and thereby protect a country. (10)

development: The *D* in R&D, and it refers to the systematic use of the knowledge and in-depth understanding gained from research investigations. Development means we are now producing useful materials, processes, devices, systems, or methods. This use of knowledge and understanding also refers to our design of prototypes or trial procedures. (13)

diagnosis-related group (DRG): A medical-care classification system that groups patients who are similar clinically, in terms of their diagnosis, treatment, and expected consumption of hospital resources. The scheme allows for the comparison of resource use across hospitals with varying mixes of patients. This system is used primarily in the United States as a method to fund hospitals—for example, a determination of costs for specific medical procedures and medications. (5)

distance education: A subset of technology-enabled teaching and learning. This education refers to a formal educational process occurring with the teacher and learner separated by either time or distance (often both). (12)

durational expectancy: A concept Alvin Toffler introduced in his *Future Shock.* This concept refers to a culturally based attitude or expectation regarding how long things are usually supposed to last. (11)

e-commerce: Sales or purchases of goods and services using the Internet. (3)

e-finance: An aspect of e-commerce specializing in money management and investments. (3)

electronic mail (e-mail): A form of correspondence in which messages can be composed and sent anytime by way of an Internet connection. (3)

entrepreneurial science: A trend especially apparent in university research laboratories in which there is a convergence between basic and applied research, such that commercial opportunities emerge. (7)

environmental-impact analysis: The process of conducting a comprehensive study and review of a broad range of environmental features, such as topography, hydrology, geology, and cultural status for a specified land area. (9)

environmental management: Managing environmental issues through appropriate business strategies. (8)

environmental release: The accidental or deliberate release of a contained substance into the natural ecosystem (air, land, or water). This release represents a central point of debate in genetic engineering experiments in which genetically altered organisms are allowed to be tested outside the laboratory. (9)

epidemiology: The systematic study of widespread contagious diseases or physiological maladies that have reached epidemic proportions. (13)

***Escherichia coli* (*E. coli*):** The single-celled bacterium commonly found in the human intestinal tract. This bacterium is used in rDNA research because of the ease with which it can be engineered.

E. coli bacteria reproduce every 25 minutes, even after their genetic code has been altered via splicing. (2)

ethnobotany: An initiative that emerged from the scientific field studying how people from a particular culture use indigenous plants. (8)

evapotranspiration: A naturally occurring process akin to Earth's tropical forests and their role in global climate management. (9)

expert system: An intelligent computer program using knowledge and inference procedures to solve problems challenging enough to require a significant amount of human expertise for their solution. This program portrays a model of the expertise of the best minds in a particular discipline (such as medicine, prospecting, or air-traffic control). (12)

extranet: An intranet that a company has made accessible to customers and other users, even if only on a limited basis. (3)

false negative: A negative consequence associated with the purchase of self-diagnostic kits for use in the home. These can occur when the user does not perform a test correctly or misinterprets the results and finds, erroneously, that she does not have the condition for which the test is being administered. (5)

false positive: A negative consequence associated with the purchase of self-diagnostic kits for use in the home. These can occur when the user does not perform a test correctly or misinterprets the results and finds, erroneously, that he has the condition for which the test is being administered. (5)

faster, better, cheaper (FBC): A policy NASA adopted to reduce costs in the early 1990s. This policy's goal was to shorten development time, reduce costs, and increase the scientific output of NASA by having more missions in less time. (4)

fetoscopy: The use of fiber-optic technology to study a fetus as it develops inside the uterus. This technology enables physicians to treat a number of diseases that might be fatal to the unborn fetus. (5)

fiber optics: A technology that converts data, sound, or images into light impulses, which a laser propels across a thin strand of glass at very high speeds. (3)

firewall: A combination of hardware and software placed between a private intranet and the Internet to keep the intranet private and protected. A firewall examines all information entering and leaving the intranet to make sure there are no unauthorized messages, thus, stopping hackers from breaking into a company's computer system. (3)

first strike: A disarming attack on an enemy. (10)

flexible manufacturing system (FMS): A fully automated, computer-controlled production system offering substantial advantages, in comparison to the conventional job shop. An FMS is a set of machines linked by a material-handling system. (6)

foreign direct investment: A channel for technology transfer in which a U.S. manufacturing plant or other type of industrial firm establishes an offshore or overseas subsidiary in order to reduce distribution costs, avoid import tariffs, or decrease labor costs. (7)

futures wheel: A forecasting technique the World Future Society first devised. This technique entails a small-group brainstorming session in which the participants examine interrelated chains of events that might be consequential to a particular social trend or technology. (13)

