COMPUTER

Von Neumann, John *(1903-57), U.S. mathematician, born in Budapest, Hungary; to U.S. 1930, became citizen 1937; research professor of mathematics Institute for Advanced Study, Princeton, N.J., after 1933, leave of absence to serve on Atomic Energy Commission 1954-57; made important contribution to H-bomb by developing high-speed calculators; expert on games of strategy and their application to economic behavior; Fermi award 1956 for contributions to atomic energy*

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A SHORT STORY OF COMPUTERS 1997

PART I. *INTRODUCTION*

Generally, a computer is any device that can perform numerical calculations even an adding machine, an abacus, or a slide rule. Currently, however, the term usually refers to an electronic device that can use a list of instructions, called a program, to perform calculations or to store, manipulate, and retrieve information.

Today's computers are marvels of miniaturization. Machines that once weighed 30 tons and occupied warehouse-size rooms now may

weigh as little as three pounds (1.4 kilograms) and can be carried in a suit pocket. The heart of today's computers are integrated circuits (ICs), sometimes called microchips, or simply chips. These tiny silicon wafers can contain millions of microscopic electronic components and are designed for many specific operations: some control an entire computer (CPU, or central processing unit, chips); some perform millions of mathematical operations per second (math coprocessors); others can store more than 16 million characters of information at one time (memory chips).

In 1953 there were only about 100 computers in use in the entire world. Today hundreds of millions of computers form the core of electronic products, and more than 110 million programmable computers are being used in homes, businesses, government offices, and universities for almost every conceivable purpose.

Computers come in many sizes and shapes. Special-purpose, or dedicated, computers are designed to perform specific tasks. Their operations are limited to the programs built into their microchips. These computers are the basis for electronic calculators and can be found in thousands of other electronic products, including digital watches (controlling timing, alarms, and displays), cameras (monitoring shutter speeds and aperture settings), and automobiles (controlling fuel injection, heating, and air conditioning and monitoring hundreds of electronic sensors).

General-purpose computers, such as personal computers and business computers, are much more versatile because they can accept new sets of instructions. Each new set of instructions, or program, enables the same computer to perform a different type of operation. For example, one program lets the computer act like a word processor, another lets it manage inventories, and yet another transforms it into a video game.

Although some general-purpose computers are as small as pocket radios, the smallest class of fully functional, self-contained computers is the class called notebook computers. These usually consist of a CPU, data-storage devices called disk drives, a liquid-crystal display (LCD), and a full-size keyboard all housed in a single unit small enough to fit into a briefcase.

Today's desktop personal computers, or PCs, are many times more powerful than the huge, million-dollar business computers of the 1960s and 1970s. Most PCs can perform from 16 to 66 million operations per second, and some can even perform more than 100 million. These computers are used not only for household management and personal entertainment, but also for most of the automated tasks required by small businesses, including word processing, generating mailing lists, tracking inventory, and calculating accounting information.

Minicomputers are fast computers that have greater data manipulating capabilities than personal computers and can be used simultaneously by many people. These machines are primarily used by larger businesses to handle extensive accounting, billing, and inventory records.

Mainframes are large, extremely fast, multi-user computers that often contain complex arrays of processors, each designed to perform a specific function. Because they can handle huge databases, can simultaneously accommodate scores of users, and can perform complex mathematical operations, they are the mainstay of industry, research, and university computing centers.

The speed and power of supercomputers, the fastest class of computer, are almost beyond human comprehension, and their capabilities are continually being improved. The most sophisticated of these machines can perform nearly 32 billion calculations per second, can store a billion characters in memory at one time, and can do in one hour what a desktop computer would take 40 years to do. Supercomputers attain these speeds through the use of several advanced engineering techniques. For example, critical circuitry is supercooled to nearly absolute zero so that electrons can move at the speed of light, and many processors are linked in such a way that they can all work on a single problem simultaneously. Because these computers can cost millions of dollars, they are used primarily by government agencies and large research centers.

Computer development is rapidly progressing at both the high and the low ends of the computing spectrum. On the high end, by linking together networks of several small computers and programming them to use a language called Linda, scientists have been able to outperform the supercomputer. This technology is called parallel processing and helps avoid hours of idle computer time. A goal of this technology is the creation of a machine that could perform a trillion calculations per second, a measure known as a teraflop. On the other end of the spectrum, companies like Apple and Compaq are developing small, handheld personal digital assistants (PDAs). The Apple Newton, for example, lets people use a pen to input handwritten information through a touch-sensitive screen and to send mail and faxes to other computers. Researchers are currently developing microchips called digital signal processors, or DSPs, to enable these PDAs to recognize and interpret human speech. This development, which will permit people in all professions to use a computer quickly and easily, promises to lead to a revolution in the way humans communicate and transfer information.

PART II. *COMPUTERS AT WORK, APPLICATIONS*

Section 1. *Communication*

Computers make all modern communication possible. They operate telephone switching systems, coordinate satellite launches and operations, help generate special effects for movies, and control the equipment in all phases of television and radio broadcasts. Local-area networks (LANs) link the computers in separate departments of businesses or universities, and larger networks, such as the Internet, permit modems telecommunication devices that transmit data through telephone lines to link individual computers to other computers anywhere in the world. Journalists and writers now use word processors to write books and articles, which they then submit to publishers on magnetic disks or through telephone lines. The data may then be sent directly to computer-controlled typesetters, some of which actually design the layout of printed pages on computer screens.

Section 2. *Science and research*

Computers are used by scientists and researchers in many ways to collect, store, manipulate, and analyze data. Running simulations is one of the most important applications. Data representing a real-life system is entered into the computer, and the computer manipulates the data in order to show how the natural system is likely to behave under a variety of conditions. In this way scientists can test new theories and designs or can examine a problem that does not lend itself to direct experimentation. Computer-aided design, or CAD, programs enable engineers and architects to design three-dimensional models on a computer screen. Chemists may use computer simulation to design and test molecular models of new drugs. Some simulation programs can generate models of weather conditions to help meteorologists make predictions. Flight simulators are valuable training tools for pilots.

Section 3. *Industry*

Computers have opened a new era in manufacturing and consumer-product development. In the factory, computer-assisted manufacturing, or CAM, programs help people plan complex production schedules, keep track of inventories and accounts, run automated assembly lines, and control robots. Dedicated computers are routinely used in thousands of products ranging from calculators to airplanes.

Section 4. *Government*

Government agencies are the largest users of mainframes and supercomputers. The United States Department of Defense uses computers for hundreds of tasks, including research, breaking codes, interpreting data from spy satellites, and targeting missiles. The Internal Revenue Service uses computers to keep track of tens of millions of tax returns. Computers are also essential for taking the census, maintaining criminal records, and other tasks.

