COMPUTER DESIGN PIONEERS

Gene M. Amdahl
C. Gordon Bell
Seymour R. Cray
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David C. Evans
William H. Gates
Steven P. Jobs
Jack St. Clair Kilby
Gary Kildall
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Robert N. Noyce
Kenneth H. Olsen
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Alan F. Shugart
Ivan E. Sutherland
Kenneth L. Thompson
Thomas J. Watson, Sr
Niklaus Wirth
Stephen G. Wozniak

THE WHITE HOUSE

WASHINGTON

November 12, 1982

I am delighted to extend my heartfelt congratulations to the pioneers who have become members of the Computer Industry Hall of Fame. Just as your colleagues and admirers recognize the stellar contributions each of you has made to this dynamic industry, your fellow citizens are aware of the benefits that this industry has given our American society.

As much as any development in the past several decades, the computer industry embodies America's world leadership in high technology. It has brought us the prosperity of a multi-billion-dollar enterprise where none existed before. It has conveyed the benefits of computers and data processing to our personal lives, to our commerce, and to our national security. And as a shining example of our free enterprise system, it has paved the way for continuing industrial progress.

As America faces the challenges of the 1980s, we look to this and other high-technology industries to continue to create new career opportunities for our citizens, to make our lives more productive, and to give us the new tools we need for our national security.

The people being honored in this Hall of Fame continue to stimulate innovation through their active industrial leadership. They are a living national resource, appreciated by all Americans, and we are pleased to have this opportunity to salute their accomplishments.

Ronald Reagan

Gene M. Amdahl:

DESIGNER OF HIGH END PLUG COMPATIBLE MAINFRAMES

The story goes that after spending 30 days of longhand calculations only to disprove a hypothesis, Gene Amdahl got frustrated enough to make his own computer. Armed with a BS in engineering physics, 2 years of Navy electronics training, and a summer course in computer programming, he designed the world's first overlapped, electronic floating point computer—at a time when the most advanced "computer" commercially available was the IBM 602A multiplier. Three years later, Amdahl earned his PhD in theoretical physics with a description of how to build his black box: the Wisconsin Integrally Synchronized Computer (WISC).

In June 1952 Amdahl joined IBM to work on character recognition and intelligence simulation. Before leaving IBM for the first time in 1955, he became chief planner and project engineer for the IBM 704 development program, as well as initial planner for the IBM 709 and 7030. Amdahl returned to IBM in 1960, and over the next 10 years served as director of experimental machines, manager of system design for advanced data processing systems, and manager of technology high speed systems. He was named IBM Fellow in 1965, during which time he directed the Advanced Computing Systems Laboratory. As manager of architecture for the System/360, Amdahl revamped computer architecture in a way that still shapes how computer families relate.

He made headlines in 1970, however, when he left IBM to found his own company, Amdahl Corp. He planned to design a family of IBM 370 compatible processors that could be substituted directly for parts made by IBM. The outcome, the Amdahl 470 family of computers, were said to be the highest performing, largest capacity general purpose business machines to date. Amdahl, the mind behind many of IBM's successes in the fifties and sixties, had left the clan successfully to break the world mainframe monopoly.

"Some people suggest I took the solutions from IBM," Amdahl remembers. "I didn't. IBM had not solved the problem. I just believed I understood finally what the nature of the problem was, and it turned out I did." In fact, IBM had already turned down Amdahl's recommendation for an advanced computer, believing that it was not economically feasible.

"Now you have to recognize that I had to have a great deal of faith that I could solve the technical problems," he reminds us. "I wanted to do large scale integration for this, when we had not been successful in doing even medium scale integration at IBM." Amdahl figured that circuits could be designed as localized patterns, with enough space between them to make interconnections. He credits John Zasio with the discovery that each of those patterns could be an identical collection of circuit components, which could then interconnect to make a variety of circuits. The outcome of this research was announced in October 1971: the first high performance, large scale integration chip—and the technological key to Amdahl's 470 V/6.

