COMPUTERS 3:

BEYOND THE INDUSTRIAL REVOLUTION

The computer is just beginning to enter daily life. Its eventual impact is almost unimaginable.

BY JOHN H. DOUGLAS

(Conclusion of a three-article series)

Two great events, hardly noticed at the time, signaled the beginning of the end for the industrial revolution in the mid-1950's: The majority of the American work force shifted from manufacturing goods to delivering services, making this country the first "post-industrial" nation. And the first commercial computer became available, making the transition from an instrument of science, born of war, to a daily tool of the emerging service industry.

In the two centuries following invention of Watt's steam engine in 1765, the industrial revolution introduced machines that supplement almost every human action. Now the post-industrial revolution promises to bring computer aid to almost every mental endeavor. By itself, and in combination with machines and communications networks, the computer is replacing the engine as the driving force of civilization and the great challenge to human imagination.

Mathematics, said Galileo, is "the language with which God hath writ the universe." To be more exact, most natural phenomena can be described either by differential equations (mathematical descriptions of how systems change in infinitesimally small steps) or by the equations of statistics (the averaged behavior of infinitely many small contributions). Only a few of these equations have tidy solutions, providing a formula into which data can be plugged and a system's behavior predicted. The rest can only be solved "numberically," adding up all the little interdependent variables. The computer began when the mathematical analysis and control of human institutions and inventions could no longer be accomplished by the human brain alone.

Recognition of just what a computer should be like has been around a surprisingly long time. The English mathematician Charles Babbage designed a general purpose "analytical engine" in 1833. It might have worked too, if he had chosen a simpler design, based on binary rather than decimal numbers, and had been able to raise sufficient funds for his great, steam-driven computer.

By the 1890's mechanical calculators were making arithmetic easier, and an electrical tabulating machine using punched data cards was used to correlate statistical data for the Census Office. World War I spawned a generation of "new differential analyzers"—mechanical plotting machines that produced graphical solutions to the differential equations of artillery shell trajectories and other selected applications. These special-purpose machines reached a peak during World War II when, using vacuum tubes, they were able to calculate trajectories in "real time," guiding 90-mm guns to shoot down V-1 flying bombs with better than 95 percent accuracy. Special-purpose statistical calculators were also used to break enemy secret codes so effectively that the details are still classified.

The goal, however, was to build a general purpose, programmable calculator, and after a couple of workable, but rather slow machines using electric relays and long strips of punched tape, the first electronic digital "computer" was formally dedicated at the Moore School of Electrical Engineering, University of Pennsylvania, in 1946. With this ENIAC, scientists could not only calculate ballistic tables and compute statistics but could also begin to solve a variety of other problems whose complexity had previously forestalled solution. Among these were equations whose solution was to make possible advanced atomic reactor design and the development of jet transport.

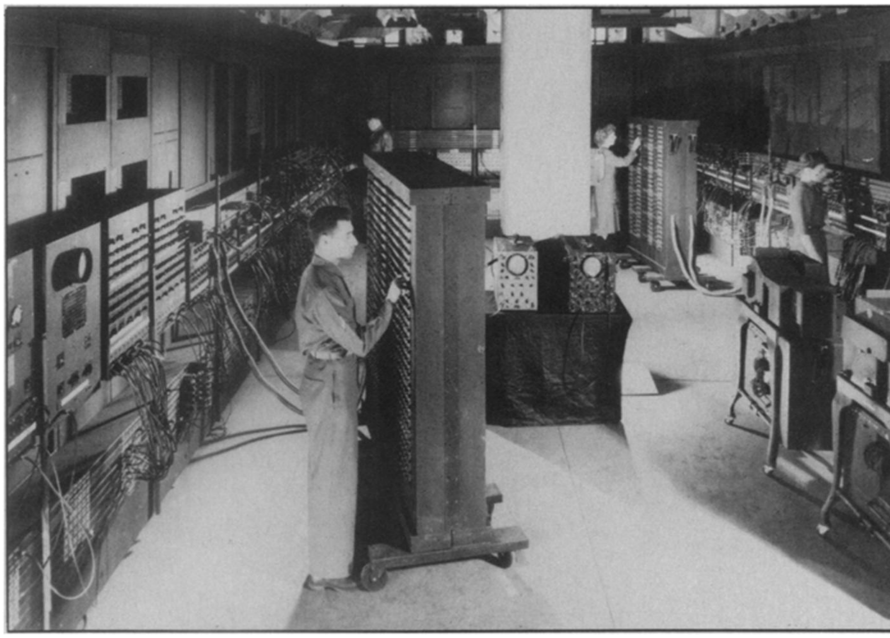
Outbreak of war in Korea stimulated design of the first production model scientific computer, the IBM 701, though the distinction of being the first "commercial" computer goes to the UNIVAC delivered to the Bureau of Census in 1951. That wars and military equipment should have played such a major role in development of the computer resulted in part from the low esteem accorded numerical calculation by the academic community. This neglect may also help explain the early prominence of women mathematicians in the computer field: The first programmer on ENIAC was Adele Goldstine, wife of the Army captain who initiated the project, and the first "compiler" for translating common instructions into machine language was the work of Grace Hopper, a pioneering UNIVAC programmer.