gene therapy: A field of study in health science, which researchers hope will enable them to cure diseases genetically transmitted from one generation to the next. The therapy entails transplanting healthy

genes into the cells of a patient who is suffering from a disabling disease, in an attempt to increase the patient's chances for survival or decrease the chance that the defect will be passed on to the patient's progeny. (2)

genetically modified (GM) food: A new food product created through biotechnology including genes or characteristics not present in the traditional food product or plant. (2)

genome: A description of an organism's genetic material, including all the DNA. (2)

geostationary orbit: A geosynchronous orbit. This orbit is approximately 22,000 miles away from Earth's surface and directly above the equator. (4)

geosynchronous orbit: An orbit around the Earth that returns a satellite to the same position at the same time each day, based on the Earth's sidereal rotation period (23 hours, 56 minutes, and 4 seconds). (4)

glass cockpit: A cockpit that has computerized or digital controls and displays. (4)

Global Positioning System (GPS): An application of satellite technology becoming popular with consumers, although it was first developed for military purposes. This system can give the exact position of a person or an object by using 24 satellites positioned so a person on Earth can receive a signal from 4 of them at one time. (4)

global warming: A widespread and long-term trend toward warmer global temperatures caused by increasing levels of CO_2 and other gases in Earth's upper atmosphere. (9)

green building: A building constructed in a way that minimizes waste and includes recycled, renewable, and reused resources to the maximum extent possible. (8)

greenhouse effect: The heating of Earth's surface, due to increased levels of CO_2 in the upper atmosphere, which traps solar energy. This phenomenon is also called *global warming*. The heating has dramatic ramifications, with reference to the stability of the planet's ecosystem. (9)

group technology (GT): An approach to manufacturing that segregates parts according to their design or manufacturing characteristics. (6)

gyroscope: A scientific instrument that has a rapidly spinning wheel in a frame, which allows the wheel to tilt freely in any direction or to rotate about any axis. Gyroscopes are used in compasses, on ships and aircraft, and in guidance systems. A gyroscope, when used in spacecraft, usually monitors motion in one or more of the three spatial movements: vertical, longitudinal, and lateral. (4)

health maintenance organization (HMO): Essentially a merger of an insurer and a provider of health care. This organization is an alternative to traditional fee-for-service providers. An HMO utilizes a fixed-payment medical plan by estimating and projecting a prospective payment on an annual basis. (5)

heuristics: Rules of thumb based on a compilation of personal experiences over time. These rules are used to help guide problem-solving exercises. In the field of AI, they are built into computer programs to enable machines to make educated guesses. Unlike algorithms, they do not guarantee a solution. (13)

imitation lag: The time it takes foreign countries to obtain the production capabilities to produce a new device, after the lead nation begins producing the device. (7)

information overload: An individual's inability to think clearly, due to an excessive amount of cognitive stimulation. (11)

instant messaging (IM): Sending of textual messages in real time through a mutually shared program. (3)

integrated pest management (IPM): A system of managing pests to keep them at levels at which they cause minimal damage to crops. This management attempts to use ecologically sound, nonpesticide methods to reduce and manage pests, such as insects, diseases, and weeds. (8)

intelligent software agent: Software acting autonomously on behalf of the user, based on the user's interests and needs. An agent has the capacity to learn from experiences and respond to unexpected situations. Such a program strives to achieve a known goal and can sense the current state of its environment in order to make continual progress toward the goal. (3)

International Organization for Standardization (ISO) 14000: A management tool with the focus of managing environmental issues through appropriate business strategies. This tool describes how a company can manage its business in an environmentally friendly manner. (8)

***International Space Station*:** An orbiting space station that serves as an international laboratory for research. (4)

Internet: The largest information-packet switching network in the world. A mammoth network of networks, its roots can be found in the academic research community with original funding from the DOD, but its current constituency has extended to the commercial world and into homes and continues to grow at an exponential rate. (3)

intranet: A private corporate computer network. (3)

in vitro fertilization (IVF): A procreation option for women who are unable or unwilling to conceive with the conventional method of intercourse. (5)

just-in-time (JIT): A manufacturing philosophy attempting to eliminate waste throughout the system, including inventory at both ends of production and all machinery and manpower that do not add value directly to the product. JIT has its roots in the Japanese automobile industry, which sought to get rid of excess, waste, and unevenness. (6)

laser: An acronym for *light amplification by stimulated emission of radiation.* (5)