Section 5. *Education*

Computers have proved to be valuable educational tools. Computer-assisted instruction, or CAI, uses computerized lessons that range from simple drills and practice sessions to complex interactive tutorials. These programs have become essential teaching tools in medical schools and military training centers, where the topics are complex and the cost of human teachers is extremely high. Educational aids, such as some encyclopedias and other major reference works, are available to personal-computer users either on magnetic disks or optical discs or through various telecommunication networks.

Section 6. *Arts and Entertainment*

Video games are one of the most popular applications of personal computers. The constantly improving graphics and sound capabilities of personal computers have made them popular tools for artists and musicians. Personal computers can display millions of colors, can produce images far clearer than those of a television set, and can connect to various musical instruments and synthesizers. Painting and drawing programs enable artists to create realistic images and animated displays much more easily than they could with more traditional tools. „Morphing” programs allow photographers and filmmakers to transform photographic images into any size and shape they can imagine. High-speed supercomputers can insert life-like animated images into frames of a film so seamlessly that movie-goers cannot distinguish real actors from computer-generated images. Musicians can use computers to create multiple-voice compositions and to play back music with hundreds of variations. Speech processors even give a computer the ability to talk and sing.

PART III. *TYPES OF COMPUTERS*

There are two fundamentally different types of computers analog and digital. (Hybrid computers combine elements of both types.) Analog computers solve problems by using continuously changing data (such as pressure or voltage) rather than by manipulating discrete binary digits (1s and 0s) as a digital computer does. In current usage, the term computer usually refers to digital computers. Digital computers are generally more effective than analog computers for four principal reasons: they are faster; they are not as susceptible to signal interference; they can convey data with more precision; and their coded binary data are easier to store and transfer than are analog signals.

Section 1. *Analog computers*

Analog computers work by translating constantly changing physical conditions (such as temperature, pressure, or voltage) into corresponding mechanical or electrical quantities. They offer continuous solutions to the problems on which they are operating. For example, an automobile speedometer is a mechanical analog computer that measures the rotations per minute of the drive shaft and translates that measurement into a display of miles per hour. Electronic analog computers in chemical plants monitor temperatures, pressures, and flow rates and send corresponding voltages to various control devices, which, in turn, adjust the chemical processing conditions to their proper levels.

Section 2. *Digital computers*

For all their apparent complexity, digital computers are basically simple machines. Every operation they perform, from navigating a spacecraft to playing a game of chess, is based on one key operation determining whether certain switches, called gates, are open or closed. The real power of a computer lies in the speed with which it checks these switches anywhere from 1 million to 4 billion times, or cycles, per second.

A computer can recognize only two states in each of its millions of circuit switches on or off, or high voltage or low voltage. By assigning binary numbers to these states 1 for on and 0 for off, for example and linking many switches together, a computer can represent any type of data from numbers to letters to musical notes. This process is called digitization.

Imagine that a computer is checking only one switch at a time. If the switch is on, it symbolizes one operation, letter, or number; if the switch is off it represents another. When switches are linked together as a unit, the computer can recognize more data in each cycle. For example, if a computer checks two switches at once it can recognize any of four pieces of data one represented by the combination off-off; one by off-on; one by on-off; and one by on-on. The more switches a computer checks in each cycle, the more data it can recognize at one time and the faster it can operate. Below are some common groupings of switches (each switch is called a binary digit, or bit) and the number of discrete units of data that they can symbolize:

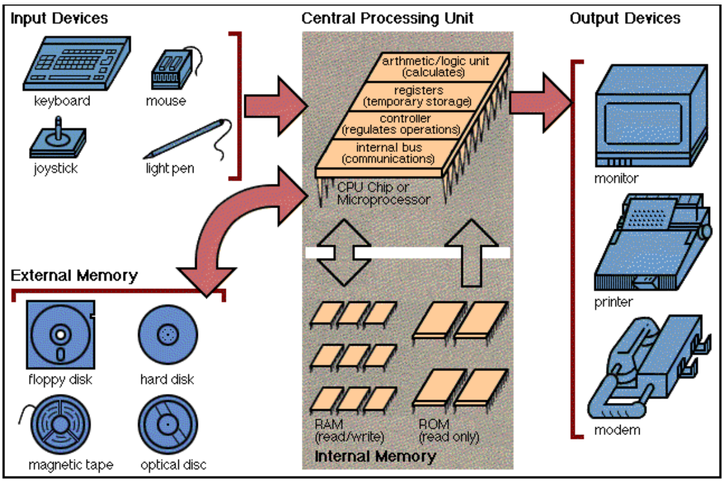
4 bits = a nibble (16 pieces of data);
8 bits = a byte (256 pieces of data);
16 bits = a word (65,536 pieces of data).
32 bits = a double word (4,294,967,296 pieces of data).

A byte is the basic unit of data storage because all characters, numbers, and symbols on a keyboard can be symbolized by using a combination of only eight 0s and 1s.

Each combination of ons and offs represents a different instruction, part of an instruction, or type of data (number, letter, or symbol). For example, depending on its context in a program, a byte with a pattern of 01000001 may symbolize the number 65, the capital letter A, or an instruction to the computer to move data from one place to another.

PART IV. *PARTS OF A DIGITAL COMPUTER SYSTEM*

A digital computer is a complex system of four functionally different elements a central processing unit, input devices, memory-storage devices, and output devices linked by a communication network, or bus. These physical parts and all their physical components are called hardware.



Without a program, a computer is nothing but potential. Programs, also called software, are detailed sequences of instructions that direct the computer hardware to perform useful operations.

Section 1. *Hardware*

1.1. The central processing unit, or CPU

The central processing unit, or CPU, is the heart of a computer. In addition to performing arithmetic and logic operations on data, it times and controls the rest of the system. Mainframe CPUs sometimes consist of several linked microchips, each performing a separate task, but most other computers require only a single microprocessor as a CPU.

Most CPU chips and microprocessors have four functional sections:

(1) the arithmetic/logic unit, which performs arithmetic operations (such as addition and subtraction) and logic operations (such as testing a value to see if it is true or false);

(2) temporary storage locations, called registers, which hold data, instructions, or the results of calculations;

(3) the control section, which times and regulates all elements of the computer system and also translates patterns in the registers into computer activities (such as instructions to add, move, or compare data); and

(4) the internal bus, a network of communication lines that links internal CPU elements and offers several different data paths for input from and output to other elements of the computer system.

1.2. Input devices

Input devices let users enter commands, data, or programs for processing by the CPU. Computer keyboards, which are much like typewriter keyboards, are the most common input devices. Information typed at the keyboard is translated into a series of binary numbers that the CPU can manipulate. Another common input device, the mouse, is a mechanical or optomechanical device with buttons on the top and a rolling ball in its base. To move the cursor on the display screen, the user moves the mouse around on a flat surface. The user selects operations, activates commands, or creates or changes images on the screen by pressing buttons on the mouse.

