company is one that sells processing time to companies that do not want to buy and manage their own computer systems.

A U.S.$7.6 billion corporation in 1999, CSC was founded in 1959 by Fletcher Jones and Roy Nutt for U.S.$100. Nutt and Jones gained their computer experience in the aerospace sector, one of the earliest industries to exploit the capabilities of the computing devices being developed in the 1950s. Nutt had worked for United Aircraft Corporation, where he developed the first widely accepted assembler, called SAP, and had been a member of the small **IBM** team that had developed **Fortran**. Jones came from North American Aviation Corporation, where he had managed a divisional computer center.

The biggest challenge for computer manufacturers in the 1950s was to find ways to simplify the extremely complex and time-consuming process of programming computers in machine language. They needed assemblers, compilers, and operating systems to make their machines commercially acceptable. Nutt and Jones saw this as a business opportunity and secured a contract from **Honeywell Corporation** to develop a business-language compiler called FACT. With the contract in hand and $100 in the bank to cover incidental expenses, they opened the first CSC office above a bakery in Palos Verdes, California. CSC went public in 1963 and was listed the following year on the Pacific and American stock exchanges. In 1968 it became the first company in the computer software and services industry to be listed on the New York Stock Exchange.

In 1964, Jones and Nutt, along with William R. Hoover, who came to CSC from the Jet Propulsion Laboratory at the California Institute of Technology, made a series of decisions that changed the nature of the company and launched its rapid growth. They decided to expand CSC's markets by serving users rather than the manufacturers of computers. Their focus became providing users with technical services to support the development and operation of computer-based information systems.

In 1999, CSC had over 54,000 employees working from more than 700 offices worldwide. Its customer base covers a broad spectrum of industries, including consumer goods, financial services, manufacturing, utilities, telecommunications, insurance, and government agencies. The company headquarters are in El Segundo, California.

FURTHER READING

Computer Sciences Corporation 1999 Annual Report. El Segundo, Calif.: CSC, 2000.

Computer Sciences Corporation. *History of CSC.* El Segundo, Calif: CSC, 1996.

Computer Sciences Corporation. *http://www.csc.com/invest/factsheet/factsheet2.html*

—*Luanne Johnson*

Computers, Generations of

The underpinning technology used to build computers has changed over the course of six decades. Accordingly, a distinction is drawn between computers built out of **vacuum tubes**, **transistors**, or **integrated circuits**. Computer scientists speak of *computer generations*, in which the first three generations are associated with the components just mentioned.

The first computers were built using electromechanical relays (the **Harvard Mark I**, the machines of **Konrad Zuse** [1910–95]) or vacuum tubes (the **Atanasoff–Berry Computer**, the **ENIAC**). Usually, the term *first-generation computer* is used to denote those machines built after 1945 using vacuum tubes. Notable examples are the **UNIVAC I**, built in the United States, or the **Atlas,** built in the United Kingdom, machines that compete for the title of first commercial computer in the world. **IBM**, which had funded the development of relay machines, was a late starter, but its first vacuum-tube computer, the IBM 701 introduced in 1952, was an immediate success.

After the invention of the transistor in 1947, the use of vacuum tubes was gradually phased out in computer circuits, enabling more compact and energy-efficient machines to be built. The *second generation* encompasses transistorized machines introduced in the 1950s. The first transistorized computer was built at **Bell Labs** in 1954. Named TRADIC (Transistorized Digital Computer), it was made of 800 transistors and many other components. It was much smaller than computers of the day and operated with just 100 watts of power.

Other sources assign the title of first transistorized computer in the world to the TX-0 (Transistorized Experimental Computer) built at the Massachusetts Institute of Technology in 1956. Indisputable is that the new technology had matured by 1958, with introduction of the UNIVAC Solid State 80 and the Philco S-2000, which launched the second generation into the commercial arena.

A third milestone in the history of computers was the invention of the integrated circuit by **Jack Kilby** (1923–) at **Texas Instruments** in 1958. The integrated circuit grouped many components in the same package, making it possible to build even smaller machines and thus started the *third generation* of computers. Today, an integrated circuit contains millions of components in a silicon chip smaller than a thumbnail. Very soon after 1958, commercial machines were built using hybrid hardware cards, on which individual transistors and integrated circuits were combined. One prototypical third-generation system was the IBM/360 family of computers, introduced in 1964. It was the first real family of computers, with processors compatible across a wide range of processing speeds.

Some authors identify a fourth and even a fifth generation of computers, but the distinction is not as clear-cut as in the case of the first three. The invention of the **microprocessor** in 1971 opened up the possibility of building microcomputers for the desktop. The necessary integrated circuits rely on **very large scale integrated circuit** (VLSI) technology. The *fourth generation* is therefore associated with the microprocessor and the emergence of VLSI.

However, apart from this classical definition of computer generations, the history of computing can be better conceptualized by looking at the main developments in the last four decades and by making a forecast for the next one. Using this approach, we can say that the history of modern computing has gone through four main 10-year technological cycles: the 1960s, the era of the **mainframe**; the 1970s, the era of the **minicomputer**; the 1980s, the era of the **microcomputer**; and the 1990s, the era of **networks**.