lean manufacturing: A system meeting high manufacturing or service demands with a small amount of inventory. (6)

licensing: A formal channel for the transfer of technology tied to a legal agreement between parties. (7)

lithotripter: A device supporting an MI medical intervention performed in a hospital. This device is a machine that uses sound waves from outside a person's body to destroy kidney stones. (5)

local area network (LAN): A network of cables and switching boxes providing high-speed data-communication links among computers or computerized machines operating in the same geographic area. (3)

low-intensity conflict (LIC): The dominant military motif that includes incidents such as border skirmishes, internal battles, police work, civil uprisings, and regional conflicts. These conflicts tend to occur in less developed areas of the world, and they rarely involve regular armies on both sides. (10)

manufacturing resource planning (MRP II): An application-software structure that allows for integrated planning of a manufacturer's material, equipment, facilities, and people. (6)

maquiladora: A foreign-owned and -operated assembly plant, most often along the U.S.-Mexican border, that imports components into Mexico, assembles

them into products ranging from televisions to auto parts, and reexports finished products. (7)

material requirements planning (MRP): A technique for planning future purchase orders and manufacturing lots, according to what is required to complete a master production schedule. (6)

microphotonics: This emerging array of technologies represents systems combining electro-optics with fiber optics and semiconductor micromachining technology. (13)

mid-intensity conflict (MIC): The Pentagon's label for periodic battles the United States might be forced to wage against well-armed regional powers. Future MICs (similar to Operation Desert Storm in the Persian Gulf) are likely to be fast paced, high-tech, and dependent on unrestrained use of the most sophisticated weapons systems. (10)

minimally invasive (MI) surgery: A group of new medical technologies employing endoscopic devices, laser beams, shock waves, or nanotechnology, instead of a scalpel, to penetrate the damaged or affected area of the patient's body. (5)

modern environmentalism: An information-based perspective supporting the need for harmony and balance between industrial objectives and environmental protection. (9)

monoclonal antibody (MAb): A protein in the bloodstream that an organism's immune system generates in reaction to foreign proteins and polysaccharides. This protein neutralizes the foreign agents and produces immunity against certain microorganisms or their toxins. (2)

most favored nation (MFN): This trading status is one in which one country gives another country the tariff treatment its least-restricted trading partner enjoys. (7)

mutual assured destruction (MAD): A military defense policy attempting to deter opponents from a first strike against each other. (10)

nanotechnology: The science and engineering methods devoted to the design, development, and application of extremely small devices, systems, and materials, which are measured in nanoscale increments. (5)

natural language processing (NLP): NLP is critical to research in the field of data mining. (13)

new urbanism: The movement of middle- and upper-class people living in the suburbs into town, where they typically purchase or rent space in what are called *in-fill developments*. (8)

nongovernmental organization (NGO): A nonprofit or for-profit organization established to promote a particular cause. An NGO is not affiliated with any particular country, but rather, it works as a quasi-governmental agent to affect change in the world. (8)

nuclear family: This concept gained popularity across post–World War II U.S. villages, towns, and cities. The nuclear family unit includes a working father, a stay-at-home mother, and two or more dependent children who live in a purchased home. (12)

nuclear winter: A variety of environmental consequences that might result from a full-scale nuclear war. (10)

optical network: A network using optical fibers to transmit data. (3)

optoelectronics: A field of technological R&D that has given us, among other things, fiber optics. This field represents an interdisciplinary blend of electronics and optics technologies. (13)

parental leave: An employee benefit that provides paid or unpaid time away from work to allow individuals to care for

children. This type of leave most commonly includes childbirth, maternity, paternity, and adoption. Parental leave figures centrally in employee-benefits packages in government agencies, institutions of higher education, large corporations, and small businesses. (12)

pharmacogenomics: A new science in the field of medicine combining knowledge of a person's genome with what is being done in the pharmaceutical industry. (5)

pharming: The use of genetically altered livestock to produce drugs. (2)

