# HISTORICAL OVERVIEW
# PREPARED BY THE IEEE HISTORY CENTER
# RUTGERS UNIVERSITY

**ELECTRICITY IN THE 1880s**

The organization of the electrical engineering profession in America in the1880s was no coincidence. It was in that decade that electrical technology finally emerged from the confines of specialized applications that had little direct impact on most people, to be seen as a force for change everywhere. This was especially apparent at the Philadelphia exhibition that gave impetus to the IEEE's birth in 1884.

For nearly a half century, the application of electricity meant telegraphy, electroplating, and electricity in medicine. It is easy now to forget what a wonderful thing the telegraph was to people in the 19th century, so crude and simple does it seem next to the electrical and electronic marvels of a later day. One must think back to what it meant to introduce instantaneous communication between distant points into a society that had never known anything like it. Although commonplace by the1880s, the telegraph had not yet lost its fascination and was the only electrical technology known or understood by many in Philadelphia.

The real excitement, however, came from new electrical inventions, some of which had begun their rapid spread across the land into households, shops, factories, and everywhere else that people sought the increased comforts and productivity promised by the most modern technology. The electric light was, of course, the most visible of these. The arc light, with its glaring, unsurpassed brightness, had been available for about a decade, but was in fact still only beginning its spread into use in public places, such as streets, squares, large stores, and theaters. The incandescent lamp, characterized by its soft, yellow glow that seemed so superior to gas, was less than 5 years old, although the efforts of Thomas Edison and a half-dozen rivals were pressing the new light, and the central power system that made it work, into service everywhere.

Hard on the heels of the electric light were the attempts of inventors and entrepreneurs to find other applications for the central electrical system. Already, small devices such as sewing machines, pumps, and hoists had been successfully linked with electric motors to make work safer, more convenient, and more productive. A multitude of similar applications seemed just around the corner, and Philadelphia provided a wonderful opportunity for showing them off. And on the horizon, a number of inventors showed, were even greater marvels, such as the application of electric power to the always difficult problem of urban transport.

Perhaps most significant, if its true importance was not realized at the time, was the application of electricity to counting and computation. Scientists and mathematicians had long been intrigued by the possibilities of mechanical calculation. As early as the 1830s, the Englishman Charles Babbage conceived of an "Analytical Engine" that would perform mathematical operations using punched cards, hundreds of gears, and steam power. Babbage's machine was beyond the capabilities of 19th-century technology, but his vision represented a goal that many were to pursue in the next century and a half. The harnessing of electricity to the problem led to such developments that, in 1890, the U.S. Census Bureau was able to adopt Herman Hollerith's Electric Tabulating System to their task.

The present therefore seemed wonderful to engineer and citizen alike during those bright autumn days in Philadelphia, and the future was so full of possibilities that it was hard even to conceive what they might be. It would have taken foresight indeed for anyone to recognize the significance of one odd little item displayed in a corner of the hall's largest single exhibit, that belonging to Thomas Edison. There, labeled simply as "apparatus showing conductivity of continuous currents through high vacuo," was Edison's "Tri-Polar Incandescent Lamp," showing off the "Edison Effect" the harbinger of electronics.

## THE TELEGRAPHERS

The organizers of the AIEE appealed to a broad audience when they issued their call for the new society in the spring of 1884: "Persons who are interested in our electrical scientific educational, manufacturing, telegraphic, telephonic, and like concerns as well as the users of electrical appliances generally, will find it to their advantage, personally and collectively, to establish, work for, and generally aid our proposed society."

It is proposed, the call went on to say, "to make electrical engineers, electricians, instructors in schools and colleges, inventors and manufacturers of electrical apparatus, officers of telegraph, telephone, electric light, burglar alarm, district messenger, electric time, and of all companies based upon electrical inventions as well as all who are inclined to support the organization for the common interest, eligible to membership."

For the most part, in the 1880s, this meant telegraphers and those associated with them. The telegraph was the primary manifestation of electrical technology in the 19th century, and even those whose activities had spread further afield, such as Thomas Edison, had usually gotten their start at the telegraph key.

The telegraphers were prominent in the list of founding members of the AIEE, and the new organization paid further homage to the industry when it elected Norvin Green, head of the Western Union Telegraph Company, its first president.

## THE MAKERS OF A NEW AGE-LIGHT & POWER

Like today, the electrical engineering of the late 19th century was an exciting and rapidly changing technology. Telegraphy had already shown how important electrical technology could be to society and had attracted many an ambitious young man to the ranks of operators and electricians. It was the newer technologies of light and power, however, that suggested the extent of possibilities for the future. These new technologies required new knowledge and new skills, and from these needs emerged the modern electrical engineer.

The telegraphers who were so prominent in the establishment of the electrical engineering profession were largely practical men, whose training had been at the telegraph key, the workbench, and the lines and cables that criss-crossed the country and the seas. Their schooling, where it existed, was often in a field far removed from their profession. This was not to be adequate for the advancement of the newer applications of electricity. The construction of dynamos, the design of central power stations and distribution systems, the making of light bulbs, motors, and a host of auxiliary devices all required a deeper understanding of engineering fundamentals and of electricity itself. The new leaders of the electrical engineering profession would be men whose practical experience was augmented by theoretical training and a concern for establishing the basic principles of their field.

## INDUSTRY OVERVIEWS: TEN KEY SECTORS

Graduates of programs in electrical and computer engineering and computer science are employed in all industry sectors. In corporations, they design and develop products for such diverse fields as telecommunications, radar and navigation, automation, consumer entertainment, power generation and distribution, data processing, aerospace, semiconductors, bioengineering, manufacturing, and transportation. In government, they participate in regulatory functions, manage contractors, plan projects, and supervise operations (for example, ports, airports, rapid transit, and emergency communications). In universities, they help develop new generations of engineers and perform the research that ensures continued advances in technology. Top EE and CE/CS graduates are also getting prime offers in areas such as financial services, wholesale/retail trade, medical systems, and hospitals.

### Jobs, Sector by Sector

Job opportunities in 10 key sectors are surveyed in Overview, Spectrum: telecommunications, energy and electric power, computers, semiconductors, aerospace, bioengineering, manufacturing, services and other professions, education, and transportation/automotive. The focus is on industry sectors whose products and services directly relate to electrical engineering, computer science, and information technology. However, many potential jobs are in other sectors, such as medicine, law, finance, and sales. These jobs represent a significant career option.

Within the key sectors, there are many kinds of employers- large corporations, medium-sized and small companies, start-ups, consulting firms, independent consultants, research organizations, universities, and governmental agencies.

Each industry sector is described in general terms, with a discussion of the current job outlook for jobs that relate directly to engineering and information technology. You will find here links to professional associations and other organizations that keep up-to-date information about their fields and industries. You will also find suggestions for further reading so that you can find the most recent sources of information through libraries and the Internet.

## ENGINEERING ON DISPLAY: CHICAGO AND NIAGARA FALLS

As the complexity and scale of the new electrical technology continued their accelerating growth at the close of the 19th century, so did electricity's visibility and impact. Nowhere was this more evident than at the two great, though very different, showplaces of American engineering in the1890s--Chicago and Niagara.

The World's Columbian Exposition at Chicago and the power station constructed at Niagara Falls, New York, were the great stages for displaying how far the electrical engineering profession had come in one short decade. On these stages were acted out not only the triumphs of electrical technology but also the controversies and struggles that accompanied explosive growth.

So grand was the World's Fair that opened in Chicago to celebrate the 400thanniversary of Columbus's discovery of America that no one minded that it was a year late. It was the first fair where electricity was given its own building, but the impact of the new technology was in fact spread throughout the "White City" that rose on the shores of Lake Michigan. The lighting, in particular, made an enormous impression on the millions of visitors who poured in from across America and around the world. The 8,000 arc lights and 130,000 incandescent lamps that the Westinghouse Company installed throughout the grounds represented a technical triumph for a manufacturer whom many still considered an upstart in the electric light and power industry. More important than the size of the effort, however, was that it demonstrated the practicality of alternating current systems, which thereafter rapidly eclipsed the direct current technology of Edison and others.

Just as in Philadelphia in 1884, the Chicago exhibition was seen as a good setting for an electrical conference. The resulting Chicago International Electrical Congress was testimony to the growing prestige of American electrical engineering, for this was a truly international meeting that made great strides in establishing the world's standards for fundamental electrical units. Particularly gratifying to the Americans was the adoption of the "henry" as the international unit of inductance-a proposal that had been advanced by the AIEE to honor one of the founders of electrical science in America.

Niagara Falls represented a showplace of a very different sort. Here electrical engineers were confronted with one of the great technical challenges of the age-how to harness the enormous power latent in Niagara's thundering waters and make it available for useful work. Years of study and heated debate preceded the start-up of the first Niagara Falls Power Station in the summer of 1895, as engineers and financiers argued about whether electricity could be relied on to transmit large amounts of power the 20miles to Buffalo and, if so, whether it should be direct or alternating current. The success of the giant polyphase alternating current generators made clear the directions that electric power technology would take in the new century, and the attraction of novel industries that consumed great amounts of electricity, such as aluminum and other electrochemical manufacturers, showed the vast potential for growth and change that electricity held for the future.

## Telecommunications

Multimedia services are opening up communications possibilities that were not dreamed of a few years ago, such as online video conferencing, international broadcasting of conferences and tutorials, real-time transfer of huge data files, and transmission of integrated voice/data/video files. The challenges surfacing in the design of the new capabilities require that engineers, software designers, and people with art background work together. Over the next decade, wireless networks will probably become as large and reliable as existing fiber-optic lines. Systems engineers will face new design challenges in processes, system partitioning, testing, and packaging. Companies will compete to be the first to market with products such as full-feature handsets and components that combine technologies into compact chip sets. Specialized terminal equipment will become available for new and innovative applications, and backbone network equipment will be enhanced or replaced with exciting new technologies. This competition will create major battles (and many jobs) as standards for multiple-access technologies are resolved.

Major applications in the telecommunications industry include communications protocols, data networking, digital compression algorithms, digital signal processing, Internet access, materials research, object-oriented and relational databases, programming languages, project management, prototyping, simulation and modeling, software engineering, systems design, and integrated circuit design. Many disciplines converge and overlap in the communications industry.

### The Players

Employers in the field of telecommunications include manufacturers of radio, television, and other audio/visual, broadcasting, and receiving equipment. Others develop hardware and associated software, including interfaces, security devices, data concentration equipment, electronic mail equipment, data transmission equipment, signaling equipment, and networking equipment; satellite and microwave communications equipment; and telephone apparatus. Still others are service organizations that provide broadcasting, consulting, data communications, custom manufacturing, research and development, and telephone-related support.

Some of the major North American communications service providers are AOL, AT&T, Bell Canada, Comcast, GTE, MCI-Worldcom, NTT, Sprint, and TCI, as well as regional and local companies. Their services include local and long-distance services, voice and data mobile services, data transmission, videoconferencing, and Internet services. Some of the major international communications carriers are BT (formerly British Telecom), Deutsche Telekom, France Telecom, KDD, and Telefonica. Other major employers involved in research and product development include Bellcore, Cisco, Ericsson, Lucent Technologies (including Bell Laboratories), Newbridge, Nokia, and Nortel.