Other input devices include joysticks and trackballs. Light pens can be used to draw or to point to items or areas on the display screen. A sensitized digitizer pad translates images drawn on it with an electronic stylus or pen into a corresponding image on the display screen. Touch-sensitive display screens allow users to point to items or areas on the screen and to activate commands. Optical scanners „read" characters on a printed page and translate them into binary numbers that the CPU can use. Voice-recognition circuitry digitizes spoken words and enters them into the computer.

1.3. Memory-storage devices.

Most digital computers store data both internally, in what is called main memory, and externally, on auxiliary storage units. As a computer processes data and instructions, it temporarily stores information internally, usually on silicon random-access memory, or RAM, chips often called semiconductor memory. Usually mounted on the main circuit board inside the computer or on peripheral cards that plug into the board, each RAM chip may consist of as many as 16 million switches, called flip-flop switches, that respond to changes in electric current. Each switch can hold one bit of data: high voltage applied to a switch causes it to hold a 1; low voltage causes it to hold a 0. This kind of internal memory is also called read/write memory.

Another type of internal memory consists of a series of read-only memory, or ROM, chips. The switches of ROM chips are set when they are manufactured and are unchangeable. The patterns on these chips correspond to commands and programs that the computer needs in order to boot up, or ready itself for operation, and to carry out basic operations. Because read-only memory is actually a combination of hardware (microchips) and software (programs), it is often referred to as firmware.

Other devices that are sometimes used for main memory are magnetic-core memory and magnetic-bubble memory. Unlike semiconductor memories, these do not lose their contents if the power supply is cut off. Long used in mainframe computers, magnetic-core memories are being supplanted by the faster and more compact semiconductor memories in mainframes designed for high-speed applications. Magnetic-bubble memory is used more often for auxiliary storage than for main memory.

1.4. Auxiliary storage units

Auxiliary storage units supplement the main memory by holding parts of programs that are too large to fit into the random-access memory at one time. They also offer a more permanent and secure method for storing programs and data.

Four auxiliary storage devices floppy disks, hard disks, magnetic tape, and magnetic drums store data by magnetically rearranging metal particles on disks, tape, or drums. Particles oriented in one direction represent 1s, and particles oriented in another direction represent 0s. Floppy-disk drives (which „write" data on removable magnetic disks) can store from 140,000 to 2.8 million bytes of data on one disk and are used primarily in laptop and personal computers. Hard disk drives contain nonremovable magnetic media and are used with all types of computers. They access data very quickly and can store from 10 million bytes (10 megabytes) of data to a few gigabytes (billion bytes).

Magnetic-tape storage devices are usually used together with hard disk drives on large computer systems that handle high volumes of constantly changing data. The tape drives, which access data very slowly, regularly back up, or duplicate, the data in the hard disk drives to protect the system against loss of data during power failures or computer malfunctions.

Magnetic-drum memories store data in the form of magnetized spots in adjacent circular tracks on the surface of a rotating metal cylinder. They are relatively slow and are rarely used today.

Optical discs are nonmagnetic auxiliary storage devices that developed from compact-audio-disc technology. Data is encoded on a disc as a series of pits and flat spaces, called lands, the lengths of which correspond to different patterns of 0s and 1s. One removable 4 ¾-inch (12-centimeter) disc contains a spiral track more than 3 miles (4.8 kilometers) long, on which can be stored nearly a billion bytes (gigabyte) of information. All of the text in this encyclopedia, for example, would fill only one fifth of one disc. Read-only optical discs, whose data can be read but not changed, are called CD-ROMs (compact disc-read-only memory). (See also Compact Disc.) Recordable CD-ROM drives, called WORM (write-once/read-many) drives, are used by many businesses and universities to periodically back up changing databases and to conveniently distribute massive amounts of information to customers or users.

1.5. Output devices

Output devices let the user see the results of the computer's data processing. The most common output device is the video display terminal (VDT), or monitor, which uses a cathode-ray tube (CRT) to display characters and graphics on a television-like screen.

1.6. Modems (modulator-demodulators)

Modems are input-output devices that allow computers to transfer data between each other. A modem on one computer translates digital pulses into analog signals (sound) and then transmits the signals through a telephone line or a communication network to another computer. A modem on the computer at the other end of the line reverses the process.

1.7. Printers

Printers generate hard copy, a printed version of information stored in one of the computer's memory systems. The three principal types of printers are daisy-wheel, dot-matrix, and laser. Other types of printers include ink-jet printers and thermal printers. (See also Photocopying.)

Section 2. *Software*

2.1. Operating system

A computer's operating system is the software that allows all of the dissimilar hardware and software systems to work together. It is often stored in a computer's ROM memory. An operating system consists of programs and routines that coordinate operations and processes, translate the data from different input and output devices, regulate data storage in memory, allocate tasks to different processors, and provide functions that help programmers write software.

Computers that use disk memory-storage systems are said to have disk operating systems (DOS). MS-DOS is the most popular microcomputer operating system. UNIX, a powerful operating system for larger computers, allows many users and many different programs to gain access to a computer's processor at the same time. Visual operating systems called GUIs (graphical user interfaces) were designed to be easy to use, yet to give UNIX-like power and flexibility to home and small-business users. Future operating systems will enable users to control all aspects of the computer's hardware and software simply by moving and manipulating their corresponding „objects," or graphical icons displayed on the screen.

2.2. Built-in programs

Sometimes programs other than the operating system are built into the hardware, as is the case in dedicated computers or ROM chips. Most often, however, programs exist independently of the computer. When such software is loaded into a general-purpose computer, it automatically programs the computer to perform a specific task such as word processing, managing accounts and inventories, or displaying an arcade game.

2.3. Programming.

Software is written by professionals known as computer programmers. Most programmers in large corporations work in teams, with each person focusing on a specific aspect of the total project. (The eight programs that run each craft in the Space Shuttle program, for example, consist of a total of about half a million separate instructions and were written by hundreds of programmers.) For this reason, scientific and industrial software sometimes costs much more than do the computers on which the programs run.

Generally, programmers create software by using the following step-by-step development process:

(1) Define the scope of the program by outlining exactly what the program will do.
(2) Plan the sequence of computer operations, usually by developing a flowchart (a diagram showing the order of computer actions and data flow).
(3) Write the code the program instructions encoded in a particular programming language.
(4) Test the program.
(5) Debug the program (eliminate problems in program logic and correct incorrect usage of the programming language).
(6) Submit the program for beta testing, in which users test the program extensively under real-life conditions to see whether it performs correctly.

Often the most difficult step in program development is the debugging stage. Problems in program design and logic are often difficult to spot in large programs, which consist of hundreds of smaller units called subroutines or subprograms. Also, though a program might work, it is considered to have bugs if it is slower or less efficient than it should be. (The term bug was coined in the early 1940s, when programmers looking for the cause of a mysterious malfunction in the huge Mark I computer discovered a moth in a vital electrical switch. Thereafter the programmers referred to their activity as debugging.)