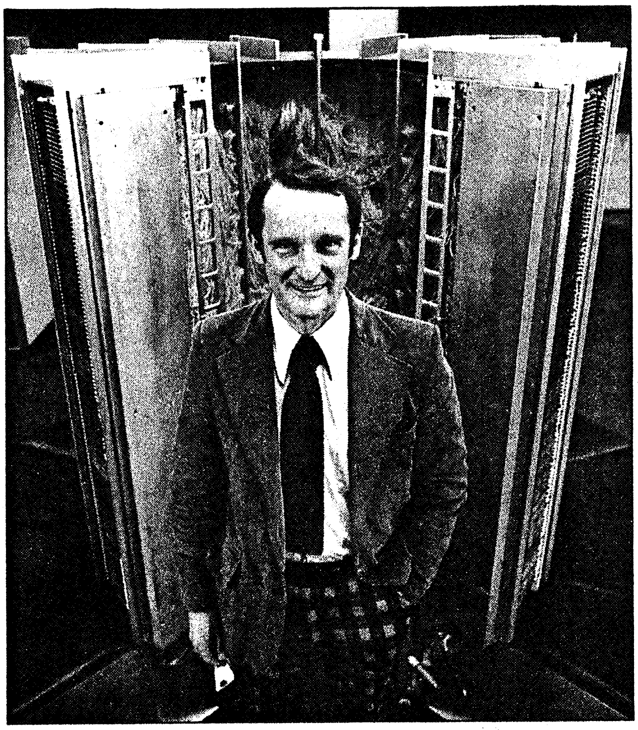
Amdahl realized that he did not need a huge marketing organization to be successful, because high end computer buyers are relatively few. However, he explains, "I knew we'd have to be compatible with IBM—not to get free software, but to make the product acceptable." Success would depend on designing for a market in which systems and applications software had already been developed.

Amdahl's technological strategy countered IBM's "invented here" philosophy by spending research and development resources only where the commercial marketplace could not provide exactly what he needed. "We concentrated on logic, packaging, and design automation. This cut our research and development to about 15% to 20% of what IBM would do for a similar system."

In 1980 Amdahl severed all ties with Amdahl Corp to devote his energies to a new venture, Trilogy Systems Corp. He expects to announce his latest brainchild in about a year. All he'll say for now is that he has some "really exciting ideas about a way to make a revolutionary advance in technology." He is piecing together an IBM compatible machine with "extremely high levels of integration" and a "very fast" circuit time—at least twice as fast as anything he expects to be competing with. "To be really bright," Amdahl professes, "our future has to include innovation." With Gene Amdahl's combination of technical ingenuity and marketing savvy, it's hard to second-guess just how he'll do that.

Seymour R. Cray:

WIZARD OF SUPERCOMPUTER DESIGN



Says Seymour Cray, "The computers I design are very simple. They are conceptually simpler than microcomputers and minicomputers because today those machines have elaborate sequences in the hardware. My computers just add, divide, multiply, and subtract."

Cray is a generalist at heart. "Most people in my business specialize," he explains. "There are not many technical people who are patient enough to do the whole job." However, he believes that supercomputer design is an art, "because there is no logical way of proceeding with it. You have to put it all together in your head and hear it."

Throughout his career, Cray has worked single-mindedly to design supercomputers that grapple with one basic problem: simulation of physical phenomena via differential equations. In 1957 Cray left Sperry Rand with Bill Norris, Frank Mullaney, and Bob Kisch to cofound Control Data. There he masterminded the 1604, the first solid-state commercial computer; the 6600; the 7600; and an even larger machine that Control Data decided not to market.

Bill Norris, president of Control Data, recognized Cray's prodigious skills and gave him free rein. "At the time I left, I had about all the support I could want from Bill Norris," Cray remembers. "In fact, there was the time a decade earlier when I moved to Wisconsin from Minneapolis and set up my own laboratory with Control Data. I thought surely I must be going out on my own. And he said, 'No, no, just do whatever you want to do and we'll take care of it.' "

When Control Data continued to diversify into commercial applications, however, Cray resigned to start his own company. "My interest lies in large computers," Cray commented upon leaving. He insisted that Cray Research produce only supercomputers. Further, only one unit was to be completed at a time, and each new design was to be a compatible add-on, not a replacement for existing parts.

Cray refuses to risk design problems with new chip technology, preferring instead to use a "low technology" approach. His strategy is to "take advantage of the unique packaging that I'm good at." In the Cray-1, for instance, he used only three kinds of integrated circuit. Through extraordinary packaging design, however, he cut maximum wire length to 4′ and cycle time to 12 ns. Fitted with cushions, the 4M-word semicircular colossus has been dubbed "the world's most expensive love seat."

The prototype of the Cray-2 reveals the same mind at work. Though packing eight times the memory of its predecessor, the Cray-2 will consume less real estate by virtue of 3-D chip modules that are totally immersed in inert fluorocarbon cooling liquid. In addition, maximum wire length of 16″ will reduce cycle time to 4 ns. This way the 4-processor, 32M-word Cray-2 will execute scalar operations about 6 times faster than the Cray-1, and vector operations about 12 times faster.