Until very recently, the computer remained the tool of a few highly trained professionals. Its impact on the average person was usually indirect and few people understood either how computers worked or how to use them to solve daily problems. At the global level, however, it is arguable that the computer has exerted a greater influence on history than the hydrogen bomb (which, like a spy's suicide pill, is more an instrument of anxiety than a stimulus for productive action). For example, the United States landed astronauts on the moon before the Soviet Union largely because of superior computers for control and navigation.


John H. Douglas

Davis: Toward intelligent function.

In a speech to the 23rd Communist Party Congress, before the first Apollo flight, Leonid Brezhnev acknowledged that the gravest deficiency in the development of Soviet science was the slow introduction of research concepts into production, especially the "poor use of electronic computer techniques." Stressing



University of Pennsylvania

ENIAC, the first general purpose, electronic computer (above). Containing 17,000 electron tubes, ENIAC is shown as it was in 1946 at the University of Pennsylvania, where a computer museum is now being developed. Many times smaller, faster and more versatile is the first portable computer, announced in September by IBM (below).

IBM

their international importance even more, the director of the Institute for Computer Sciences and Technology of the National Bureau of Standards, Ruth M. Davis, told an international conference that "World War III is being fought with computer science. The first battles of World War III may well have occurred when mathematical formulations of strategies and counter-strategies of realistic proportions were able to be tried out as war games on computers."

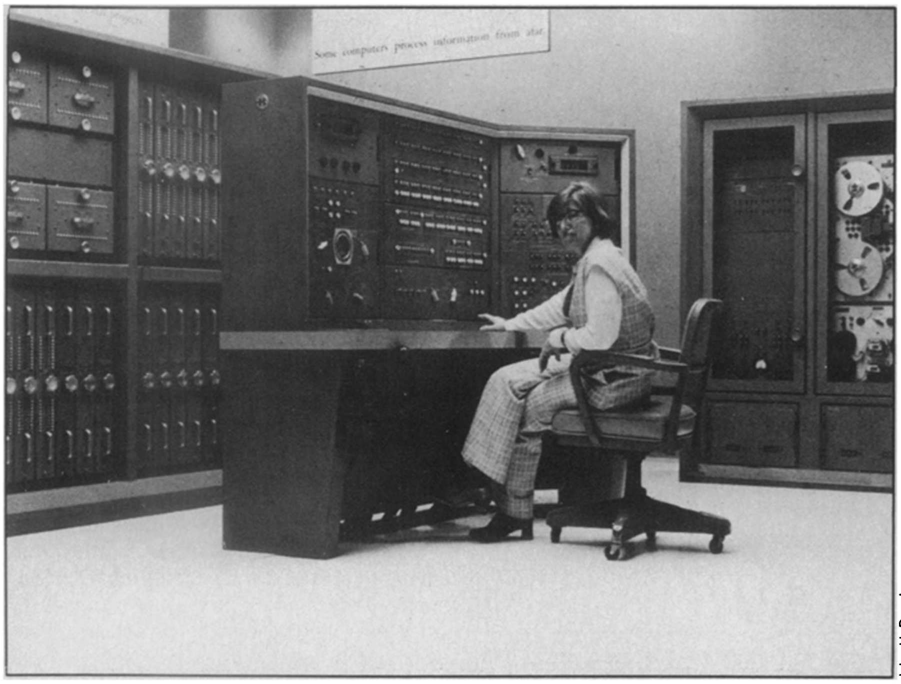
Now the emphasis is changing, however. Since the introduction of commercial computers, the cost of calculation has fallen more than a hundred-fold, calculation speed has increased by a factor of 10,000 and space requirements have shrunk to about one-eight-hundredth of their original size. The computer revolution is about to reach the average person.