2.4. Logic bombs, viruses, and worms.

In an effort to sabotage other people's computers, some computer users (sometimes called hackers) create software that can manipulate or destroy another computer's programs or data. One such program, called a logic bomb, consists of a set of instructions entered into a computer's software. When activated, it takes control of the computer's programs. A virus attaches itself to a program, often in the computer's operating system, and then copies itself onto other programs with which it comes in contact. Viruses can spread from one computer to another by way of exchanged disks or programs sent through telephone lines. Worms are self-contained programs that enter a computer and generate their own commands. Logic bombs, viruses, and worms, if undetected, may be powerful enough to cause a whole computer system to crash.

2.5. Programming languages.

On the first electronic computers, programmers had to reset switches and rewire computer panels in order to make changes in programs. Although programmers still must „set" (to 1) or „clear" (to 0) millions of switches in the microchips, they now use programming languages to tell the computer to make these changes.

There are two general types of languages low-level and high-level. Low-level languages are similar to a computer's internal binary language, or machine language. They are difficult for humans to use and cannot be used interchangeably on different types of computers, but they produce the fastest programs. High-level languages are less efficient but are easier to use because they resemble spoken languages.

A computer „understands" only one language patterns of 0s and 1s. For example, the command to move the number 255 into a CPU register, or memory location, might look like this: 00111110 11111111. A program might consist of thousands of such operations. To simplify the procedure of programming computers, a low-level language called assembly language was developed by assigning a mnemonic code to each machine-language instruction to make it easier to remember and write. The above binary code might be written in assembly language as: MVI A,0FFH. To the programmer this means „MoVe Immediately to register A the value FF (hexadecimal for 255)." A program can include thousands of these mnemonics, which are then assembled, or translated, into binary machine code. High-level languages use easily remembered English-language-like commands (such as PRINT, OPEN, GOTO, INCLUDE, and so on) that represent frequently used groups of machine-language instructions. Entered from the keyboard or from a program, these commands are intercepted by a separate program an interpreter or compiler that translates the commands into the binary code the computer uses. The extra step, however, causes programs to run more slowly than do programs in low-level languages.

The first commercial high-level language was called FLOW-MATIC and was devised in the early 1950s by Grace Hopper, a U.S. Navy computer programmer. In 1954, as computers were becoming an increasingly important scientific tool, IBM began developing a language that would simplify the programming of complicated mathematical formulas. Completed in 1957, FORTRAN (Formula Translating system), became the first comprehensive high-level programming language. Its importance was immediate and long-lasting, and it is still widely used today in engineering and scientific applications.

FORTRAN manipulated numbers and equations efficiently, but it was not suited for business-related tasks, such as creating, moving, and processing data files. COBOL (Common Business-Oriented Language) was developed to address those needs. Based on FORTRAN, but with its emphasis shifted to data organization and file-handling, COBOL became the most important programming language for commercial and business-related applications and is widely used today.

A simplified version of FORTRAN, called BASIC (Beginner's All-purpose Symbolic Instruction Code), was developed in the 1960s by two professors at Dartmouth College. Considered too slow and inefficient for professional use, BASIC was nevertheless simple to learn and easy to use, and it became an important academic tool for teaching programming fundamentals to non-professional computer users. The explosion of microcomputer use in the late-1970s and 1980s transformed BASIC into a universal programming language. Because almost all microcomputers are sold with some version of BASIC included, millions of people now use the language, and tens of thousands of BASIC programs are now in common use.

Hundreds of computer programming languages (or language variants) exist today. Pascal is a highly structured language that teaches good programming techniques and therefore is often taught in universities. Another educational language, LOGO, was developed to teach children mathematical and logical concepts. LISP (list processing), developed to manipulate symbolic lists of recursive data, is used in most artificial-intelligence programs. C, a fast and efficient language used for operating systems and in many professional and commercial-quality programs, has recently evolved into the computer world's most powerful programming tool C++. This object-oriented programming (OOP) language lets programs be constructed out of self-contained modules of code and data, called classes, that can be easily modified and reused in other products

2.6. Software Publishing

Software is the term used to describe computer programs. Since 1979 when VisiCalc, one of the most successful early programs, was introduced, software publishing has grown even faster than the computer industry itself. In the late 1980s there were more than 14,000 companies producing about 27,000 products.

The range of software programs has expanded dramatically to include accounting, bookkeeping, foreign languages, office management, school subjects, games, engineering and drafting, graphics design, inventory records, legal services, medical records, real estate management, travel reservation systems, library acquisitions, word processing, and much more. Individual computer owners often use programs for desktop publishing. These programs make it possible to combine word processing with illustrations on a single page (see Word Processing).

Marketing for software is very similar to that for books. The software itself is on floppy discs of various sizes, and these are packaged along with instructional material and encased in clear plastic wrapping or in boxes. The packages are displayed on shelves, much the same way books are. Some of the larger producers sell their software directly to companies. Because of the enormous software production each year, the products are catalogued for reference in such publications as the 'Software Encyclopedia' published by the R.R. Bowker Company.

PART V. *HISTORY OF THE COMPUTER*

The ideas and inventions of many mathematicians, scientists, and engineers paved the way for the development of the modern computer. In a sense, the computer actually has three birth dates one as a mechanical computing device, in about 500 BC, another as a concept (1833), and the third as the modern electronic digital computer (1946).

Section 1. *Calculating Devices*

The first mechanical calculator, a system of strings and moving beads called the abacus, was devised in Babylonia around 500 BC. The abacus provided the fastest method of calculating until 1642, when the French scientist Blaise Pascal invented a calculator made of wheels and cogs. When a units wheel moved one revolution (past ten notches), it moved the tens wheel one notch; when the tens wheel moved one revolution, it moved the hundreds wheel one notch; and so on. Improvements on Pascal's mechanical calculator were made by such scientists and inventors as Gottfried Wilhelm Leibniz, W.T. Odhner, Dorr E. Felt, Frank S. Baldwin, and Jay R. Monroe. (See also Abacus; Calculator; Leibniz, Gottfried Wilhelm; Pascal, Blaise.)

Section 2. *Beyond the Adding Machine*

The concept of the modern computer was first outlined in 1833 by the British mathematician Charles Babbage. His design of an „analytical engine" contained all of the necessary elements of a modern computer: input devices, a store (memory), a mill (computing unit), a control unit, and output devices. The design called for more than 50,000 moving parts in a steam-driven machine as large as a locomotive. Most of the actions of the analytical engine were to be executed through the use of perforated cards an adaptation of a method that was already being used to control automatic silk-weaving machines called Jacquard looms. Although

Babbage worked on the analytical engine for nearly 40 years, he never actually constructed a working machine. (See also Babbage, Charles.)