## Energy and Electric Power

### Adapting to Deregulation

When it comes to working in the electric power industry, whose end product is electrical energy itself, it is time to rethink. With the deregulation of the power industry, there are going to be fewer jobs with large utilities and more jobs in other power technology areas. Engineers will continue to be needed in power electronics, such as power quality and end-use applications. Engineers with strong backgrounds in computing and communications will find opportunities in areas such as distribution automation, monitoring and diagnostics, and intelligent protection and control. Looking forward, there are emerging technologies such as renewable energy (hydro, wind, solar), the environmental impact of power generation and distribution, superconductive equipment, and electric vehicle research and development. There will be more jobs in the newer, smaller utilities that will surely be created in response to deregulation.

If you think that you might be interested in working for a large, established power utility, the big U.S. firms include Pacific Gas and Electric, Southern Co., Southern California Edison, Unicom Corp., Energy Group, Public Service Enterprise Group, American Electric Power, Texas Utilities, and Florida Power and Light. ABB (Asea Brown Boveri) is the world's largest engineering service conglomerate, heavily involved in energy, with more than 2000 profit centers.

### A Strategic Industry

There have always been other employers of electrical engineers in the power industry: the U.S. Department of Energy, the military, the national labs, companies that manufacture power equipment, private consulting firms (architect-engineers and reliability engineers), and other industries that generate their own power (for example, the petrochemical industry).

Students with advanced degrees such as an MS or PhD are well positioned to find employment with companies that focus on the development of new products and technologies. Companies in this category include General Electric Corporate Research and Development, Sundstrand Aerospace, Reliance Electric, Rockwell Automation/Allen-Bradley, and General Motors. As companies continue to develop new products and technologies, the demand for students with advanced training will increase.

Salaries are relatively high in the power field, even though power engineering doesn't have the same allure as, say, computer engineering, at least in terms of initial salaries. Power is a strategic industry and it will always have a need for engineers. So, while industry recruiting is down in the United States, the large size of the industry has nevertheless produced a continued demand for well-trained power engineering specialists. Graduates with a traditional technical depth of knowledge of power are still being sought by some segments of the industry; however, those with broader skills, such as expertise in computers or another specialty, are being hired by the utilities in response to the recent deregulation and its new marketplace demands. Computers

The industry looks for engineers who can design, develop, and test new products, as well as manage the information flow generated by these activities. Companies want professionals with experience in a variety of computer operating systems and languages, and a working knowledge of various database packages. These engineers develop software for transactions (billing, accounting, database storage and retrieval, and so forth), embedded control and logic (control algorithms, failure detection, displays of text and diagrams), software tools (compilers and editors), arithmetic and logic subroutines, simulation (mechanical, fluid, electrical, and medical processes, training), and CAD/CAM for design and manufacture at all levels. Many specialize in testing and determining the reliability of software.

Also needed are engineers who design, build, test, and evaluate new computer chips, circuit boards, computer systems, and peripheral devices. The range of peripherals includes mass storage peripherals (magnetic disks and tapes, optical disks, semiconductor memories, RAM, ROM, disk arrays, floppy disks, DAT), output peripherals (printers and plotters, displays, speech and sound hardware, modems), and input peripherals (readers and scanners, speech input systems, keyboards, mouse devices, modems). Other specializations include reliability engineering, systems architecture, component engineering, power system engineering, and packaging engineering.

Issues to be addressed by computer engineers are system peak capacity, perceived response time, "up" time or availability, serviceability, and expandability. Many of these attributes involve tradeoffs among cost, complexity, and quality of service.

**Ubiquitous Opportunities**

If you are interested in computer engineering, many fields beckon you: electronics (components and systems), consumer electronics (audio, video, home automation, and home computers), telecommunications (communications equipment and services), entertainment (movies, TV, games), and the printing and publishing industries.

The computer industry is not only vast but also permeates many other industries.  You can look to any other industry that uses computers for a career in professional services: consulting, training, custom programming, systems integration, and outsourcing. Many companies want to move from a mainframe to a client/server system or need contingency plans for disaster recovery. The computer engineer can provide these services.

Among the key areas of specialization are operating systems, graphical user interfaces, languages, utilities, computer-aided software engineering, and security. Business applications include accounting, inventory and sales management, manufacturing resource planning, and design and simulation.  Office automation serves word processing, database management, spreadsheets, graphics, communication, project management, and decision making. Educational applications develop computer literacy and provide computer-aided instruction and computer-based training. And then there are recreational products, such as those for games, music, and hobbies.

What's in a Title?
As for as job titles, you should be aware that there is no industry standard: computer scientists, computer engineers, computer analysts, information scientists, and software engineers may all have the same responsibilities at different companies. Or conversely, the same title at different companies may carry completely distinct responsibilities. Despite the terminology, the goal remains the same: the engineer must understand what the user wants from a computer system program and develop software and hardware that meet the user's needs.      Semiconductors

Job opportunities abound in fundamental research and development, packaging, product design, manufacturing, testing, product management and marketing, and customer support. Research engineers, for example, are directing their attention to materials other than silicon; they are even studying ways of growing chips from biological materials. (However, most engineering opportunities involve bringing products to the marketplace, as opposed to generating a ider and deeper knowledge base.) Packaging engineers are combining high-performance ICs in multichip modules (MCMs) that extract the ultimate in speed and functionality from the components.

The major companies looking for engineers in this field include AT&T, Fujitsu, Hitachi, Intel, IBM, Jet Propulsion Labs, Lucent (Bell Laboratories), Microsoft, Mitsubishi, Motorola, National Semiconductors, NEC, NTT, Packard Bell, Sandia, Sharp, Sun Microsystems, VLSI Technology, Advanced Micro Devices (AMD), and Texas Instruments. Although they are relatively small, consortiums such as Sematech and Semiconductor Research Corp. conduct important research and development on semiconductors and semiconductor manufacturing and may offer attractive career opportunities.

More Multidisciplinary Than Most
Engineers in this industry, particularly packaging engineers, need a more multidisciplinary background than most, and well-prepared graduates are therefore hard to find and in great demand.  EEs in packaging are often primarily concerned with the electrical effects of shrinking device sizes and faster operation (that is, with pulse reflections, cross talk, stray inductance, switching noise, and electromagnetic compatibility, for example) and with reduced noise margins imposed by lower power supply voltages.      Aerospace

Recently, some companies have bought out or merged with their competition as the industry shakes itself out. As the focus of aerospace engineering shifts from military to commercial, new technologies are growing: global positioning systems, launch systems for commercial satellites, low-earth-orbit satellite systems. And commercial airlines are ordering hundreds of new airplanes and thousands of avionics systems as they prosper and retire their aging fleets.

Critical Skills
Students interested in the aerospace industry should develop skills related to the design, development, analysis, integration, test, and operation of complex systems involving radar, sonar, optics and navigation, robotics, energy, and transportation.

The employment outlook for engineers and computer engineers in aerospace is currently good. There are many companies or government agencies that hire graduates in this specialty, including the Department of Defense, the Federal Aviation Administration, the Department of Transportation, NASA, Boeing, Lockheed Martin, Rockwell International, Raytheon, Northrop Grumman, Allied Signal, TRW, and United Technologies, to name only a few.

## Bioengineering

Continued Expansion
With the success of these advances in improving the quality of life for patients, there is no doubt that the bioengineering industry will continue to expand in the near future, and that research and development of new devices and techniques will continue to be funded. However, it remains to be seen what effect health care maintenance organizations and their emphasis on controlling health care expenses will have on R&D in the long term. Certainly, engineers who can use technology to help contain rising health care costs are going to be very valuable people indeed for many years to come.

Right now the outlook for biomedical engineers is good. There are jobs available in companies manufacturing devices, in hospitals, in research facilities of educational and medical institutions, in teaching, and in government regulatory agencies. Some biomedical engineers may work as technical advisors for marketing departments or serve in management positions.

Biomedical engineers may also have advanced training in another specialty, such as an MD degree, thereby combining an understanding of advanced technology with direct patient care or clinical research. Some of the well-established specialty areas within this field are bioinstrumentation, biomechanics, biomaterials, systems physiology, clinical engineering, and rehabilitation engineering.

Major employers in this field include Johnson and Johnson, Siemens, Intermedic, Accuson, and Krug Life Sciences. Among the many small start-up companies are Gentronics and Spectrx. Consulting companies like Anderson Consulting value the depth and breadth that biomedical engineers bring to the job and hire many.

## Manufacturing

Expertise Needed
While there are many companies whose primary product is the manufacture of equipment used in the fields of aerospace, advanced materials, biotechnology hardware, electrical apparatus, and electronic and photonic devices, there are also companies that provide

peripheral services such as consulting, engineering, fabrication, materials processing, and testing. In the field of manufacturing, jobs will also be found in any company that produces more mundane products; that is, any factory that needs to adapt its production to be more competitive also needs the expertise of engineers with systems, concepts, management, and quality control experience.

Job opportunities in this field will continue to expand rapidly in the future because companies see the need for advanced manufacturing to remain competitive in a global economy.

Employers seeking manufacturing-oriented electrical engineers abound; a sampling might include such firms as Audiovox, AMP, CP Clare, Harris, International Rectifier, Motorola, Schlumberger, Teradyne, U.S. Robotics, and Zenith. The Consumer Electronics Manufacturers Association (CEMA) has many potential employers in its membership. For those interested in manufacturing research, the National Center for Manufacturing Sciences (NCMS), sponsored by the National Science Foundation, may offer career possibilities. Services and Other Professions

Golden Futures
With niche companies, the trick is to latch onto one with a golden future. In stable traditional industries like banking, on the other hand, the outlook is uniformly promising. As banks become even more competitive, and as more and more banks go online, they will have to develop more high-tech services. For its part, the entertainment industry has been pursuing a high-tech direction for more than a decade, and there is no indication that it will change direction; more movies than ever use special effects that require the expertise of electronics engineers.

Another option is consulting. Some engineers, after working in manufacturing, energy, or any of the hard engineering industries, eventually feel they have the expertise and entrepreneurial drive to become consultants to those industries, and have found rewarding careers in that role. Many work as independent consultants, while others work for large organizations such as Anderson Consulting or for smaller organizations serving a particular industry.

Finding an engineering job in services and other professions will probably require more research and hard work because the jobs may not be so easy to see. They will not necessarily be in the want ads under "Engineering." Persistence and interest will be major factors in unearthing these jobs.

**Education and Research**

Government/Industrial Research
Education is strongly linked to research; universities are major players in research. However, research work can be found at research labs, funded by the U.S. government and by private corporations to conduct research and development for public and private sector needs, such as biomedical, environment, defense, energy, and transportation. These include organizations such as Sandia National Laboratories, Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Oak Ridge National Laboratory, Southwest Laboratories, and Jet Propulsion Laboratories. Military organizations (Army, Navy, and Air Force) also employ research engineers. Industry and government funding accounts for 95 percent of funding for R&D.

Industrial laboratories perform much of the applied research carried out in the United States. Examples are Lucent's Bell Laboratories, Xerox's Research PARC, and IBM's Watson Laboratories. The industry sector is both the largest source of R&D funds (59%) and the leading R&D-performing sector in the United States (70%).

**Transportation and Automotive**

Electronic Cars

In the auto industry, "mechatronics" has married mechanical and electrical/electronic devices in systems such as antilock brakes, controlled suspensions, load-sensing suspensions, brake-by wire controls, air bags, security protectors, collision avoidance controls, and intelligent highways. The burgeoning field of communications, particularly wireless and satellite, has also given rise to automated toll collection, video and audio traffic sensors, and navigation systems, such as the Global Positioning System (GPS), by which drivers map their location and route with the aid of satellites.