Some technological advances and their immediate applications can be fairly confidently predicted; but ultimate impact on society remains as much in doubt as when Joseph Black told his friend James Watt, then an instrument maker, about the latent heat of steam. According to a survey of experts, conducted by the Institute of Electrical and Electronic Engineers (IEEE SPECTRUM, April 1975), by 1981 computers will be used as the basis of medical diagnosis and traffic control, able to receive information through optical character recognition, and composed of ultra-small integrated circuits fabricated using electron beams and X-ray lithography. Over the following three years, computer terminals will become common in general office use, which will also benefit from electronic data files and communications networks. By 1987 Josephson junctions are expected to revolutionize the central processing units of large computers, while miniature computers may be used to control artificial human organs.

When ENIAC was first built, some experts predicted that 100 similar machines would be sufficient to fill the country's needs. Now the United States has 134,000 computers and another 100,000 or so are spread out around the rest of the world. Nearly 88 percent of these systems are produced by U.S. industry. (These figures ignore altogether small electronic calculators, which are now selling at a rate of about 16 million a year.) American Government, science and the financial community now function only by grace of the computer, and as the proliferation continues, other industries—and some individuals—will be turning to computers to increase productivity.

By itself, the computer extends the capacity of the human brain, retrieving information, shuffling vast quantitaties of data or solving tedious problems faster than any individual. To the scientist, this capacity means being able to manipulate and even visualize ever more subtle and more abstract concepts—solving the wave-particle equations of quantum mechanics or deducing the structure of complex proteins from spectral data. To decision-makers of government and industry, the computer represents a new means for determining trends amidst a maze of events and for creating models to predict the outcome of those trends. Philip J. Kiviat, technical director of the Federal Computer Performance Evaluation and Simulation Center, estimates that already computer modeling is five to ten years ahead of the decision-makers' ability to utilize it effectively.

Impact of the computer will be further enhanced by marriage to the machine. Although automation, in the form of programmed machines, predates computers by more than a century, and robots have been favorite fictional characters for decades, only the recent development of tiny microprocessors has made an age of automatons possible. James S. Albus, who works in computer automation at the National Bureau of Standards, says that "mankind may be on the threshold of a new industrial revolution. Within two decades it may be practical for computer-controlled factories and robots to produce virtually unlimited quantities of manufactured goods, and to even reproduce themselves at continuously decreasing costs." Already, introduction of numerically controlled machine tools to existing industries can result in productivity increases of up to 400 percent, he says. In the long run, "artificial intelligence" (self-teaching, decision-making computers) may provide the final link to complete automation of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Computers like this Burroughs MOD 1, one of the first fully transistorized computers, were key to the success of America's space program. Now in the Smithsonian Institution, shown with Mathematics Curator Uta Merzbach, it guided early rockets.

many complex processes.

Possibly the greatest impact on daily life may come from combining computers with sophisticated means of communication to form data networks. Just as the growth of industry drew great masses of people together into overcrowded, filthy cities, networks and computer-coordinated transportation systems may free them again to seek alternate lifestyles in communities of their choosing. The National Academy of Engineering and the Department of Housing and Urban Development have been sponsoring for several years a project to study these possibilities, under the direction of Peter C. Goldmark, the retired head of CBS Laboratories. Although three-quarters of the American people now live in the environs of major cities, Goldmark's team found that more than half of them would rather live in the country (SN: 10/19/74, p. 246). By creating what Goldmark calls the "wired city," people will soon be able to enjoy the benefits of urban jobs, services and culture, wherever they live.