Herman Hollerith, an American inventor, spent the 1880s developing a calculating machine that counted, collated, and sorted information stored on punched cards. When cards were placed in his machine, they pressed on a series of metal pins that corresponded to the network of potential perforations. When a pin found a hole (punched to represent age, occupation, and so on), it completed an electrical circuit and advanced the count for that category. First used to help sort statistical information for the 1890 United States census, Hollerith's „tabulator" quickly demonstrated the efficiency of mechanical data manipulation. The previous census took seven and a half years to tabulate by hand, but, using the tabulator, the simple count for the 1890 census took only six weeks, and a full-scale analysis of all the data took only two and a half years.

In 1896 Hollerith founded the Tabulating Machine Company to produce similar machines. In 1924, after a number of mergers, the company changed its name to International Business Machines Corporation (IBM). IBM made punch-card office machinery the dominant business information system until the late 1960s, when a new generation of computers rendered the punch card machines obsolete.

In the late 1920s and 1930s, several new types of calculators were constructed. Vannevar Bush, an American engineer, developed the differential analyzer, the first calculator capable of solving differential equations. His machine calculated with decimal numbers and therefore required hundreds of gears and shafts to represent the various movements and relationships of the ten digits.

In 1939 the American physicists John V. Atanasoff and Clifford Berry produced the prototype of a computer based on the binary numbering system. Atanasoff reasoned that binary numbers were better suited to computing than were decimal numbers because the two digits 1 and 0 could easily be represented by electrical circuits, which were either on or off. Furthermore, George Boole, a British mathematician, had already devised a complete system of binary algebra that might be applied to computer circuits. Developed in 1848, Boolean algebra bridged the gap between mathematics and logic by symbolizing all information as being either true or false. (See also Algebra, „Boolean Algebra"; Boole, George.)

Section 3. *Electronic Digital Computers*

The modern computer grew out of intense research efforts mounted during World War II. The military needed faster ballistics calculators, and British cryptographers needed machines to help break the German secret codes.

As early as 1941 the German inventor Konrad Zuse produced an operational computer, the Z3, that was used in aircraft and missile design. The German government refused to help him refine the machine, however, and the computer never achieved its full potential.

A Harvard mathematician named Howard Aiken directed the development of the Harvard-IBM Automatic Sequence Controlled Calculator, later known as the Mark I an electronic computer that used 3,304 electromechanical relays as on-off switches. Completed in 1944, its primary function was to create ballistics tables to make Navy artillery more accurate.

The first fully electronic computer, which used vacuum tubes rather than mechanical relays, was so secret that its existence was not revealed until decades after it was built. Invented by the English mathematician Alan Turing and in operation by 1943, the Colossus was the computer that British cryptographers used to break secret German military codes. Messages were encoded as symbols on loops of paper tape, and the 2,000-tube computer compared them at nearly 25,000 characters per second with codes that had already been deciphered.

Because Colossus was designed for only one task, the distinction as the first modern general-purpose electronic computer properly belongs to ENIAC (Electronic Numerical Integrator and Calculator). Designed by two American engineers, John W. Mauchly and J. Presper Eckert, Jr., ENIAC went into service at the University of

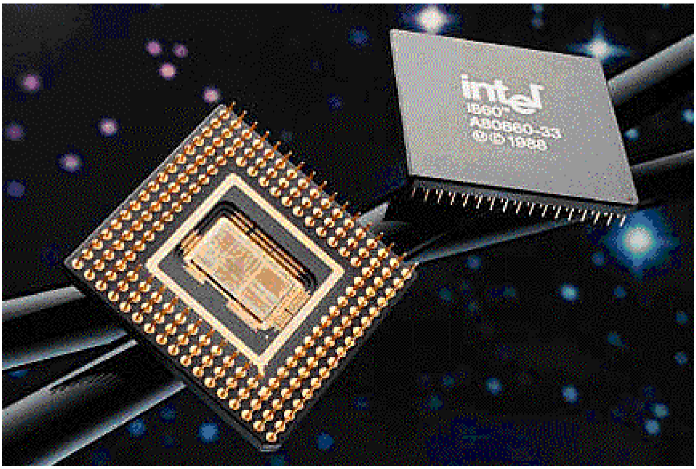
Pennsylvania in 1946. Its construction was an enormous feat of engineering the 30-ton machine was 18 feet (5.5 meters) high and 80 feet (24 meters) long, and contained 17,468 vacuum tubes linked by 500 miles (800 kilometers) of wiring. ENIAC performed 100,000 operations per second, and its first operational test included calculations that helped determine the feasibility of the hydrogen bomb.

To change ENIAC's instructions, or program, engineers had to rewire the machine. The next computers were built so that programs could be stored in internal memory and could be easily changed to adapt the computer to different tasks. These computers followed the theoretical descriptions of the ideal „universal" (general-purpose) computer first outlined by Turing and later refined by John von Neumann, a Hungarian-born mathematician.

The invention of the transistor in 1948 brought about a revolution in computer development. Hot, unreliable vacuum tubes were replaced by small germanium (later silicon) transistors that generated little heat yet functioned perfectly as switches or amplifiers (see Transistor).

The breakthrough in computer miniaturization came in 1958, when Jack Kilby, an American engineer, designed the first true integrated circuit. His prototype consisted of a germanium wafer that included transistors, resistors, and capacitors the major components of electronic circuitry. Using less expensive silicon chips, engineers succeeded in putting more and more electronic components on each chip. The development of large-scale integration (LSI) made it possible to cram hundreds of components on a chip; very-large-scale integration (VLSI) increased that number to hundreds of thousands; and engineers project that ultra-large-scale integration (ULSI) techniques will allow as many as 10 million components to be placed on a microchip the size of a fingernail.

Another revolution in microchip technology occurred in 1971 when the American engineer Marcian E. Hoff combined the basic elements of a computer on one tiny silicon chip, which he called a microprocessor. This microprocessor the Intel 4004 and the hundreds of variations that followed are the dedicated computers that operate thousands of modern products and form the heart of almost every general-purpose electronic computer. (See also Microprocessor.)



Section 4. *PCs and other Revolutions*

By the mid-1970s, microchips and microprocessors had drastically reduced the cost of the thousands of electronic components required in a computer. The first affordable desktop computer designed specifically for personal use was called the Altair 8800 and was sold by Micro Instrumentation Telemetry Systems in 1974. In 1977 Tandy Corporation became the first major electronics firm to produce a personal computer. They added a keyboard and CRT to their computer and offered a means of storing programs on a cassette recorder. Soon afterward, a small company named Apple Computer, founded by engineer Stephen Wozniak and entrepreneur Steven Jobs, began producing a superior computer.

IBM introduced its Personal Computer, or PC, in 1981. As a result of competition from the makers of clones (computers that worked exactly like an IBM-PC), the price of personal computers fell drastically. Today’s personal computer is 400 times faster than ENIAC, 3,000 times lighter, and several million dollars cheaper. In rapid succession computers have shrunk from tabletop to lap-top and finally to palm size. With some personal computers, called pen-pads, people can even write directly on an etched-glass, liquid-crystal screen using a small electronic stylus, and words will appear on the screen in clean typescript.