Potential employers include the large auto manufacturers, such as General Motors, Ford, and Chrysler in the United States, as well as Honda, Mitsubishi, Mercedes Benz, and Fiat in other countries. Other employers include governmental highway authorities and the many suppliers that develop products and services related to transportation, such as Andrew Corporation, Delco Electronics, and Lockheed Martin IMS. Some of the major North American communications service providers are AOL, AT&T, Bell Canada, Comcast, GTE, MCI-Worldcom, NTT, Sprint, and TCI, as well as regional and local companies. Their services include local and long-distance services, voice and data mobile services, data transmission, videoconferencing, and Internet services. Some of the major international communications carriers are BT (formerly British Telecom), Deutsche Telekom, France Telecom, KDD, and Telefonica. Other major employers involved in research and product development include Bellcore, Cisco, Ericsson, Lucent Technologies (including Bell Laboratories), Newbridge, Nokia, and Nortel. If you think that you might be interested in working for a large, established power utility, the big U.S. firms include Pacific Gas and Electric, Southern Co., Southern California Edison, Unicom Corp., Entergy Group, Public Service Enterprise Group, American Electric Power, Texas Utilities, and Florida Power and Light. ABB (Asea Brown Boveri) is the world's largest engineering service conglomerate, heavily involved in energy, with more than 2000 profit centers. You'll find job opportunities at a seemingly endless variety of firms, from start-ups to established companies. Among the industry leaders at this writing are Apple, Compaq, Dell, Digital Equipment, Hewlett-Packard, IBM, Intel, Lotus, Microsoft, Motorola, Novell, Oracle, Sun Microsystems, and Western Digital. This list changes quickly. Consulting companies also offer boundless opportunities; an example is Andersen Consulting, currently the largest recruiter of engineers in the United States. The nonprofit Software Productivity Consortium may offer opportunities to those interested in software process improvement, software reuse, and rapid systems development techniques. The major companies looking for engineers in this field include AT&T, Fujitsu, Hitachi, Intel, IBM, Jet Propulsion Labs, Lucent (Bell Laboratories), Microsoft, Mitsubishi, Motorola, National Semiconductors, NEC, NTT, Packard Bell, Sandia, Sharp, Sun Microsystems, VLSI Technology, Advanced Micro Devices (AMD), and Texas Instruments. Although they are relatively small, consortiums such as Sematech and Semiconductor Research Corp. conduct important research and development on semiconductors and semiconductor manufacturing and may offer attractive career opportunities. The employment outlook for engineers and computer engineers in aerospace is currently good. There are many companies or government agencies that hire graduates in this specialty, including the Department of Defense, the

Federal Aviation Administration, the Department of Transportation, NASA, Boeing, Lockheed Martin, Rockwell International, Raytheon, Northrop Grumman, Allied Signal, TRW, and United Technologies, to name only a few. Major employers in this field include Johnson and Johnson, Siemens, Intermedic, Accuson, and Krug Life Sciences. Among the many small start-up companies are Gentronics and Spectrx. Consulting companies like Anderson Consulting value the depth and breadth that biomedical engineers bring to the job and hire many. Employers seeking manufacturing-oriented electrical engineers abound; a sampling might include such firms as Audiovox, AMP, CP Clare, Harris, International Rectifier, Motorola, Schlumberger, Teradyne, U.S. Robotics, and Zenith. The Consumer Electronics Manufacturers Association (CEMA) has many potential employers in its membership. For those interested in manufacturing research, the National Center for Manufacturing Sciences (NCMS), sponsored by the National Science Foundation, may offer career possibilities.

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## NEW CONCERNS FOR A NEW PROFESSION

The men who set out to establish electrical engineering as a respected profession were aware that their field posed special opportunities and problems. The new technologies of which they were masters presented technical challenges that needed to be addressed by the profession lest progress be stymied by narrow commercial interests. Many engineers also recognized that public concern about the use and safety of electrical technology reflected on their profession and themselves. Finally, there were those who felt that the social responsibilities of a true profession went beyond purely technical issues to include ethical and political concerns as well. There could be seen in these first decades, therefore, the same variety of issues and viewpoints that would characterize the electrical engineering community for the next century.

By the time the American electrical engineers took up the problem, the resolution of technical standards and terminology was a widely recognized responsibility of an organized engineering profession. The AIEE's first serious effort in this regard was the appointment of a committee on "units and standards" in June 1891. Soon afterwards, another committee was formed to make recommendations for a "standard wiring table" to guide engineers in specifying wiring requirements. The overwhelming importance of standardization quickly became apparent in the growing electrical industry, where the intensity of competition led to confusion and conflict in technical specifications, test standards, and even terminology. The engineers recognized an opportunity to rise above commercial considerations by establishing themselves as the authorities for standardization. The AIEE appointed its permanent Committee on Standardization in March 1898, and from that time, in conjunction with other engineering societies and international groups, the engineers have set the standards for electrical technology and practice.

The extent to which the responsibilities of engineers, either as individuals or as organized professionals, extend beyond purely technical concerns was a matter for debate from the earliest years of the AIEE. The conflicts that arise due to the engineer's position as both a professional and, frequently, an employee have always been a source of concern, perhaps best illustrated by the experience of Charles Steinmetz.

Not only was Steinmetz a brilliant engineer, the creator of many of the most important analytical methods for designing and describing electric power devices and systems, but he was also a man deeply concerned about the proper role of the professional engineer in society. As an employee of a very large company (General Electric), Steinmetz was well aware of the problems that the corporate engineer experienced in defining his loyalties and responsibilities. In 1907, conflict over these problems prevented the AIEE from adopting a Code of Ethics for its members. When, five years later, the Institute resolved to try again to develop an acceptable Code, Steinmetz's was an influential voice, speaking out for the engineer's obligation to commit himself to the best possible technical practice while at the same time recognizing that his ultimate loyalty was to his client or employer. Above all, Steinmetz spoke out for his belief that engineers "must be more than mere engineering machines," a belief that still motivates many of the creators of modern electrical technology.

## THE ETHER IN HARNESS

The dawn of the present century saw the birth of several technologies that were to be revolutionary in their impact. The most exciting of these was radio, or, as it was generally called at the time, "wireless." No other technology would seem to so thoroughly obliterate the barriers of distance in human communication or to bring individuals together with such immediacy and spontaneity. And seldom had there emerged an activity that seemed so mysterious and almost magical to most of the population--setting apart its practitioners as a special and privileged breed. Radio was mysterious not only to the layman, but also to many engineers and technically informed individuals. The mystery lay largely in radio's application of principles and phenomena only recently identified by physicists and engineers working at the frontiers of their specialties.

The existence of electromagnetic waves that traveled like light had been predicted by the brilliant physicist James Clerk Maxwell in the 1860s and proven by the German Heinrich Hertz in the 1880s. The possible use of these waves for communicating through space without wires occurred to many. The first practical steps to making radio useful are generally attributed to Oliver Lodge in England, Guglielmo Marconi in Italy, and Aleksandr Popov in Russia. Marconi's broadcast of Morse code across the Atlantic in 1901 first showed to the world just what enormous potential radio had for changing the whole concept of long-distance communication. The next few years saw feverish activity everywhere as men tried to translate the achievements of the pioneers into the foundations of a practical technology.

By 1912, radio technology had attracted a small number of dedicated individuals who identified their own future with the progress of their chosen field. Some of these had organized themselves into small, localized societies, but it was clear to many that a broader vision was needed if radio practitioners were to achieve the recognition and respect of technical professionals. It was with such a vision in mind that representatives of two of these local societies met in New York City in May 1912, to form the Institute of Radio Engineers. The IRE was to be an international society dedicated to the highest professional standards and to the advancement of the theory and practice of radio technology. The importance of radio, however, lay not simply in its expansion of the means for human communication over distances, but also in its exploitation and expansion of very novel scientific and technical capabilities, for, as the century progressed, radio would give rise to the 20th century's most revolutionary technology of all--electronics.

## A TECHNOLOGY FOR THE YOUNG

Radio was regarded as a marvelous technology by most people who came in contact with it. In its early years, however, it had a special fascination for the younger generation, those just beginning to make the choices that would determine their careers and the vehicles for their ambition, in the same way that computers do today. The extent to which radio was indeed a technology for the young was reflected in the radio clubs that sprang up in cities and towns everywhere, in the popular literature that was published to appeal to young radio buffs, and in the men who gave the impetus to the formation and growth of the Institute of Radio Engineers.

In 1912, the year of the IRE's founding, John V. L. Hogan was only 22 and had already been working with radio inventor Reginald Fessenden for over two years; Alfred Goldsmith was 24 and already had the experience to serve as a radio consultant for the U.S. Department of Justice; Robert Marriott, the IRE's first president, had reached the ripe age of 33 and had more than ten years of radio experience under his belt; and David Sarnoff, just 21, had been working for the American Marconi Company since he had been 15. All of this youth was very much within radio's brief tradition -- after all, Marconi himself had been only 21 when he announced to the world in 1895 that he could transmit wireless messages over miles of open country. Not all of the leaders of the radio profession in its early years were quite so youthful; John Stone, one of the key architects of the IRE, was 43 in 1912, and the presidency of the organization was usually given to an older individual in recognition of his age and experience. Nonetheless, the dynamism of the new profession clearly owed much to the youthful ambition of its most active members.

## THE TEST OF WAR AND PEACE

To most people in the early years of the 20th century, radio was a wonderful new invention, but its usefulness and importance for the world of affairs was unclear. At just the time that the radio engineers were organizing themselves, however, there occurred two events that starkly demonstrated just how indispensable the world was to find the new technology. In so doing, they also provided a glimpse at the pivotal role that the new breed of engineers was to play in the turbulent century ahead.

One month before the radio engineers in New York met together to form the IRE, one of history's greatest maritime disasters focused attention on the new capabilities that radio had given the world, both for reporting events as they happened and for affecting them. On the night of April 14, 1912, the White Star liner Titanic, with more than 2,200 aboard, collided with an iceberg in the North Atlantic and rapidly began to sink. The ship's wireless operator sent out a distress call, which was not received by some nearby ships because their receiving sets were not in operation at the time, but which other ships picked up and relayed to stations on the American mainland. The saving of more than 700 lives was attributed to the work of wireless operators that night. The entire world was caught up in the event by the activity of the mainland operators who passed on the news of both tragedy and survival. Only a few months later, governments everywhere began mandating radio operation aboard ships at sea--radio and its engineers thus became indispensable to world commerce.

If the pursuits of peace were not enough to demonstrate radio's key place in the modern world, then the waging of war would bring the message home with a dreadful finality. When the guns of August began sounding in 1914, the European powers had already begun supplying their armies and navies with the most advanced communications equipment, for the importance of wireless signaling that could be set up instantly anywhere in the field or on the seas was obvious to every strategist. Learning how to use the new tool to best advantage took some time, but the key role to be played by the new devices and the men who made them was recognized early. And when the new radio technology was wedded to the equally new technology of aviation, the whole face of warfare began to change.

The impact of the First World War on radio engineers and engineering was enormous. The needs of war pushed the technology ahead at a pace barely thinkable for peacetime. Radio facilities were placed under direct government control and brilliant young men like Edwin Howard Armstrong were pressed into military service. To develop a radio technology that could be readily used by soldiers and seamen required the rapid advancement of radiotelephony, which began replacing coded wireless everywhere. Such needs generated many technical achievements, of which Armstrong's superheterodyne circuit was perhaps the most brilliant. Just as important, however, was the war's role in exposing much of the population that had been recruited into wartime service to the wonders of radio, thus building the foundations for the boom that was to come. The interaction between military needs and engineering advancement was to be a pattern repeated through the century, with consequences that both the engineers and the public would have to learn to live with.