But dangers lurk. Computer networks are already coming under fire for alleged abuse by Government agencies, violating the privacy of citizens. Automation can threaten jobs. And the very existence of sophisticated computers leads to a power gap between those trained to use and understand them, and those who are not. For individual companies in a fiercely competitive industry, the stakes are especially high: Such giants as RCA and General Electric eventually gave up entirely and turned their computer divisions over to UNIVAC and Honeywell, respectively. Now the French-Dutch-German computer venture, Unidata, is splitting apart, with American and British firms gathering inquisitively about the ruins. Countries, too, may rise or fall according to how well they use the computer to "leapfrog" in development. The disparity is great: China has about 44 computers; Brazil has more than 490.

Much depends on how carefully the computer's advance is planned ahead of time. SCIENCE NEWS discussed this issue with Ruth Davis, who considers her role at NBS as one of a "Pied Piper," facilitating integration of computer technology into the Government. Innovators and technologists must cooperate more closely, she says, particularly in soliciting the help of workers and consumer representatives in planning for the introduction of automation. She is concerned that the direction of much research is focused on the special needs of a few large industries rather than on a broader spectrum of technical challenges. Most of all, she takes to task the academic community, which has been a "drag on the advance of computer science" through its neglect. In an editorial in SCIENCE (10/10/74), she concludes: "As computers increase their capacities to perform more of the tasks formerly considered only within man's intellectual province, man must equip himself for other functions or his survival will seem less important to himself, leading to a physical and intellectual ennui."

But there can be no turning back. The industrial revolution freed the human race from the land, creating in two centuries a largely artificial environment from which there is now no escape. The computer revolution promises to free the human mind; where that could lead in two centuries staggers the imagination. □

OFF THE BEAT

High Stakes in the Monopole Claim Game; Alvarez: 'Too Bad It Wasn't Right'

Physicist Luis W. Alvarez, in a hallway at the White House prior to the recent National Medal of Science awards ceremonies (he's a former winner), talking to fellow scientific notables about the much-disputed report of discovery of a magnetic monopole: "It would have been a great discovery—too bad it wasn't right. I don't know of anybody who believes it's a monopole except the people whose names are on the paper. It would have been a sensational discovery."

Following the ceremonies, Alvarez reiterated to SCIENCE NEWS his conviction that the particle track P. Buford Price and colleagues recorded is not that of a monopole but of a platinum nucleus fragmenting to osmium and then to tantalum (SN: 9/13/75, p. 13). "It is unthinkable that fragmentation was not discussed by these experienced heavy-ion physicists as a possible explantion for the glitch." Alvarez has graphed the Price data in a slightly different way and says, "If you showed any physicist [my graph], he'd say, 'My, what a beautiful fragmenting nucleus.' " He finds it "extraordinarily interesting" that physicist Peter Fowler, in Munich, had independently come to the same conclusions—"not to similar conclusions but to the *identical sequence:* platinum decaying to osmium and then to tantalum, with the fragmentations at the same places."

Alvarez feels strongly that Price and colleagues violated long-established, severe criteria—"ground rules of physics"—involved in the reporting of a great discovery. It is true, he says, that Price's data are *consistent with* the hypothesis that the cosmic ray track recorded was caused by a magnetic monopole. But that's not enough. To lay claim to "a great discovery," one must first, Alvarez cautions, "reject all other alternatives." To illustrate, he notes that physicist C.D. Anderson did not publish his great discovery of the positron in 1932 until he had ruled out all other possibilities. "Many observers had seen particles that were consistent with the positron hypothesis, but Anderson was the first one to be able to reject all other alternatives. That is why we recognize him as the discoverer of the positron."

With such high stakes of fame and reputation involved in any confirmed discovery of a magnetic monopole, the debate over the reported claim has at times been acrimonious. But in a newly