PART VI. *VIRTUAL REALITY*

As personal computers became faster and more powerful in the late 1980s, software developers discovered that they were able to write programs as large and as sophisticated as those previously run only on mainframes. The massive million-dollar flight simulators on which military and commercial pilots trained were the first real-world simulations to be moved to the personal computer.

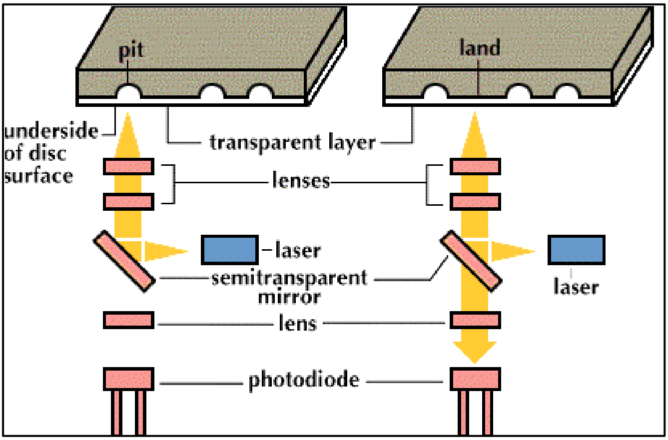
Flight simulators are perfect examples of programs that create a virtual reality, or a computer-generated „reality” in which the user does not merely watch but is able to actually participate. The user supplies input to the system by pushing buttons or moving a yoke or joystick, and the computer uses real-world data to determine the results of those actions. For example, if the user pulls back on the flight simulator’s yoke, the computer translates the action according to built-in rules derived from the performance of a real airplane. The monitor will show exactly what an airplanes viewscreen would show as it begins to climb. If the user continues to climb without increasing the throttle, the „virtual plane” will stall (as would a real plane) and the „pilot” will lose control. Thus the user’s physical actions are immediately and realistically reflected on the computer’s display. For all intents and purposes, the user is flying that is, the „plane” obeys the same laws of nature, has the same mechanical capabilities, and responds to the same commands as a real airplane.

Virtual reality programs give users three essential capabilities immersion, navigation, and manipulation. People must be immersed in the alternate reality, not merely feel as if they are viewing it on a screen. To this end, some programs require people to wear headphones, use special controllers or foot pedals, or wear 3-D glasses. The most sophisticated means of immersing users in a virtual reality program is through the use of head-mounted displays, helmets that feed slightly different images to either eye and that actually move the computer image in the direction that the user moves his or her head. Virtual reality programs also create a world that is completely consistent internally. Thus one can navigate one's way though that world as „realistically" as in the real world. For example, a street scene will always show the same doors and windows, which, though their perspective may change, is always absolutely consistent internally. The most important aspect of a virtual reality program is its ability to let people manipulate objects in that world. Pressing a button may fire a gun, holding down a key may increase a plane's speed, clicking a mouse may open a door, or pressing arrow keys may rotate an object.

Many amusement parks now have rides and attractions that use virtual reality principles for creating exciting alternate realities for their audiences for example, a simulated ride in a spaceship, complete with near collisions and enemy attacks. Acceleration and deceleration are simulated by pitching and moving seats, all computer-controlled and cleverly coordinated with stereo sound effects and wrap-around video displays.

PART VII. *MULTIMEDIA*

In the early 1990s, manufacturers began producing inexpensive CD-ROM drives that could access more than 650 megabytes of data from a single disc.



This development started a multimedia revolution that may continue for decades. The term multimedia encompasses the computer's ability to merge sounds, video, text, music, animations, charts, maps, etc., into colorful, interactive presentations, a business advertising campaign, or even a space-war arcade game.

Audio and video clips require enormous amounts of storage space, and for this reason, until recently, programs could not use any but the most rudimentary animations and sounds. Floppy and hard disks were just too small to accommodate the hundreds of megabytes of required data. The enormous storage potential of CD-ROM changed all that. Driving simulations, for example, can now show actual footage of the Indianapolis Speedway as the user plays the game.

The manufacturer first digitizes video scenes of the speedway and records the real sounds of the racers as they circle the track. Those images and sounds are then stored on a CD-ROM disc with the driving program itself. When a user runs the simulation and turns his computerized car, for example, the program senses the „turn" and immediately flashes the corresponding real sounds and scenes on the screen. Likewise, when a driver's car approaches another car, a video image of a real car is displayed on the screen. By using simultaneous clips from several different media, the user's senses of sight, sound, and touch are merged into an astonishingly real experience.

Faster computers and the rapid proliferation of multimedia programs will probably forever change the way people get information. The computer's ability to instantly retrieve a tiny piece of information from the midst of a huge mass of data has always been one of its most important uses. Since video and audio clips can be stored alongside text on a single CD-ROM disc, a whole new way of exploring a subject is possible. By using hyperlinks a programming method by which related terms, articles, pictures, and sounds are internally hooked together material can be presented to people so that they can peruse it in a typically human manner, by association. For example, if you are reading about Abraham Lincoln's Gettysburg Address and you want to read about the battle of Gettysburg, you need only click on the highlighted hyperlink „battle of Gettysburg." Instantly, the appropriate text, photos, and maps appear on the monitor. „Pennsylvania" is another click away, and so on. Encyclopedias, almanacs, collections of reference books, interactive games using movie footage, educational programs, and even motion pictures with accompanying screenplay, actor biographies, director's notes, and reviews make multimedia one of the computer world's most exciting and creative fields.

PART VIII. *THE INFORMATION SUPERHIGHWAY*

A computer network is the interconnection of many individual computers, much as a road is the link between the homes and the buildings of a city. Having many separate computers linked on a network provides many advantages to organizations such as businesses and universities. People may quickly and easily share files; modify databases; send memos called E-mail, or electronic mail; run programs on remote mainframes; and get access to information in databases that are too massive to fit on a small computer's hard drive. Networks provide an essential tool for the routing, managing, and storing of huge amounts of rapidly changing data.

The Internet is a network of networks: the international linking of tens of thousands of businesses, universities, and research organizations with millions of individual users. It is what United States Vice-President Al Gore first publicly referred to as the information superhighway. What is now known as the Internet was originally formed in 1970 as a military network called ARPAnet (Advanced Research Projects Agency network) as part of the Department of Defense. The network opened to non-military users in the 1970s, when universities and companies doing defense-related research were given access, and flourished in the late 1980s as most universities and many businesses around the world came on-line. In 1993, when commercial providers were first permitted to sell Internet connections to individuals, usage of the network exploded. Millions of new users came on within months, and a new era of computer communications began.