## THE SYSTEM BUILDERS

When the 20th century began, electricity was still to most people a very distant and unfamiliar thing, and its applications touched relatively few directly. While electric lighting and electric trolleys were familiar to dwellers in large urban centers, America, like most of the rest of the world, was largely a country of small towns, villages, and farms, and electric light and power was seldom encountered in such settings. The great work of electrical engineers in the first decades of the century was the bringing of their miracles to the mass of people-to those outside the big cities, to those of average economic and social station. In so doing, the electrical engineers became primary architects of 20th-century life.

In the first decades after 1900, the electric power industry continued its rapid growth. In 1902 the amount of electric power available per person in the United States was about 75 kW; twenty years later this figure was 565 kW per person. The pace of expansion slowed in the 1920s, for the technical challenges of carrying electric power beyond metropolitan areas were complex and expensive. It was no longer possible to sustain growth by simply building on to existing systems-electrical engineers began to think in terms of much larger, extended systems, a concept sometimes referred to as "Super Power." Such systems, which were proposed to bring electricity to large areas, even entire states, raised important social, economic, and political issues as well as technical ones, and the electrical engineers were caught up in the debates over how best to extend access to the new technology to everyone. It became widely recognized, in societies as divergent as the United States and the Soviet Union, that "electrification" was to be the key to national development in the 20th century and that electrical engineering was the profession holding that key.

In the 1920s, only a few saw any need to change the way in which electric power was being extended to the people. The Great Depression of the 1930s changed attitudes, however, as politicians and the public sought ways to alleviate the suffering caused in some areas by the economic calamity. The most important single project to result from this was the creation in 1933 of the Tennessee Valley Authority. The TVA was created to administer a multipurpose river project, with responsibility for flood control, fertilizer production, waterway construction, and hydroelectric power generation. It was in the generation and distribution of power that TVA was to make an international reputation for itself, and the electrical engineers who designed and operated TVA's power system became the pioneers of large power systems of the future.

## EDUCATION FOR A NEW CENTURY

The first electrical engineers had very mixed backgrounds. Some had purely practical training, some had formal education in fields far removed from engineering, and a number were schooled in allied fields such as mechanical engineering or physics. The leaders of the profession, however, were quick to recognize that a new field would require a new kind of education. The first college-level electrical engineering programs were thus established at the same time that the engineers began organizing themselves in the 1880s,and their rapid growth in following decades became one of the sources of strength and unity for the profession.

When the Massachusetts Institute of Technology in Boston established America's first electrical engineering program in 1882, it was attached to the physics department. The curriculum reflected the close ties to physics, and included generous amounts of mechanical engineering and the liberal arts. There was actually little formal study of "electrical engineering" as such, for the subject hardly existed yet. Textbooks, laboratory procedures, trained teachers, and all the other apparatus of an academic subject had to be created. To some, this was one of the most important tasks of the electrical engineers in the 20th century-one that was carried out with enormous success.

From the beginning, electrical engineering attracted many of the brightest and most ambitious engineering students--by 1892, for example, the field claimed 27 percent of MIT's graduates. For the first several decades, the electrical curriculum was built almost exclusively around power engineering, for the ever-expanding power industry was the chief source of demand for engineers. Furthermore, the principles and theory needed for effectively teaching the subject developed rapidly, thanks to the work of power engineers like Charles Steinmetz and Elihu Thomson, who distinguished themselves as educators as well as inventors and researchers. The greatest influence in electrical engineering education was, however, wielded by men who devoted their entire careers to working with students and fellow teachers, men like Dugald Jackson or Harris J. Ryan.

After World War I, the importance of radio and of further possible applications of vacuum tubes could not be ignored by even the most power-oriented electrical engineering department. The "communications option" became a more and more common feature in programs everywhere. Other efforts to make engineering education more responsive to the changing technology and needs of industry included the establishment of "cooperative" programs, the most famous of which was that begun at MIT in the 1920s. These saw faculty and students working shoulder to shoulder with company engineers, dealing directly with the practical problems of industry. Although individual professors might make important contributions to electrical technology-the invention of the loading coil by Columbia's Michael Pupin was a key to the expansion of telephone technology-most engineering educators in the early 20th century thought little about research or publication. They sought to make their contribution through teaching and left the creation of new technologies to industry's laboratories. This would change dramatically by mid-century.

## THE ENGINEER AND SOCIETY

The turbulent first decades of the 20th century, marked by global war, unprecedented prosperity, and then calamitous depression, saw engineers assuming new roles in society. The enormous impact that the work of the engineer had on the lives and affairs of individuals and nations alike was obvious to all. There were some, in fact, who believed that the engineer's responsibilities extended to the management of a more efficient and rational society, that "technocrats" rather than politicians should be looked to as the natural leaders of a complex modern world. Although such views in their extreme form were held by a relative few, they stimulated a wide-ranging debate over the true duties and obligations of the engineer.

In the years after World War I, the relationship between electrical engineers and government rapidly came to be an important issue for many in the profession. The tremendous importance of radio that the war had made clear to all also made clear the need for strong, technically sophisticated government regulation. When the United States entered the war in 1917, the federal government quickly acted to take over all wireless stations in the country. The radio spectrum was obviously too valuable a resource to be left uncontrolled in times of national emergency or unregulated in times of peace. The growth of broadcasting in the 1920s made the need for concerted government action increasingly urgent, and Secretary of Commerce Herbert Hoover called four National Radio Conferences during the decade to bring engineers and politicians together to address both technical and policy issues. Finally, the Federal Radio Commission was established in 1928, and a long tradition of close cooperation between radio engineers and government regulators began.

Radio was not the only area in which engineers found themselves dealing directly with questions concerning the public interest and the engineer's responsibilities toward it. In almost all areas of electrical technology, the rapid expansion and increasing importance of the engineer's work made his activities a matter for public, and hence government, concern. From the beginning of the electric power and telecommunications industries, local government exerted authority over utility construction and competition. In some places, political involvement was limited to rate setting and franchise control, but in other jurisdictions, electrical technology was thought to be so essential that governments took on the complete responsibility for providing power and communications, thus becoming major employers of electrical engineers. The TVA was only the most famous example of government initiative in this area, for local governments in many areas of the country also provided service, and government control of power and telecommunications was usually the norm in countries other than the United States.

During the early 20th century, electricity continued to expand into more and more corners of society. This included continued development of electric-powered calculation and control devices in industry, and also the introduction of machines for consumer use and business use, and sometimes for both, as in the electric typewriter.

The increasing complexity of 20th-century technology and the increasing reliance that everyone was forced to place on it put special burdens on electrical engineers. Not only were they to pursue the ever more rapid advancement of their field and the fulfillment of the needs of employers and clients, but they had to be increasingly conscious of the irresponsibilities to society and, in the dangerous world of the later 20th century, to humanity itself.

## THE NEW WORLD

No single event had a greater effect on electrical engineering than the Second World War. The years from 1939 to 1945 saw a radical change in the way that the world perceived electrical engineers and in how they perceived themselves. Their field was transformed from a specialty with well-defined applications, primarily in power and communications, into the source for the most powerful and pervasive technologies of the 20th century. As the century matured, as global war gave way to cold war, and as allies became enemies and former foes became friends, the expansion of the electrical and electronics technologies became one of the hallmarks of the age-shaped by as well as shaping history.

In the heat of war, radio engineering was transformed into electronics, and the radio engineers were similarly transformed. Theirs became a technology to harness the most advanced and subtle knowledge of the very parts of matter itself, manipulating electrons and electromagnetic waves almost at will in an effort not simply to communicate, but to detect, control, and even, as some saw it, think. The tremendous pressures of wartime development forged a new relationship between engineers and physical scientists. More and more the realms and tasks of both overlapped, for advances in electronics made use of the latest findings, theories, and even techniques of physicists and chemists, while scientific discovery came to rely progressively more on the instrumentation created by engineers. This merging of science and technology was one of the war's greatest legacies, and has continued to shape our times.

The enormous demands that war put on the world's economies brought home another lesson about electrical technology--the indispensable and strategic place of electric power. World War II marked the final passage of electric power to the status of necessity, not only swelling the general industrial consumption of power, but also highlighting specialized uses of electricity, such as the production of aluminum and explosives, that were critical to the pursuit of war. In Europe, the targeting of power plants and dams by both Allied and Axis bombers provided gruesome proof of electricity's central place in modern warfare. The harnessing of the technology of peace to the needs of war provided prelude to a fine irony, however, for the most dramatic development in electric power production in the coming decades was the effort to transform the energy in the war's most awful weapon, the atomic bomb, into a servant of power generation.

The postwar years were ones of growth and change, accompanied by tensions and conflicts both within the engineering community and in society at large. Again, war was followed by unprecedented prosperity, but this time it was in a world where the dangers and possible consequences of international conflict were distressingly obvious. The efforts of engineers were thus divided between the creation of a consumer society, powered by electricity and tuned in by electronics, and the demands of national and international security, with their heavy drain on both resources and manpower. Along side this division was another, as the anomaly of an engineering community split between the AIEE and the IRE became less and less justifiable. In the coming decades, this problem was resolved, as engineers everywhere recognized their common interests.

## MOBILIZATION

Engineering began as a military pursuit, and at least since Archimedes engineers and scientists have been pressed into service in time of national danger, but never on such a scale as during World War II or with such enormous consequences. From the day that Nazi tanks rolled into Poland in September 1939, it was clear to everyone that this was to be a war of technology, and the nation that could create and put to use the most advanced science and engineering would have the upper hand.

New circumstances required new forms of organization. During World War I, the United States relied on such agencies as the Naval Consulting Board, headed by Thomas Edison, which spent much of its effort simply reviewing ideas for inventions sent in from around the country. Such a mechanism was clearly inadequate for the crisis of total war. Electrical engineers were prominent in creating the new tools required to mobilize the nation's scientific and technical manpower. The most significant of these tools was the Office of Scientific Research and Development, headed by former MIT electrical engineering professor Vannevar Bush. The OSRD was to spearhead much of the war's engineering developments, including the perfecting of sonar for submarine detection, the proximity fuze to increase the effectiveness of ordnance, and shortwave radar, which revolutionized air defense.

Most of the scientific and engineering research carried out during the war was not carried out by the government itself, but in academic and industrial laboratories by people recruited from all technical fields. Numerous special laboratories were set up, and it was in these institutions that many electrical engineers learned how the war was transforming their field. The best engineers of the day were chosen to organize and run the labs, as, for example, Stanford's Frederick Terman, who was called upon to head the Radio Research Laboratory at Harvard, which had the prime responsibility for electronic countermeasures, such as "jamming." Another example was the team assembled at the University of Pennsylvania. Wartime pressure saw an increased use of electronics in calculation, both for purposes of cryptography and for ballistics. These developments, and parallel developments in information theory, led directly to modern programming and the modern electronic digital computer, as pioneered by the Pennsylvania group in the form of the ENIAC. In the long term, the ENIAC was perhaps to have the greatest impact on society of all war-time developments.