Pollutant Standards Index (PSI): An index the EPA developed with the Council on Environmental Quality to comply with the Clean Air Act. The PSI is used to convert the concentration of pollutants in the air to a number from 0 to 500. (9)

preferred provider organization (PPO): This form of managed medical care has an advantage over the HMO, in that it can be imposed on the present network of hospitals and doctors without having to build clinics or convert doctors into employees. (5)

preimplantation genetic diagnosis (PGD): A genetic testing procedure used after a woman's egg is fertilized in vitro and before the resulting embryo is transferred to her uterus. (5)

product lifecycle management (PLM) software: A computer-mediated tool that assists with the designing and marketing of a product. (6)

quality function deployment (QFD): A systematic way for a manufacturing firm to identify customer requirements and convert them into design and manufacturing needs. QFD is a management planning tool that can be used in any phase of production to help concerned personnel identify the critical design parameters. (6)

quality of life: A balance between what people need and want and the extent to which the environment can provide for them. (11)

radio frequency identification (RFID): An electronic device used to identify and track people, animals, and products with radio wave technology. (6)

rapid prototyping (RP): An emerging technology associated with customized fabrication. RP machines are computer-driven units that fabricate parts directly from design data. (6)

recombinant deoxyribonucleic acid (rDNA): Presently one of the most refined genetic engineering technologies. This technology involves splicing specific codes along the DNA chain of a host organism in the laboratory. (2)

renewable energy: Sources of energy that are always available because, in reality, they cannot run out and they can be replenished. (8)

response mode: A human behavior. These behaviors are influenced by emotions, expectations, experiences, and the nature of the stimulating incidents. Response modes might equate behavioral responses to changes usually thought to be out of one's direct personal control. (11)

reverse engineering: An astute capacity to carefully disassemble an imported device, examine it, and eventually copy it. This is a form of an unplanned transfer of technological know-how taking place through a formal channel (export of manufactured goods). (7)

risk assessment: A method of studying the risks of a new technology, material, or device so they can be better avoided, reduced, or otherwise managed. (13)

risk-benefit analysis: An analysis that attempts to and must ultimately answer the question "How safe is safe enough?" (11)

science: A stream of human events involving a mathematical or systematic study of nature, resulting in a body of knowledge that is practical, as well as theoretical. (1)

Single Integrated Operational Plan (SIOP): The U.S. plan for the conduct of a nuclear war incorporating weapons-arrival and survival probabilities, weapons characteristics matched to targets' damage criteria, routing and timing of weapons, and modeling to assure the plan's viability under various conditions. (10)

***Skylab*:** A preliminary version of a U.S. space station. *Skylab* was a huge orbiting space laboratory NASA launched in the early 1970s. The project was scrapped a few years later, and *Skylab* burned in the late 1970s after its orbit had decayed. (4)

smart growth: Development accommodating the needs of a community without sacrificing the environment. This growth aims to balance development and environmental protection by creating new developments that are centered more in the towns and cities, include alternative transit options, and have mixed-use development. (8)

smart weapon: A missile or bomb that can be steered toward a target through a laser or video guidance system. Smart weapons that the U.S. military uses today are all autonomously guided and include capabilities for functioning in adverse weather. They have been added to almost every U.S. aircraft flown today and include laser-guided bombs, precision cruise missiles, and air-to-surface GPS-guided glide bombs. (10)

social institution: A formal entity existing in society primarily to nurture and contain certain behavior patterns, rituals, and beliefs considered important to a group of human beings. Several that have been preserved for many centuries include family, church, marriage, government, and schools. (12)

social lag: Related to the phenomenon of social readiness, with respect to new inventions in technology, the length of time required for society to adapt to or accept new technological ideas, processes, or devices, once they have been introduced. (11)

social networking: Meeting and connecting with individuals through on-line communities. This networking requires third-party Web sites to share profiles and files among users. (3)

space adaptation syndrome: A malady commonly referred to as *space sickness*. This malady continues to be a number one medical concern among space agencies internationally. The syndrome is a generic label ascribed to a series of undesirable physiological and psychological side effects associated with weightlessness, or zero (z) gravity, in space. (4)

space junk: Pieces of spacecraft, nuts, bolts, gloves, and other debris from space missions forming an orbiting garbage dump around Earth. (4)

spectrograph: A scientific instrument that separates the light from a telescope into different components so, for example, the composition and temperature of a planet or star can be analyzed. (4)

spectrometer: An instrument that separates light into its different wavelengths to create spectra. This instrument allows scientists to determine what elements are present in an object. (4)

statistical process control (SPC): An approach to quality assurance differing from the traditional policy of product control via inspection. SPC is prevention oriented, versus inspection driven. This approach involves statistical analysis and increased personnel responsibility to ensure that all equipment and processes are operating within acceptable limits. SPC implementation focuses initially on two or three critical parameters in each process that must be controlled. (6)

Strategic Defense Initiative (SDI): A military strategy defined to be a comprehensive R&D program to explore the possibilities of strategic defense. (10)