Most networks on the Internet make certain files available to other networks. These common files can be databases, programs, or E-mail from the individuals on the network. With hundreds of thousands of international sites each providing thousands of pieces of data, it’s easy to imagine the mass of raw data available to users.

The Internet is by no means the only way in which computer users can communicate with others. Several commercial on-line services provide connections to members who pay a monthly connect-time fee. CompuServe, America OnLine, Prodigy, Genie, and several others provide a tremendous range of information and services, including on-line conferencing, electronic mail transfer, program downloading, current weather and stock market information, travel and entertainment information, access to encyclopedias and other reference works, and electronic forums for specific users’ groups such as PC users, sports fans, musicians, and so on.

PART IX. *ARTIFICIAL INTELLIGENCE AND EXPERT SYSTEMS*

The standard definition of artificial intelligence is „the ability of a robot or computer to imitate human actions or skills such as problem solving, decision making, learning, reasoning, and self-improvement." Today's computers can duplicate some aspects of intelligence: for example, they can perform goal-directed tasks (such as finding the most efficient solution to a complex problem), and their performance can improve with experience (such as with chess-playing computers). However, the programmer chooses the goal, establishes the method of operation, supplies the raw data, and sets the process in motion. Computers are not in themselves intelligent.

It is widely believed that human intelligence has three principal components: (1) consciousness, (2) the ability to classify knowledge and retain it, and (3) the ability to make choices based on accumulated memories. Expert systems, or computers that mimic the decision-making processes of human experts, already exist and competently perform the second and third aspects of intelligence. INTERNIST is a computer system that diagnoses 550 diseases and disorders with an accuracy that rivals that of human doctors. PROSPECTOR is an expert system that aids geologists in their search for new mineral deposits. Using information obtained from maps, surveys, and questions that it asks geologists, PROSPECTOR compares the new data to stored information about existing ore deposits and predicts the location of new deposits.

As computers get faster, as engineers devise new methods of parallel processing (in which several processors simultaneously work on one problem), and, as vast memory systems (such as CD-ROM) are perfected, consciousness the final step to intelligence is no longer inconceivable. English scientist Alan Turing devised the most famous test for assessing computer intelligence. The „Turing test" is an interrogation session in which a human asks questions of two entities, A and B, which he or she can't see. One entity is a human, and the other is a computer. The interrogator must decide, on the basis of the answers, which one, A or B, is the human and which the computer. If the computer successfully disguises itself as a human and it or the human may lie during the questioning then the computer has proven itself intelligent. (See also Artificial Intelligence.)

PART X. *THE FUTURE OF COMPUTERS*

Research and development in the computer world moves simultaneously along two paths hardware designs and software innovations. Work in each area alternately influences the other.

Many hardware systems are reaching natural limitations. RAM chips that can store 64 megabits (millions of 0s or 1s) are currently being tested, but the connecting circuitry is so narrow that its width must be measured in atoms. These circuits are susceptible to temperature changes and to stray radiation in the atmosphere, both of which could cause a program to crash (fail) or lose data. Newer microprocessors have so many millions of switches etched into them that the heat they generate has become a serious problem. For these and other reasons, many researchers feel that the future of computer hardware might not be in further miniaturization, but in radical new architectures, or computer designs. Almost all of today's computers process information serially, one element at a time. Massively parallel computers consisting of hundreds of small, simple, but structurally linked microchips break tasks into their smallest units and assign each unit to a separate processor. With many processors simultaneously working on a given task, the problem can be solved much more quickly. One design, called the Thinking Machine, uses several thousand inexpensive microprocessors and can outperform many of today's supercomputers.

Some researchers predict the development of biochips, protein molecules sandwiched between glass and metal, that would have a vastly greater storage capacity than current technology allows. Several research labs are even now studying the feasibility of biocomputers that would contain a mixture of organic and inorganic components.

Several hundred thousand computer-controlled robots currently work on industrial assembly lines in Japan and America. They consist of four major elements: sensors (to determine position or environment), effectors (tools to carry out an action), control systems (a digital computer and feedback sensors), and a power system. As computers become more efficient and artificial intelligence programs become more sophisticated, robots will be able to perform more difficult and more human-like tasks. Robots currently being built by researchers at Carnegie-Mellon University have been used in scientific explorations too dangerous for humans to perform, such as descending into active volcanoes or exploring nuclear sites in which radiation leakage has occurred.

As exciting as all of the hardware developments are, they are nevertheless dependent on well-conceived and well-written software. Software controls the hardware, uses it efficiently, and forms an interface between the computer and the user. Software is becoming increasingly user-friendly easy to use by non-computer professional users and intelligent able to adapt to a specific user's personal habits. A few word-processing programs now learn their user's writing style and offer suggestions; some game programs learn by experience and become more difficult opponents the more they are played. Future programs promise to adapt themselves to their user's personality and work habits so that the term personal computing will take on an entirely new meaning.

PART XI. *CAREERS IN THE COMPUTER FIELD*

Computer-related jobs are among the most rapidly growing employment segments in the United States. Economic studies project that computer equipment will represent about one-fifth of all capital expenditures by businesses in the 1990s. Hundreds of thousands of people will be needed to manufacture, operate, program, and manage new equipment. The most sought-after computer specialists will probably be systems analysts, programmers, and operators.

Systems analysts develop methods for computerizing businesses and scientific centers. They and computer consultants also improve the efficiency of systems already in use. Computer security specialists will be in great demand to help protect the integrity of the huge information banks being developed by businesses and the government.

Programmers write the software that transforms a machine into a personal tool that not only is useful for increasing productivity but also can enlighten and entertain. Applications programmers write commercial programs to be used by businesses, in science centers, and in the home. Systems programmers write the complex programs that control the inner-workings of the computer. Many specialty areas exist within these two large groups, such as database and telecommunication programmers.

As more small- and medium-sized businesses become computerized, they will require more people to operate their systems. Computer operators will need to handle several types of computers and be familiar with a diversified range of applications, such as database managers, spreadsheets, and word processors.

Other important careers in this rapidly expanding field include computer scientists, who perform research and teach at universities; hardware designers and engineers, who work in areas such as microchip and peripheral equipment design; and information-center or database administrators, who manage the information collections developed by businesses or data banks.

Various support careers also exist. Technical writers, computer-based training specialists, and operations managers do not need extremely technical backgrounds to work in their fields; they need only an expertise in their original fields, a knowledge of computers, and a desire to share their knowledge with others. (See also Automation; Electronics; Information Theory.)