During the war, however, the largest and most prominent of the OSRD-sponsored labs was set up for the development of effective and reliable radar systems. Named the Radiation Laboratory to suggest to the outside world that it was concerned with supposedly more innocent problems in physics, the establishment eventually employed some 4,000 people spread throughout 15 acres of floor space on and around the campus of MIT. At its height, the "Rad Lab" employed fully one fifth of the physicists in the United States, plus hundreds of electrical engineers from both academe and industry. More money-an estimated $2.5 billion-was spent on radar research, development, and production than was consumed by the work on the atomic bomb, and the technical fruits, although not as spectacular, were from an engineering point of view every bit as impressive. Working closely with British researchers, the laboratory turned out a whole series of sophisticated microwave devices, laying the foundations for a large family of radar and navigation instruments, which were key parts of the war effort and which became mainstays of postwar electronics technology. Above all, the close relationship forged between physicists and engineers under the stress of war gave a glimpse of the ever more complex research environment of the engineer in the late 20th century.

## NEW HORIZONS

The world that electrical engineers faced at the end of World War II was a very different one from that of the 1930s, but the underlying agencies for change were institutions that had been in the making for many years. The most important of these were the industrial research laboratories that a number of the largest electrical technology firms had set up in the first decades of the century. In such laboratories, engineers were brought together with scientists, technicians, and material resources, all organized in an effort to improve the "state of the art" or to create breakthroughs that would extend technological and commercial opportunities into new areas.

The fruitfulness (and profitability) of such efforts was amply demonstrated very early. The laboratory that General Electric's Willis Whitney set up in Schenectady, NY, in 1900 was a model for many to follow, and its productivity was a persuasive advertisement for industrial "R & D." William Coolidge's process for making ductile tungsten lamp filaments and Irving Langmuir's improved light bulbs and vacuum tubes were sources not only of profit but of justifiable pride for the G.E. engineers and managers. The policy of trying to put technological innovation on a systematic basis was seen as a resounding success, one to be followed on a large or a small scale by many others.

No one, however, made such good use of industrial research as the American Telephone and Telegraph Company. In 1907, AT&T and the Western Electric Company combined their engineering departments and established the Bell Telephone Laboratory on West Street, in New York City. By 1921, the laboratories constituted the largest industrial research organization in the country, occupying 400,000 square feet in a 13 story building in lower Manhattan and employing more than 1500 men and women. The organization was put on a more formal footing in 1925, when Frank B. Jewett was made President of Bell Telephone Laboratories, Inc. In the following decades, the labs distinguished themselves by contributions not only to communications technology, but to basic science as well. The awarding of the Nobel Prize in Physics to Clinton J. Davisson in 1937 was only one of the Nobel Prizes awarded to Bell Labs personnel, and even those prizes were simply the most prominent recognition of the laboratories' scientific work.

The true importance of the fusion of science and engineering in the industrial laboratory was made apparent to all in the years after World War II. In 1947, three Bell Labs physicist-engineers produced the single most significant electronic invention of the era-the transistor. John Bardeen, Walter Brattain, and William Shockley were consciously seeking to exploit new knowledge about the behavior of semiconducting materials when they devised a way to make a crystal of germanium do the work of a triode vacuum tube, a fundamental electronic component. Their work built on the research of many before them, and much had to be done before the transistor and the solid-state devices that followed could become practical engineering tools, but in retrospect, it is clear that the transistor gave the engineer the key to a whole new electronic world.

**THINKING WITH MACHINES**

As mentioned above, of all the new technologies to emerge from the tumult of World War II, none was to have such profound and pervasive impacts as the electronic digital computer. Like all of the revolutionary developments of the war and the postwar period, the emergence of the computer owed much to the work of earlier decades. The needs of electrical engineers themselves were to provide considerable incentive to the construction of some of the earliest practical computers. In the mid-1920s, MIT electrical engineer Vannevar Bush devised the "product integraph," a semiautomatic machine for solving problems in determining the characteristics of complex electrical systems. This was followed a few years later by the "differential analyzer," the first general equation-solving machine. These machines were electromechanical analog devices, but at the same time that they were being built and copied, the principles of electrical and electronic digital machines were being laid out. In 1937, Claude Shannon published in the Transactions of the AIEE the circuit principles for an "electric adder to the base two," and George Stibitz of Bell Labs built such an addingdevice on his kitchen table. In that same year, Howard Aiken, then a student at Harvard, proposed a gigantic calculating machine that could be used for everything from vacuum tube design to problems in relativistic physics. With support from Thomas J. Watson, president of IBM, Aiken was able to build his machine, the "Automatic Sequence Controlled Calculator," or "Mark I." When it was finished in 1944, the Mark I was quickly pressed into war service, calculating ballistics problems for the Navy.

The usefulness of such machines for the war was widely apparent, and this need stimulated even more rapid development. In 1943, the government contracted with John W. Mauchly and J. Presper Eckert of the University of Pennsylvania to build the "Electronic Numerical Integrator and Computer"--the first true electronic digital computer. When the ENIAC was finally dedicated in February, 1946, it was both a marvel and a monster weighing 30 tons, consuming 150 kW of power, and using 18,000 vacuum tubes. With all this, it could perform 5,000 additions or 400 multiplications per second, which was about a thousand times faster than any other machine of the day. More than any other machine, the ENIAC showed the immense possibilities of digital electronic computers.

These possibilities were to occupy engineers, mathematicians, and others in the coming decades. The stored-program concept of John von Neumann, the ideal machines of Alan Turing, the memory devices of Jay Forrester, and the program compiler of Grace Hopper were just some of the insights and innovations that went into creating the modern digital electronic computer. Gradually, but surely, the computer wrought a revolution in science, business, government, and engineering, by providing the capacity for handling vast quantities of data very quickly and very accurately. The computer represented another kind of revolution to electrical engineers, however, for it put into their hands the challenge of and the responsibility for the most powerful new machine of the 20th century.

**RIVALRIES WITHIN**

Almost all fields of electrical engineering grew in the years after World War II, some gradually and others explosively. This growth and its different impact on various technical fields and parts of the profession made the1940s and 1950s a period of both exciting change and of difficult tensions. The tensions were vividly reflected in the changing relationship between the two professional societies that divided electrical engineering between themselves-the American Institute of Electrical Engineers (AIEE) and the Institute of Radio Engineers (IRE). In the early 1960s these tensions were to be resolved in the merger of the two societies to form the IEEE--unifying the profession under a single, transnational banner.

The tremendous growth of electronics was the primary force for change in the profession, even before the end of the World War. The effect of the war could be seen in the membership of the IRE, which grew from 5,200 in 1940 to more than 18,000 by 1946. Membership continued to climb rapidly during the1950s, finally surpassing the AIEE's in 1957, when total IRE membership, including students, reached 64,773. Students represented one fifth of that total, and the accelerating growth of the IRE's student membership was evidence of a society that was successfully riding the wave of a technological revolution.

This success story was not repeated in the AIEE. There, by the late 1950s,overall membership growth had slipped to barely 3% per year, and its student membership was only two thirds that of the IRE. The organization was by no means moribund, for it had strived throughout the 1950s to adapt itself to the growing status of new electronics and communications technologies. By the end of the decade, the AIEE was not a society of just power engineers over 30 percent of its technical papers were in communications, electronics or instrumentation, and participation in joint technical conferences with other societies was rapidly increasing. Still, the society felt a little left behind by the tremendous growth of its younger brother. With greater frequency, questions were raised in both societies about how appropriate it was for the increasingly inter-related fields of electrical engineering to be represented by two large, independent organizations.

The idea that there should be only one organization for electrical engineers was an old one. At its founding, the members of the IRE had consciously decided that the burgeoning new field of radio could be best served by an organization outside the confines of the AIEE, and in those days, the technical concerns of the two societies did seem comfortably distinct. By the 1940s, however, the ever-increasing scope of electronics was clearly moving into the power, control and communications concerns of the AIEE. As early as the mid-40s, prominent AIEE members advocated joining with the IRE, a call repeated at intervals during the 1950s. Late in the decade, cooperative arrangements were worked out for members of the two societies, and finally, in 1961 top officers of the AIEE and the IRE began seriously discussing merger. A joint committee made recommendations, and when merger was put to a vote the following year, 87 percent of the membership of each organization approved. On January 1, 1963, the Institute of Electrical and Electronics Engineers (IEEE) was officially born.

**SECURITY AND ORDER**

The supreme effort necessary to win the Second World War demanded an unprecedented degree of cooperation among the military, industry, and academe. Working together, these institutions developed the technologies necessary to win the war. But the end of the shooting war was followed all too quickly by the cold war; the demand for sophisticated weaponry would not go away. As a result, the alliance of convenience among the military, industry, and academia, forged to meet the wartime emergency, became a permanent part of modern life.

The requirements of the military strongly influenced the direction of postwar technology. Digital computers were applied to the problems of air defense, producing the SAGE (Semi-Automatic Ground Environment) system for coordinating the detection and interception of enemy bombers. The Navy, with its atomic submarines, pioneered the production of electricity from nuclear energy, and the first commercial nuclear generating station in the United States, at Shippingport, Pennsylvania, was based on the Navy designs. Even technologies that did not arise directly from military research were affected. The transistor was a civilian invention, but the development work that made it into a useful, reliable device was funded largely by the military.

A network of organizations grew up during this time to serve defense needs. Some, like the Johns Hopkins Applied Physics Laboratory and the MIT Servomechanisms Laboratory, were formed during World War II. Others, such as System Development Corporation, which provided the programming and training for the SAGE system, were postwar creations. In still other cases established firms such, as General Electric, Westinghouse, and Raytheon, that had done little military work before the war found defense work to be a major component of their post war activities.

The career of Charles Stark Draper illustrates the opportunities and challenges this defense network offered electrical engineers. Working at MIT's Instrumentation Laboratory, Draper developed a gyroscopic gunsite which greatly improved the effectiveness of naval gunnery during the war. After the war, Draper turned his attention to the problems of navigation and guidance. Nuclear submarines, which could stay submerged for days or weeks, could not depend upon the celestial navigation used by surface ships or conventional subs. In addition, ballistic missiles designed to strike targets hundreds or thousands of miles from the launch site posed formidable guidance problems. Combining gyroscopes with servomechanisms, accelerometers, and electronics, Draper developed inertial guidance systems that were successfully applied to submarines and the Polaris, Poseidon, Thorand Titan missiles. His crowning achievement was the system that safely guided the Apollo astronauts to the moon and back to earth.

The challenge of providing security and readiness in an increasingly dangerous world was the key stimulus to the advancement of electronic technology in the decades after World War II. With the challenge came unprecedented opportunities for engineers to exploit the possibilities of their field without many of the usual constraints of cost and competition present in the commercial environment. Engineers faced another challenge, however, in keeping their independence and professional integrity in an environment dominated by the enormous, impersonal establishment responsible for national defense. For most of the last half of the 20th century, the public perception of engineers has been shaped largely by how they have met this challenge.

**ON THE FRONTIERS**

The ideal engineering project is one that is highly challenging, is well funded, offers the opportunity to work with well-qualified people, produces tangible results, and enjoys wide public support. In the 1960s, the American aerospace programs came close to fulfilling these specifications.

The technological fruits of these programs were many, but developments in two areas, microelectronics and computers, were particularly important for electrical engineers. The growth of microelectronics, and specifically integrated circuits, was accelerated by the demand for small, rugged, lightweight electronics packages with low power consumption for use in satellites, aircraft, spacecraft, and missiles. In addition, the massive mathematical challenges posed by space flight stimulated the development of digital computers. Large mainframe machines were essential for design and trajectory calculations, and small, on-board computers were needed for guidance and control of manned spacecraft.