Let us first review the 1960s. IBM was the principal computer company at the time and the introduction of System/360 cemented its dominance for several years to come. Computers were expensive machines and were confined to the data processing centers of medium-sized and large corporations. But the seed for the next 10-year cycle had been planted. This seed was the introduction of the series of PDP minicomputers by **Digital Equipment Corporation** (DEC) in 1960 and 1961. However, IBM made the same error that many other computer companies would make in ensuing years: It could not identify a significant market for minicomputers and left this market segment totally open for newcomers such as DEC.

The relentless advance of miniaturization documented in **Moore's law**, which posits a doubling in circuit density every 18 months, led in time to the introduction of ever-cheaper and smaller computers. DEC became the success story of the 1970s, and other companies entered the new market, even IBM, producing computers for small businesses. But again, a new technology was already emerging and making great strides: The microprocessor, introduced by **Intel** in 1971, was being used by hobbyists to put together small microcomputers. Exactly as IBM did before with minicomputers, DEC did not enter the market for microcomputers because DEC executives could not envision what kind of applications someone would want to run on a home computer.

The heyday of the **personal computer** (PC) came in the 1980s. Important companies were founded in the 1970s, but their explosive growth began only in the next decade. This was the case for **Apple**, **Microsoft**, **Lotus**, and the makers of IBM **clones**. Determined to avoid the minicomputer fiasco of the past, IBM developed its own microcomputer, the IBM PC, and adopted an open architecture approach that allowed almost anybody to produce a clone, a functional copy of IBM's machine. But the now-familiar pattern of the previous decades repeated again: As the microcomputer was just starting to penetrate most households in the industrialized world, a new technological wave was spreading, the development of networked systems.

The next 10-year cycle, the 1990s, was the era of the **Internet**. Started in 1969 as the **ARPANET**, the computer network had grown steadily until in the 1990s, it began moving from the academic to the commercial sector and to the homes of end users. In a few years the numbers of Internet users reached several hundred million. The isolated PC became the exception rather than the norm.

The last four decades demonstrate that the development of computer technology has followed a similar path in each period. Each new age develops in stages. First, a new product is introduced that makes use of the latest advances in miniaturization. At this point established companies cannot identify a market for the new product; introduction of the new product is an example of pure "technology push." Then a **killer application** appears that suddenly opens a mass market for the new technology (spreadsheets for microcomputers, **World Wide Web** browsers for the Internet). The new application floods the market and the "demand pull" from customers makes the new computers cheaper and more affordable for new consumers. Finally, every old and new consumer discovers that its investment becomes more valuable with every new user of the same system because data can be exchanged, new programs are written for the machine, and so on. Then the cycle starts again, because while the old technology was growing and maturing, another new technology appeared which entrepreneurs attempt to transform into the next success story.

Following the model described above, one can attempt to predict what the first decade of the 21st century will bring: It will be the decade of even smaller **embedded systems** which will be networked by fixed and wireless links. The next 10-year cycle will continue with a trend to further miniaturization and will lead to the broad deployment of embedded processors in the **information appliances** of the future.

FURTHER READING

Campbell-Kelly, Martin, and William Aspray. *Computer: A History of the Information Machine.* New York: Basic Books, 1996.

Ceruzzi, Paul E. *A History of Modern Computing.* Cambridge, Mass.: MIT Press, 1998.

Riordan, Michael, and Lillian Hoddeson. *Crystal Fire: The Birth of the Information Age.* New York: Norton, 1997.

Sichel, Daniel, and Marilyn Whitmore. *The Computer Revolution: An Economic Perspective.* Washington, D.C.: Brookings Institution, 1997.

Williams, Michael R. *A History of Computing Technology.* Englewood Cliffs, N.J.: Prentice Hall, 1985; revised edition, Los Alamitos, Calif.: IEEE Computer Society Press, 1997.

— *Raúl Rojas*

Computer Society

The Computer Society is a professional organization of computer scientists and a subdivision of the **Institute of Electrical and Electronics Engineers** (IEEE). Its emergence during the 1950s not only illustrated the importance of engineering skills to the development of computing machinery, but also showed the importance of information to this new field. From its inception, the Computer Society devoted itself to disseminating new ideas to computer professionals.

Like the Institute for Electrical and Electronics Engineers itself, the Computer Society has its roots in two distinct professional organizations, the American Institute of Electrical Engineers and the Institute of Radio Engineers. These two organizations gave the Computer Society an international scope and a focus on computer engineering problems. By contrast, the other major professional society of computing, the **Association for Computing Machinery** (ACM), grew out of the U.S. scientific community of World War II. The ACM originally had a more American membership and was less concerned with problems of designing and constructing new machines.

The American Institute of Electrical Engineers formed a subcommittee on Large Scale Computing in 1946, and the Institute of Radio Engineers established a working group on electronic computers five years later. The two institutes had shared interests and many members in common and often cosponsored meetings. In 1952, the two groups organized one of the first computer conferences on the west coast of the United States. At the start of the decade, the Institute for Radio Engineers was the smaller of the two groups, but during the 1950s, it attracted a large international membership and soon eclipsed the American Institute of Electrical Engineers. The two organizations agreed to merge in 1963, forming the IEEE. Their two comput-