Superfund: Formally labeled *CERCLA,* this program earmarks federal funds to clean up the nation's more critical hazardous-waste sites. (9)

sustainable agriculture: A philosophical and practical approach to farming and agriculture built on three broad goals: farm profitability, improvement of the environment, and increased quality of life for farmers and their communities. This agriculture is future oriented and has the principle that we should meet our food needs for the present without limiting the ability of future generations to meet their food needs. (8)

swaggering: The deployment of military power by a government to enhance prestige, national pride, or the personal ambitions of its rulers. (10)

technological imperative (TI): The common tendency to believe that new technology should be developed if we have the capacity to develop it. (13)

technological literacy: A topic of discussion in social studies and technology education. Technological literacy is generally thought to involve an effective level of knowledge and understanding, with general reference to events and issues in S & T, and an above-average grasp of technical terminology in one's field of specialization. (11)

technology: The cumulative sum of human means developed in response to society's needs or desires to systematically solve problems. (1)

technology accordance: This social behavior or attitude refers to the extent to which a social group is able to recognize and take advantage of the potential benefits of a technological breakthrough and simultaneously control any of its negative side effects or risks. (11)

technology assessment: The process of making projections about the future state of specific technologies, so we can assess and plan for their impacts on society. (13)

technology equity: An issue implying that all technologies are available to and used by all socioeconomic segments in a society. (8)

technology transfer: The development of a technology product or process in one setting, which is then transferred for use in another setting. (7)

technology transfer channel: The formal or informal route through which technological artifacts travel from the supplier to the end user, within the international network of technology exchange and transfer. (7)

technology trap: A contemporary social phenomenon describing our dependence on a technological system or device that we either do not understand or cannot control. (11)

technophobia: A general tendency to shy away or refrain from using the tools of technology due to a lack of faith and trust in common technological systems, a low level of confidence in the use or operation of technology-intensive products, and the perception that one is not technologically literate. (11)

technostress: A modern affliction referring to a person's inability to adapt to or cope with new computer technologies in a healthy manner. This affliction manifests itself in two distinct, but related, ways: in the struggle to accept computer technology and in the more specialized form of overidentification with computer technology. (11)

telecommuting: The concept of using telecommunications technology to transport work to employees who,

therefore, avoid the daily commute to a distant job site. (3)

teleconferencing: A videoconferencing option found in desktop systems connected to a network utilizing digital video transmission. (3)

telematics: The use of wireless voice and data technologies between a car and some other place. (3)

terrorism: The ability to use readily available technologies as tools of mass destruction. (10)

transgenic: A characteristic describing GM foods or animals containing genes outside their species. (2)

Trojan horse: A computer file masquerading as something else. These files contain computer programs that, when started, can cause the loss or theft of data. Trojan horses do not start automatically; you must start them by, for example, opening an e-mail attachment. (3)

turnkey plant: A formal channel for the transfer of technology from one nation to another. (7)

ultrasound: This procedure uses sound waves to produce a sonogram, which is a visual image of a person's internal organs (such as liver, kidneys, uterus, bladder, and lungs). (5)

universalism: A characteristic of modern technology making it very difficult, if not impossible, for people to live in cultures not at all interested in advanced technology. Universalism describes a high level of interdependence among nations and the fact that technological changes, advancements, and accidents do not occur in a vacuum. (11)

videoconferencing: The ability to communicate visually using computer technology, television monitors, cameras, microphones, and special modems. (3)

virtual private network (VPN): A new type of network that is a low-cost alternative to a private WAN. This network is a secure connection between two points on the Internet and is available through an Internet provider. (3)

virtual reality: A realistic, three-dimensional, computer-based simulation of reality that allows the user to become immersed in the experience. (3)

virus: A small program, designed to alter the way a computer operates, that functions without the knowledge of the user. (3)

Web bug: A small software program on a Web site that can record the actions users take while on the Web site. (3)

wide area network (WAN): A connection among computers or LANs over a large geographic area. These networks are commonly referred to as *backbone networks*. (3)

wireless network: A LAN or WAN that operates using wireless connections. (3)

worm: A program that moves from one computer to another automatically, usually through e-mail. (3)

xenotransplantation: The transplantation of animal cells, tissues, or organs into human beings. (2)

zapping: The modern day television-watching habit of switching channels with a remote control to avoid watching commercials or to simply get a sampling of several different programs simultaneously. (12)

zipping: A technique enabling the viewer to fast-forward through a prerecorded tape to avoid watching any segments that do not interest her (such as commercials and time-outs during sporting events). With regard to DVDs, zipping refers to cueing the laser to a specific segment of the disk to begin watching the program at that point. (12)

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