The Apollo moon missions were in a very real sense the pinnacle of the space program, for afterwards shifting national priorities resulted in the dismantling of much of the space apparatus, putting many engineers out of work. By 1971, the unemployment rate among electrical engineers involved in the space-related fields of computers, electronics, and systems engineering was over 6.5 percent, twice the rate for all engineers.

A related problem was the fact that engineers in the aerospace industries were highly mobile, moving from job to job as opportunities improved or as contracts were won or lost. The result was that many of these engineers did not accumulate the pension and other benefits that were available in more stable industries. Rising unemployment only exacerbated this problem.

In the end, the "ideal engineering project" left both a technical and anon-technical legacy for electrical engineers. The space program contributed greatly to technological advancement and was a source of justifiable pride to the participants. But the economic dislocation caused by the program's decline led many electrical engineers to urge the IEEE to become more active in promoting the economic interests of its members. This effort was successful in 1973 when the Institute decided to broaden its concerns to include the economic and professional status of its members.

Of course, other areas of the military also continued their interest in the utilization of electronic technology, and telecommunications was one important area of development. An interest in allowing the growing number of computers to communicate with one another led to the establishment of the Arpanet, the first packet-data network, in 1969.

**THE MICRO WORLD AND THE COMPUTER**

Microelectronics and digital computers, both of which received a strong boost from the aerospace programs of the 1960s, developed into the "glamour" technologies of the 1970s.

The two technologies had, and continue to have, a profound effect upon the course of electrical engineering. First of all, they opened much wider the door to entrepreneurial activity by individual engineers, recapturing, perhaps, the spirit of the earliest pioneers. The technologies are moving so rapidly, innovation is so important, and the capital requirements are, relatively speaking, so modest that a small group of talented, ambitious engineers can start their own company, with the potential for enormous profits.

The integrated circuit was one of the major fruits of this growing entrepreneurial activity. The increasing complexity of electronic devices meant that even transistorized circuits could be too large and heavy, especially for aerospace applications. In addition, the reliability of such circuits was limited by the ever-increasing number of interconnections. The integrated circuit was a solution to both of these problems.

Integrated circuits did more than merely solve a technological problem; they actually changed the way electrical circuits were designed. Engineers had grown accustomed to creating circuits with a minimum of active components, since transistors and diodes were relatively more expensive than resistors and capacitors. But active components are both smaller and easier to put on a silicon chip than inactive ones. Thus, the circuits most adaptable to integration are digital circuits, with many active components performing "yes-no" logic functions. Since these are the sorts of circuits used in computers, the integrated circuit not only made truly small computers possible, it actually encouraged engineers to look for digital solutions to design problems.  The technique of large-scale integration

These developments led to a boom in computers in two opposite directions: On the one hand, the possibility of a truly small computer led to the introduction first of minicomputers and then of "personal computers," which an individual could keep on his or her desktop; these PCs were, of course, to revolutionize society.  At the other end of the scale, the miniaturization allowed the design of new architectures, which in turned spurred the development of large "supercomputers," capable of previously unimaginable calculations. These supercomputers had an impact on many branches of science and mathematics comparable to the impact of the PC on the general public.

Furthermore, the proliferation of computer large and small, and their growing use in any number of fields, led to increased interest in interconnecting them and allowing them to communicate. Throughout the1970s and 1980s, the Arpanet grew and developed until it came to resemble the Internet we know today.

TECHNOLOGY ON THE DEFENSIVE

In the midst of the tremendous technical innovations of the 1960s and early 1970s, various elements of society began to question the wisdom of some of those advances.

The growing unpopularity of the Vietnam War and the inability of the United States to translate its overwhelming technological advantage into swift military victory tarnished the reputation of defense and aerospace industries. The increasing concern over environmental pollution emphasized the negative effects of technology, which had hitherto been underestimated.

The very generation of electricity itself was challenged. All the major methods of power production were charged with creating environmental and even commercial damage. Hydroelectric dams caused needless destruction of useful agricultural land as well as wildlife habitats. Coal-fired steam plants produced large-scale air pollution, and the strip mining of coal did serious damage to the landscape. Oil-, coal- and gas-fired plants consumed shrinking, costly natural resources. The Arab oil embargo of the 1970s, rather than being seen as a technological challenge, was considered further evidence of a world too dependent on technological fixes.

The most serious and vocal opposition was reserved for nuclear power. A series of accidents at such plants, culminating with the Three Mile Island accident in Pennsylvania, plus the ever-growing cost of building nuclear plants, caused critics to charge that nuclear power was another example of technology that was too big, too expensive, too complicated, and too dangerous.

The computer, one of electrical engineering's proudest achievements, was also the object of much scrutiny and criticism. The list of computer-related evils seemed endless: unemployment and the devaluing of existing skills; government and business files that were a threat to privacy; computer crime; "computer junkies" who wasted away their lives in front of a terminal; and computer malfunctions that caused credit card overcharges and might someday cause a nuclear war, as portrayed in the popular film "Failsafe."

Engineers who had traditionally seen themselves as problem solvers now found themselves accused of being problem causers. Engineers reacted to this criticism in a variety of ways. Some felt that the answer to the problems caused by technology lay in improving that technology, refining it and often substituting even more sophisticated technology. Others rallied under the banner of "appropriate technology," seeking simpler and often decentralized solutions. Still others urged their colleagues to actively enter into the debate over technology, to participate in the non technical decisions about how technology was used, and to consider other than strictly technical factors in their work. Finally, many engineers insisted that such involvement was simply inappropriate for engineers; that their job was to provide technical expertise and that to inject subjective elements into the engineering process was to subvert that process.

These social changes were linked to economic dislocations, including the recession of the 1970s that may have been directly linked to the oil embargo. For the first time, a degree in electrical engineering was not seen as a guarantor of a lucrative career. Yet, despite all this, while the membership increases in the IEEE slowed, they did not stop, and seen in broader perspective the growth in electrical engineering was explosive. In the twenty years after the 1963 merger, for example, the membership of the IEEE increased by sixty percent, from about 150,000 to over 240,000. The increase in the number of students studying in the fields covered by the IEEE computers, communications, power, and the like was dramatic. By1984, the centennial of the AIEE's founding, the electrical engineering community had come to represent THE largest single technical group in the world, and the almost one-quarter million members of the IEEE made up the world's largest engineering society. Electrical engineering was poised to rebound from the malaise of the late 1970s and early 1980s.

## TOWARD THE 21st CENTURY

The unprecedented growth in the U.S. and world economies that began in the mid-1980s and continues to this day was no doubt in part sparked by increases in productivity made possible by new electrical technologies, and the grow thin turn stimulated further technical developments. There was certainly are turn to government attention in this area, for example the money put into the Strategic Defense Initiative. Where Vietnam may have been seen as a technology failure, the Gulf War was taken as evidence that technology could make the difference on the battlefield.

However, with the end of the Cold War, most of the action in technological innovation shifted to the private sector. Microprocessor technology continued to advance according to "Moore's Law," with component densities doubling every 18 months, even as costs were dropping. This allowed both tremendous adoption of desktop computers, now multimedia-ready with powerful CD-ROM drives, by private households and businesses of all sizes, and the proliferation of microprocessors in products that were previously "dumb," such as microwave ovens or photocopy machines. Consumer electronic advances included CD players, now standard in many cars, let alone the home, HDTV, DVD, virtual reality, and sophisticated video games for the home and arcade.

The wide availability of powerful computers has led to advances in many other industries, from the use of robotics and computer-assisted drafting in manufacturing, to desktop publishing and computerized special effects in cinema.

Perhaps the most important advance has been the linking of these widespread computers via the Internet. The addition of World Wide Web to the Internet in the early 1990s led to an unprecedented interconnectedness throughout the world. What had originally been conceived of as a military application is now an indispensable personal and professional tool for millions and millions of people the world over, the backbone of the much touted "information superhighway."

Advances in telecommunications, such as the proliferation of cellular phones and the global positioning network have, through the electrical engineering field of signal processing, converged with the computer developments to create a true world system of information flow.

The older areas of electrical engineering interest have also seen a resurgence. As power deregulation follows telecommunications deregulation, engineers will be grappling with the technical needs of the new systems. Energy conservation is being given a boost with renewed interest in the electric car, in renewable technologies such as wind-generated electric power, and the application of magnetic levitation (MAGLEV) to systems of mass transport.

We therefore seem poised to continue this technological explosion into the 21st century. How has the engineering profession responded?

## UNITY AND DIVERSITY

The three and a half decades since the formation of the IEEE have witnessed a revolution in electrical and, especially, electronics technology. Paced by changes in solid-state electronics that greatly expanded capabilities while at the same time radically reducing size and costs, the entire domain of electrical engineering has grown far beyond the boundaries that characterized it just a generation ago. Electrical engineers have become the creators and masters of the most pervasive technology of our time, with profound effects on society and on their profession.

This growth in electrical engineering has generated both unifying and dividing forces within the profession and in society at large. Modern electric power systems, for example, allow energy to be applied in fragmented and discrete ways, allowing the wider and wider distribution of productive activity. At the same time, such systems link all users together into a tightly woven net of dependency. Microelectronics has the same dual tendency, allowing individuals to work with powerful computers that are wholly contained on their desks or engage in a variety of commercial or social activities without ever actually dealing with another human being. Yet the same technology that fosters such isolation allows the person with a miniature television or a citizens band radio to be "plugged in" to the world wherever he may be, thus making him truly part of a "global village."

These forces of unity and divergence are also at work in the engineering community. With increasing size and complexity, many of the tendencies that work to separate the practitioners of different specialties from one another are harder to overcome. Jargon, differing technical problems, and divergent institutional and economic environments compartmentalize engineers into smaller groups that may have increasing difficulty communicating with one another. On the other hand, the sheer size of the electrical engineering community and the multiplicity of common interests-professional, economic, and technical-has provided considerable common ground for all electrical engineers to meet on.

## NETWORKING THE WORLD

These recent developments have also had a tremendous impact on the IEEE as an institution. When the AIEE was founded more than 100 years ago, electrical engineering was concerned with wire communication and the production and distribution of direct current electricity for lighting. In the following 80 years, electrical technology expanded to encompass alternating current, high-voltage transmission, radio, vacuum-tube electronics, and solid-state electronics.

The 1963 merger of the American Institute of Electrical Engineers and the Institute of Radio Engineers came about, in part, because neither organization represented the full scope of electrical technology. The IRE Professional Group system had done much to attract members from the newer fields of electronics, but the IRE held little interest for power engineers. The AIEE, on the other hand, was power oriented, and had, by its own admission, had failed to enter certain new fields. Furthermore, the IRE had always been international in scope and the AIEE, while its international membership had been growing, was focused on North America.

The IEEE resolved not only to merge the two diverse organizations, but to accommodate new technologies and social developments as they came along. The new Institute adopted the Professional Group structure of the IRE, which evolved into its present technical society structure. By means of the societies, the IEEE has assimilated such new technologies as microelectronics, satellite communications, and digital computers. A cross-cutting geographical structure, known as Regional Activities, allows the IEEE to better serve its members internationally.