PART XII. *APPENDIX*

Section 1. *Terms*

arithmetic/logic unit (ALU). The section of the central processing unit that performs arithmetic and logic operations.

binary code. A coding system that uses two alternative elements 0 or 1, TRUE or FALSE, voltage or no voltage to represent numbers, characters, and symbols.

bit. A binary digit. The smallest unit of information that a computer can handle, represented by a single 0 or 1.

byte. A group of eight bits (representing, for example, a number or letter) that the computer operates on as a single unit.

cathode-ray tube (CRT). A vacuum tube, like that in a television, that projects a beam of high-speed electrons onto a fluorescent screen in order to display information to the computer user.

central processing unit (CPU). The main part of a computer. Contains internal memory, an arithmetic/logic unit, and control circuitry and performs data-processing and timing and controlling functions.

chip, or microchip. A thin slice of silicon containing an integrated circuit.

control unit. The part of the central processing unit that determines the sequence of computer activities, interprets instructions, and controls the way in which those instructions are carried out.

database. A collection of information organized for rapid search and retrieval.

data processing. The converting of raw data to machine-readable form and its subsequent processing (as storing, updating, combining, rearranging, or printing) by a computer.

disk drive. A device that rotates a magnetic storage disk and that can record data on the disk and read data from the disk.

floppy disk. A thin flexible plastic disk that stores data in the form of magnetic patterns on its surface. Used primarily in microcomputers.

flowchart. A diagram that uses connecting lines and a set of conventional symbols to show the sequence of operations and the flow of data in a computer program.

hardware. The physical components of a computer system, such as the chips, disk drives, monitor, and other devices. Dis tinguished from software.

input. Data to be processed that is entered into the computer from a keyboard, disk drive, or other input device.

integrated circuit (IC). An electronic circuit containing thousands of electronic components combined on one chip.

interface. The hardware and software that enable a user to interact with a computer (called a user interface) or that enable two computer systems to interact.

logic circuit. An electronic switching circuit that performs a logic operation; its binary output is entirely determined by the combination of binary input.

memory. A storage area in which a computer saves data and from which it retrieves data.

microprocessor. A single chip containing all the components found in a computer's central processing unit.

network. A system of computers, terminals, and databases connected by communications lines. Allows users of different types of computers to exchange data and to make use of special programs or of very large computers. Scopes range from local-area networks (LANs) to international networks.

operating system. A linked series of programs that controls, assists, and supervises all other programs on a computer system and that allows dissimilar hardware systems to work together.

output. Data that has been processed by the computer and sent to a screen, printer, or other output device.

program. A step-by-step series of instructions directing the computer to carry out a sequence of actions in order to perform an operation or to solve a problem.

random-access memory (RAM). A temporary computer memory system in which data can be stored and from which data can be quickly retrieved.

read-only memory (ROM). A permanent computer memory system containing data and instructions that can be retrieved and used but never altered.

simulation. A computer representation of a real-life system or process that imitates the behavior of the real system under a variety of conditions.

software. Instructions or programs used by a computer to do its work. Distinguished from hardware.

terminal. A device with a keyboard for inputting data to a computer and a display screen for receiving data from the computer.

word processing. An automated means of creating and editing text. Uses computer programs that accept input (text) from a keyboard or from computer memory, enable the user to manipulate the text, and can send the original or revised text to a display screen or printer.

Section 2. *Some Major Figures*

Some prominent persons are not included below because they are covered in the main text of this article or in other articles in Compton's Encyclopedia.

Aiken, Howard (1900-73). American mathematician who in 1944, with the engineers Clair D. Lake, B.M. Durfee, and F.E. Hamilton, invented an early electromechanical computer, the Mark I the first large-scale automatic calculator. Completed an improved all-electric computer, Mark II, in 1947.

Atanasoff, John V. (born 1903). American physicist who, with Clifford Berry, in 1939 built a prototype of an electromechanical digital computer called the ABC (Atanasoff-Berry Computer) the first computer that used a binary numbering system.

Bush, Vannevar (1890-1974). American electrical engineer who in 1928 designed the differential analyzer, the first calculator capable of solving differential equations. Also developed the Rapid Selector, a device that uses a code and microfilm to facilitate information retrieval.

Byron, Augusta Ada (1815-52). English mathematician who was countess of Lovelace. Sometimes called the first computer programmer because she created a program for Charles Babbage's proposed analytical engine, forerunner of the modern digital electronic computer (see Babbage, Charles).

Cray, Seymour (born 1925). American electronics engineer and preeminent designer of supercomputers. In 1957 he helped found Control Data Corporation. In 1972 he founded Cray Research, Inc., which in 1976 developed the Cray-1 supercomputer the fastest and most powerful computer of the time.

Eckert, J. Presper, Jr. (born 1919). American engineer. Coinventor, with John W. Mauchly, of the first general-purpose all-electronic digital computer, ENIAC (Electronic Numerical Integrator and Calculator). Completed in 1946, it was the prototype for most computers in use today. In 1948 they completed Binac (Binary Automatic Computer), which stored information on magnetic tape rather than on punch cards. Their manufacturing firm merged into Sperry Rand Corporation.

Hoff, Marcian E. (born 1937). American engineer who in 1971 designed the first microprocessor, combining all of the essential elements of a computer's central processing unit on a single silicon microchip.

Hollerith, Herman (1860-1929). American inventor who in 1889 patented a tabulating machine that recorded statistics by electrically reading punched cards. In 1896 he organized the Tabulating Machine Company, which, through subsequent mergers, grew into the International Business Machines Corporation (IBM).

Hopper, Grace (1906-92). American mathematician and retired rear admiral in the United States Navy who first conceived of compilers. Developed the first commercial high-level programming language, called FLOW-MATIC a major forerunner of COBOL. Also worked with Howard Aiken on Mark I.

Kilby, Jack (born 1923). American engineer working for Texas Instruments, Inc., who in 1958 designed the first true integrated circuit.

Mauchly, John W. (1907-80). American physicist and engineer. Coinventor in 1946, with J. Presper Eckert, Jr., of ENIAC and later models Binac and Univac I.

Noyce, Robert (1927-90). Electronics physicist and founder of Intel Corporation. In 1959, six months after Jack Kilby designed an integrated circuit, Noyce introduced a more practical version of the silicon chip. His invention brought about the PC revolution of the 1980s and led to the extensive use of microchips in consumer products. From 1988 headed Sematech.

Turing, Alan M. (1912-54). English mathematician and logician whose theoretical universal computer, called the Turing machine, provided the theoretical basis for the digital computers developed in the 1940s. Designed the first all-electric computer, the Colossus, in the early 1940s.

Von Neumann, John (1903-57). Hungarian-born American mathematician who did much pioneering work in the areas of logical design of computers, methods of programming, the problem of designing reliable machines using unreliable components, machine imitation of randomness, and the problem of constructing machines that can reproduce their own kind.

Zuse, Konrad (born 1910). German inventor who built several working computers, including the first automatically controlled calculator, during World War II. An unreceptive wartime government hampered his attempts to build what would have been the first modern electronic general-purpose computer.

This article was contributed by Gary Masters, former managing editor, Microsoft Press; former technical editor and writer, Tandy Corporation; winner of the Southwest Technical Writer's Association Award for Excellence; and author of books about computers.

Section 3. ***Something to read***

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Notes