Yet this very effort to accommodate diversity raises its own problems. One such problem is the identity of the profession itself. What is it beyond a common undergraduate curriculum that ties together members of the Electrical Insulation Society, the Antennas and Propagation Society, and the Engineering Management Society and makes them all members of the same profession?

A second, related problem is the degree to which the practitioners of a specialty feel that the IEEE serves their interests, and the amount of influence the Institute is willing to grant to a given specialty. As individual technical subgroups grow in size and influence, the centrifugal forces acting upon the Institute increase. Thanks to the technological changes discussed above, the Computer Society, which has its origins in the establishment of a small Subcommittee on Large-Scale Calculating devices at the AIEE in 1946, now represents one third of the IEEE membership. Its leaders must balance their intellectual and historical position within the IEEE with the unique needs of their membership.

The increasing technical diversity of the Institute has been accompanied by continued rapid growth. Membership has continued to soar from some 240,000 in 1984 to over 320,000 today. Furthermore, most of this growth has occurred outside of North America. The sheer size and scope of the IEEE requires special efforts to keep all members adequately informed and to encourage participation by more than an active minority.

In sum, the ever-widening scope of electrical, electronic and computing technologies in both intellectual content and spatial application continuously challenges the IEEE to attract the practitioners of new technologies while at the same time defining and promoting the common bonds among them. Owing to the international nature and intellectual breadth of the electrical engineering endeavor, the IEEE is uniquely placed to apply the technologies DEVELOPED BY ITS OWN MEMBERS in networking the world and aiding in the continuing development of the global economy. That there still exists a single organization to speak for electrical engineering at the end of the 1990s is testimony to the enduring legacy of a century of growth and change.

## FURTHER READING

John D. Ryder and Donald G. Fink, Engineers & Electrons: A Century of Electrical Progress, IEEE Press, New York, 1984.

A. Michal McMahon, The Making of a Profession: A Century of Electrical Engineering in America, IEEE Press, New York, 1984.

Lawrence P. Grayson, The Making of an Engineer: An Illustrated History of Engineering Education in the United States and Canada, John Wiley & Sons, New York, 1993. To Probe Further

Books:

A Book of Object-Oriented Knowledge: An Introduction to Object-Oriented Software Engineering, Brian Henderson-Sellers, Prentice Hall, 1996.
Codesign: Computer-Aided Software/Hardware Engineering, Jerzy Rozenblit and Klaus Buchenrieder (editors), IEEE Press, 1995.
Computer Circuits Electrical Design, Ron K. Poon, Prentice-Hall, 1995.
Computers: An Introduction to Hardware and Software Design, Larry L. Wear et al., McGraw-Hill, 1991.

Magazines/Journals:

IEEE Computer Magazine
IEEE Design and Test of Computers Magazine
IEEE Software Magazine
Journal of the Association for Computing Machinery
Software Practice and Experience
Communications of the ACM To Probe Further

Books:

Circuits, Interconnections, and Packaging for VLSI, H. B. Bakoglu, Addison-Wesley, 1990.
Microelectronics Packaging Handbook, Vols. 1 and 2, Rao R. Tummala et al. (editors), Chapman and Hall,1997.
Multichip Module Technologies and Alternatives, Daryl Ann Doane and Paul D. Franzon (editors), Van Nostrand Reinhold, 1992.
Packaging of Electronic Systems: A Mechanical Engineering Approach, James W. Dally, McGraw-Hill, 1991.
Principles of Electronic Packaging, Donald Seraphim et al., McGraw-Hill, 1988.

Magazines/Journals:

Advanced Packaging Surface Mount Technology
Electronics Packaging and Production
IEEE Circuits and Devices Magazine
IEEE Electron Devices Society Newsletter
IEEE Transactions on Components, Packaging, and Manufacturing Technology
IEEE Transactions on Semiconductor Manufacturing
IEEE/OSA Journal of Lightwave Technology To Probe Further

Books:

After the Breakup: U.S. Telecommunications in a More Competitive Era, Robert W. Crandall, Brookings Institution, 1991.

Applying Telecommunications and Technology from a Global Business Perspective, Jay J. R. Zajas and Olive D. Church, Haworth Press, 1997.
Cellular and PCS : The Big Picture, Lawrence Harte, et al., McGraw-Hill,1997.

Magazines/Journals:
Data Communications
IEEE Communications Magazine
IEEE Network Magazine
IEEE Personal Communications Magazine
Network World

To Probe Further

Books:
Cogeneration and Small Power Production Manual, Scott A. Spiewak and Larry Weiss, Fairmont Press, 1997.
Electric Machines and Drives, Gordon R. Slemon, Addison-Wesley, 1992.
Power Generation and the Environment (Monographs on Science, Technology and Society, No 6), L.E.J. Roberts et al., Oxford University Press, 1990.
The Essence of Electric Power Systems (Essence of Engineering), J. A. Harrison, Prentice Hall, 1996.

Magazines/Journals:
IEEE Computer Applications in Power Magazine
IEEE Industry Applications Magazine
IEEE Power Engineering Review
Power Magazine

Additional Resources:

IEEE Power Engineering Society
IEEE Industry Applications Society
IEEE Power Electronics Society
IEEE Nuclear and Plasma Society
Electric Power Research Institute (EPRI)
Edison Electric Institute (EEI)
American Public Power Association (APPA)
National Rural Electric Cooperative Association (NRECA)

Conferences

Cement Industry Conference
Industrial and Commercial Power Systems Conference
Petroleum and Chemical Industry Conference
Appliance Industry Technical Conference
Rural Electric Power Industry Conference
Pulp and Paper Industry Conference
Rubber and Plastics Industry
Textile Industry Conference
Applied Power Electronics
IAS Annual Meeting
IEEE Power Engineering Society Winter and Summer Meetings
IEEE Power Engineering Society Transmission and Distribution Conference
Power Industry Computer Applications Conference (PICA)
Electrical Safety in Maintenance and Operations Conference

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**To Probe Further**

Books:
Advances in Optronics and Avionics Technologies, M. Garcia (editor), Wiley, 1995.
Computing in Aerospace: A Collection of Technical Papers, American Institute of Aeronautics and Astronautics, 1995.
Introduction to Avionics, Dale R. Cundy and Rick S. Brown, Prentice Hall, 1996.

Magazines/Journals:
Aerospace Engineering
Aviation Week and Space Technology
IEEE Aerospace and Electronic Systems Magazine
IEEE Transactions on Aerospace and Electronic Systems

Conferences

Aerospace
Autotescon
Battery Test
Carnhan
Digital Avionics
International Conference on Instrumentation in Aero Simulation Facilities
Intelligent Transportation Systems
International Conference on Systems Engineering
International Radar Conference
Intersociety Energy Conversion Engineering Conference
National Radar Conference
National Telesystems Conference and Position-Location and Navigation Systems

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Books:
Bioengineering of the Skin: Methods and Instrumentation (CRC Series in Dermatology: Clinical and Basic Science), Enzo Berardesca , CRC Press, 1995.
Introduction to Bioengineering, S. A. Berger et al. (editors), Oxford University Press, 1996.

Regulation and Control Mechanisms in Biological Systems (Prentice Hall Biophysics and Bioengineering Series), Vishnampet S. Vaidhyanathan, Prentice Hall, 1992.

Magazines/Journals:
Biotechnology Newswatch
IEEE Engineering in Medicine and Biology Magazine      Additional Resources:

Association for the Advancement of Medical Instrumentation (AAMI)
IEEE Engineering in Medicine and Biology Society
IEEE Medical Imaging Committee
IEEE Signal Processing Society
Health Industry Manufacturers Association (HIMA)
Imaging Society
Medical Device Link (Web site)
Medical Device Manufacturers Association (MDMA)
National Electronic Manufacturers Association (NEMA), Diagnostic Imaging and Therapy Systems Division      To Probe Further

Books:
Advances in Distributed Sensor Integration: Application and Theory (Prentice Hall Series on Environmental and Intelligent Manufacturing Systems), L. Prasad et al., Prentice Hall, 1995.
Applications of Fuzzy Logic: Towards High Machine Intelligence Quotient Systems (Prentice Hall Series
on Environmental and Intelligent Manufacturing), Mohammad Jamshidi (editor), Prentice Hall, 1997.
The Design of the Factory With a Future (McGraw-Hill Series in Industrial Engineering and Management
Science), J. Temple Black, McGraw-Hill, 1991.

Magazines/Journals:
IEEE Industry Applications Magazine
IEEE Industry Applications Magazine
IEEE Robotics and Automation Magazine
Integrated Design and Manufacturing

**To Probe Further**

Books:
The Art and Science of Computer Animation, Stuart Mealing, Cromland, 1995.
Control Systems for Live Entertainment, John Huntington, Butterworth-Heinemann, 1994.
Creating Internet Entertainment: A Complete Guide for Web Developers and Entertainment Professionals, Jeannie Novak and Pete Markiewicz, John Wiley & Sons, 1996.
The Electronic Future of Banking: Succeeding in the New Electronic Age for Tomorrow's Financial
Institutions, Floyd E. Egner, Financial Sourcebooks, 1991.
Standard Handbook of Consulting Engineering Practice: Starting, Staffing, Expanding, and Prospering
in Your Own Consulting Business, Tyler Gregory Hicks and Jerome F. Mueller, McGraw-Hill, 1996.

Magazines/Journals:
ASIFA News (International Association of Animation)
Bank Network News
Digital Kids
Dreamscape
IEEE Computer Graphics and Applications Magazine
IEEE Internet Computing Magazine

Additional Resources:

IEEE Engineering Management Society
IEEE Professional Communication Society

**To Probe Further**

Books:
Research-Doctorate Programs in the United States: Continuity and Change, Marvin L. Goldberger and
Brendan A. Maher (editors), National Academy Press, 1995.
1996 IEEE Frontiers in Education Conference, IEEE Press, 1997.
Electronics Research Centres: A World Directory of Organizations and Programmes, Gale Research, 1989.

Magazines/Journals:
Computers in Education Journal
IEEE Engineering Management Review
International Journal of Engineering Education
Journal of Engineering Education
Proceedings of ACM
SIGSCE (Special Interest Group Computer Science Education)
Technical Symposium

Additional Resources:

Computer Research Association
National Science Foundation
American Society for Engineering Education
IEEE Education Society
National Academy of Engineering
ACM Special Interest Group in Computer Science Education (SIGSCE)

**Conferences**

Conference on Lasers and Electro-Optics (CLEO)
International Electronics Packaging Conference (NEPCON East or West)
IEDM
Optical Fiber Communication Conference (OFC)

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**To Probe Further**

Books:
Automated Highway Systems, Petros A. Ioannou (editor), Plenum, 1997.
Automotive Electricity and Electronics: Concepts and Applications, Boyce H. Dwiggins and Edward F.
Mahoney, Prentice Hall, 1996.
Manual of Transportation Engineering Studies, H. Douglas Robertson and Joseph E. Hummer, Prentice
Hall, 1994.

Magazines/Journals:
Automotive Engineering

**Additional Resources:**

IEEE Industrial Electronics
IEEE Geoscience and Remote Sensing
IEEE Vehicular Technology Society
ITS America
Society of Automotive Engineers
Institute of Transportation Engineers
American Society of Naval Engineers

**Conferences I**

IEEE International Symposium on High Performance Computer Architecture (HPCA)
IEEE Computer Elements Mesa Workshop
International Symposium on Environmentally Conscious Design and Inverse Manufacturing - EcoDesign
Symposium on Operating Systems Design and Implementation
BAST Workshop: Pacific Northwest Test
IEEE Workshop on Mobile Computing Systems and Applications
IEEE Volta Memorial Workshop on Low-Power Design
IEEE Symposium and Workshop on Engineering of Computer Based Systems
IEEE Computer Society Virtual Reality
IEEE Symposium on Mass Storage Systems
International Symposium on Autonomous Decentralized Systems (ISADS)
INFOCOM
IEEE International Conference on Data Engineering
IEEE Workshop on Hot Topics in Operating Systems
IEEE Data Compression Conference (DCC)
IEEE Computer Society Annual Workshop on VLSI

IEEE International Parallel Processing Symposium/ IEEE Symposium on Parallel and Distributed Processing - IPPS/SPDP
IEEE Symposium on Computer Arithmetic
International Symposium on Advanced Research in Asynchronous Circuits and Systems - ASYNC
IEEE VLSI Test Symposium
International Workshop on Hardware Software Co-Design/CASHE
IEEE Symposium on Security and Privacy
IEEE International Conference on Software Engineering
IEEE International Symposium on Software Engineering Standards
Science and Engineering in Software
IEEE Workshop on Signal Propagation on Interconnects
International Symposium on Multiple-Valued Logic (ISMVL)
North Atlantic Test Workshop
EEE Real-Time Technology and Applications Symposium
IEEE Southwest Test Workshop
IEEE International Conference on Requirements Engineering (RE)
IEEE International Symposium on Fault-Tolerant Computing
IEEE International Test Mixed Signal Testing Workshop
International Conference on Software Engineering and Knowledge Engineering
IEEE International Conference on Microelectronic Systems Education
IEEE Workshop on Computer Vision Beyond the Visible Spectrum Methods and Applications
IEEE Workshop on Empirical Evaluation Method in Computer Vision (EEM)
International Conference on Scale-Space Theories in Computer Vision
IEEE Workshop on Photometric Modeling for Computer Vision and Graphics
Workshop on Statistical and Computational Theories of Vision
IEEE Workshop on Content- Based Access of Image and Video Libraries
IEEE Workshop on Integration of Appearance and Geometric Methods in Object Recognition
IEEE Conference on Computer Vision and Pattern Computer Vision and Pattern
IEEE Workshop on Visual Surveillance
IEEE Workshop on Perception for Mobile Agents
IEEE Workshop on Multi-View Modeling and Analysis of Visual Scences
IEEE Frontiers in Education Conference - FIE
IEEE Asian Test Symposium (ATS)
IUI: Intelligent User Interfaces
POPL: Symposium on Principles of Programming Languages
The Sixth International Workshop on Foundations of Object-Oriented Languages (Co-located with POPL)
WACC: International Conference on Work Activities Coordination and Collaboration

**Additional Resources:**

IEEE Antennas and Propagation Society
IEEE Broadcast Technology Society
IEEE Communications Society
IEEE Consumer Electronics Society
IEEE Information Theory Society
IEEE Laser Electro-Optics Society
IEEE Signal Processing Society
IEEE Vehicular Technology Society

International Society for Optical Engineering (SPIE)
Laser Institute of America
Telecommunications Industry Association

**Additional Resources:**

Association for Computing Machinery
IEEE Computer Society
IEEE Neural Networks Council
IEEE Circuits and Systems Society
IEEE Components, Packaging, and Manufacturing Technology Society
IEEE Consumer Electronics
IEEE Electron Devices Society
IEEE Solid State Circuits Society

**Additional Resources:**

Electronic Industries Association
IEEE Electron Devices Society
IEEE Circuits and Systems Society
IEEE Solid State Circuits Society
IEEE Laser and Electro-Optics Society
IEEE Computer Society
IEEE Components, Packaging, and Manufacturing Technology Society
Laser Institute of America
Optical Society of America
SPIE - International Society of Optical Engineering
SRC - Semiconductor Research Corporation
Sematech

**Additional Resources:**

American Institute of Aeronautics and Astronautics
IEEE Aerospace and Electronics Systems Society (AESS)
IEEE Geoscience and Remote Sensing Society
IEEE Microwaves Theory and Techniques www.mtt.org
IEEE Robotics and Automation Society
IEEE Signal Processing Society
IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society
IEEE Vehicular Technology Society Conferences

IEEE International Performance Computing and Communications Conference (IPCCC)
International Conference on Personal Wireless Communications
Internet Workshop (IWS)
Annual UCSD Conference on Wireless Communications
INFOCOM 1999 IEEE Wireless
IEEE Open Architectures & Network Programming (OPENARCH)
Telecommunications Information Network Architecture Conference
(TINA)

IEEE Technical Committee on Quality and Reliability Telecom Networks International Workshop (TCQR)
International Conference on Intelligence in Services and Networks - (IS&N)
IEEE/LEOS Workshop on Interconnections Within High Speed Digital Systems Bioengineering
IFIP/IEEE International Symposium on Integrated Network Management (IM)
IEEE Communications Theory Workshop
IEEE ATM Workshop
IEEE International Workshop on Quality of Service (IWQoS)
International Workshop on Wireless Mobile ATM Implementations
ICC --IEEE International Conference on Communications
IEEE Digital Cross Connect Systems Workshop VIII
International Working Conference on Active Networks (IWAN)
IEEE Radio and Wireless Conference - (RAWCON)
International Conference on Standardization and Innovation in IT (SI2T)
IEEE Wireless Communications & Networking Conference (WCNC)
European Conference on Optical Communication (ECOC)
MILCOM -- IEEE Military Communications Conference
GLOBECOM '99 - 1999 IEEE Global Telecommunications Conference
IEEE International Workshop on Intelligent Signal Processing and Communication Systems (ISPACS)
NOMS 2000 - 2000 IEEE Network Operations and Management Symposium
EUROCOMM

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**Conferences**

Annual International Conference of the IEEE/EMBS and Annual Fall Meeting of the BMES
Annual Rocky Mountain Bioengineering Symposium
Nordic Baltic Conference on Biomedical Engineering
International Workshop on Biosignal Interpretation
National Conference of the Hungarian Biomedical Engineering
Computers in Cardiology Conference
Australasian Conference on Bioelectromagnetics

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**Conferences**

IEEE Industry Applications Society Annual Meeting
IEEE/PCIC Electrical Safety Workshop
IEEE Applied Power Electronics Conference and Exposition - APEC
IEEE 41st Cement Industry Technical Conference
IEEE-IAS Advanced Process Control Applications for Industry Workshop
IEEE/IAS Industrial & Commercial Power Systems Technical Conference (I&CPS)
IEEE International Electric Machines & Drives Conference
IEEE Pulp and Paper Industry Conference
IEEE Petroleum and Chemical Industry Technical Conference (PCIC '99)
IEEE/IAS Industrial & Commercial Power Systems Technical Conference (I&CPS)
IEEE Cement Industry Technical Conference
Annual Reliability and Maintainability Symposium (RAMS)
IEEE International Reliability Physics Symposium:
IEEE International Integrated Reliability Workshop (IRWS)
SME AUTOFACT Conference
SME Computer Technology Solutions
SME International Conference on Education in Manufacturing
SME Lean Supply Chain Management Conference
SME Manufacturing
SME Rapid Prototyping & Manufacturing '99 Conference

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**Conferences**

IEEE International Engineering Management
PICMET-- Portland International Conference on Management of Engineering Technology

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**Conferences**

Conferences listed by IEEE www.ieee.org:

American Society of Engineering Education -- ASEE Annual Conference
IEEE Frontiers in Education Conference - FIE

Conferences listed by ACM www.acm.org:
Innovation and Technology in Computer Science Education
Conference on Information and Knowledge Management

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**Conferences:**

IEEE Vehicular Technology International Congress & Exposition
Earthmoving Industry Conference & Exposition
Government/Industry Meeting
International Automotive Manufacturing Conference & Exhibition (IAM)
Noise & Vibration Conference & Exposition
Digital Human Modeling for Design & Engineering Conference
Vehicle Thermal Management Systems Conference & Exhibition
International Pacific Conference on Automotive Engineering
International Future Transport Technology Conference
International Off-Highway & Power Plant Congress & Exposition
Small Engine Technology Conference
Southern Automotive Manufacturing Conference & Exposition (SAMC)
AUTOTECH
International Truck & Bus Meeting & Exposition
Global Vehicle Development Conference

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**Conferences II**

Virtual Reality Modeling Language
Symposium on Applied Computing
ACM SIGUCCS CSMS XXVI: ACM/SIGUCCS Computer Services Management Symposium XXVI

TAU: ACM/IEEE International Workshop on Timing Issues in Specification and Synthesis of Digital Systems
SIGCSE The ACM SIGCSE Technical Symposium
SIGCPR: Special Interest Group on Computer Personnel Research Annual Conference
RECOMB: International Conference on Computational Molecular Biology
ISPD International Symposium on Physical Design
Symposium on Interactive 3D Graphics
ACM SIGMETRICS Conference (part of FCRC)
IOPADS: Workshop on I/O in Parallel and Distributed Systems
(part of FCRC)
CHI : Conference on Human Factors in Computing Systems
SSR: Symposium on Software Reusability
International Conference on Management of Data and Symposium on Principles of Database Systems
(ACM) Symposium on Solid Modeling and Applications
Java: ACM Conference on Java Grande
The Symposium on Computation Geometry ID
ICS: The ACM International Conference on Supercomputing
DAC: The ACM/IEEE-CAS/EDAC Design Automation
Innovation and Technology in Computer Science Education
SPAA: Annual ACM Symposium on Parallel Algorithms and
Architectures
The Fourth Australasian Computer Science Conference
ISSAC: International Symposium on Symbolic and Algebraic
Computation
SIGGRAPH: the international Conference on Computer Graphics and Interactive Techniques
SIGGRAPH/EUROGRAPHICS Workshop On Graphics Hardware
APL Conference on APL
Digital Libraries KDD The First Annual International Conference on Knowledge
Discovery in Data
Annual International ACM SIGIR Conference on Research and Development in Information Retrieval
ISLPED: International Symposium on Low Power Electronics and Design
ACM SIGCOMM - Applications, Technologies, Architectures, and Protocols for Computer Communication
SIGSOFT - ESEC/FSE: SIGSOFT Symposium on Foundations of Software Engineering together with European Software Engineering Conference
SIGDOC: International Conference on Systems Documentation
New Security Paradigms Workshop
ICFP: International Conference on Functional Programming
C&C: Creativity and Cognition
ACM SIGAda Annual International Conference
ACM Conference on Computer and Communication Security
OOPSLA: Conference on Object Oriented Programming Systems Languages and Applications
Conference on Information and Knowledge Management
SIGUCCS User Services Conference
UIST: Annual Symposium on User Interface Software and Technology
GROUP: Conference on Supporting Group Work
SC

WSC: Winter Simulation Conference Symposium on Operating Systems Principles

For additional technical resources, including conferences, publications, upcoming events, and helpful IEEE web sites, go to "Technical Activities" on the IEEE Home Page. Here is a listing of current and upcoming technical conferences in TAG or "Technical Activities Guide." Other technical resources can be found through links to 38 IEEE Technical Societies and Councils, and information about the conferences and publications they sponsor. URL: (www.ieee.org/tab). For recent information about conferences by IEEE Computer Society (www.computer.org), ACM (www.acm.org), and other professional associations, go to the appropriate web site.

**Additional Resources:**

Society of Manufacturing Engineers (SME)
IEEE Industry Applications Society