Despite skepticism "that you could immerse a computer in liquid without causing insurmountable problems such as deterioration," Cray can't imagine why immersion has not been done before. "I guess we're all chicken," he sighs. "I have been working for more than a decade on 3-D structures and circuit modules because they offer a tremendous increase in density," Cray notes. "So these two things came together. You couldn't do the 3-D structure without the liquid immersion."

In late 1981 Cray turned the chairmanship of Cray Research over to the president, John Rollwagen. Now an independent contractor, Cray is free to pursue his true interest which, he explains, is "really to do the 'thing' part with computers, not the 'people' part." His reason, like his computer, is fundamental: "I can't think about my Boolean problems if all these people problems are rolling around in my head."

Edson D. DeCastro:

LEADER AND INNOVATOR IN PRODUCING MINICOMPUTERS

To Ed DeCastro, president of Data General, the greatest problem facing American industries in transition is inertia. "American firms are remarkably successful at creating technologies. We take an innovative idea, apply resources to it, add considerable value, and success results—but usually only for one generation," he explains.

American firms resist change when they are producing a successful line of computers, he says, and customers avoid using a new line of computers when existing ones still seem adequate. As a result, manufacturers tend to improve the technology of known devices rather than design new ones. Inertia is the reason frustrated computer designers leave established firms to start new firms, or join smaller ones with no past. Says DeCastro, "The result of all this has been the stagnation of many older firms and the proliferation of new ones."

Stagnation is the reason why DeCastro left Digital Equipment Corp: because he could not convince management in 1967 to finance a 16-bit minicomputer, he decided to do it himself. "We all want to make money," he says. "But more than that is the challenge and the opportunity to do your own thing. There are real satisfactions in being able to accomplish something significant. That is the number one motivator."

In 1968, DeCastro cofounded Data General, now one of the world's leading designers and manufacturers of mini- and microcomputers. The key ingredient in most successful companies, he points out, is a good staff that is talented in a variety of disciplines. "Virtually all of the people who have been involved in Data General over the years have made a substantial contribution," he observes. "Some people were involved in various phases of the company's growth and did a great job, then moved on. But that doesn't diminish the value of their contributions.

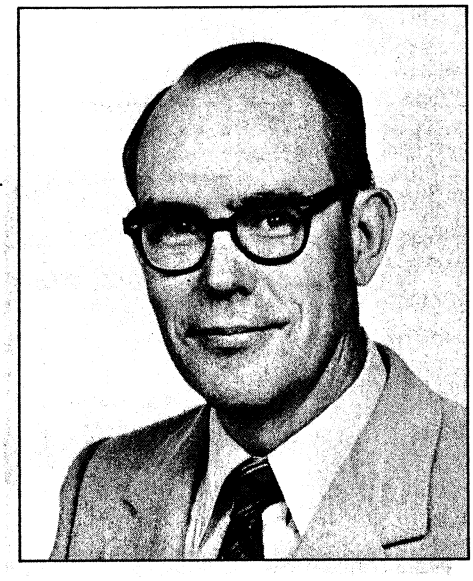
"If you look at the companies that are successful, I think you'll find the one constant is that they did everything reasonably well. A company that does one thing perfectly and messes up other things won't do as well as the company that does everything *reasonably* well. You can design good products, but if you don't have decent marketing, financing, manufacturing, and public relations behind it, that doesn't do you much good." According to DeCastro, it is pulling together all these disciplines that ensures success.

DeCastro admits that Data General, too, has succumbed to the dangers he warns against. But inertia is not always fatal. To wit, he notes that some ultralarge companies remain successful while others fall by the wayside. DeCastro's strategy for Data General is to broaden the product line in three major market areas: information systems, technical systems, and small business systems, "not only in terms of getting smaller and larger machines, but in terms of offering more services than we currently do—marketing our products through lots of different channels. We're basically moving toward becoming as broadly based as possible, as rapidly as possible." Even Data General's "personal" computers, for instance, will continue to be aimed at business applications, although these will also include applications for professional pursuits such as engineering, medicine, and law.

"Software is getting to be an enormous part of the product. It comes in a lot of flavors and varieties, and I don't believe that it's possible for a company such as ours, or even IBM, to write all the software that people need. We're going to write certain portions of that software, but I think that people who are involved with particular applications can do a better job of writing applicatons software." DeCastro observes that Data General will have to work with other companies in order to supply this application software, but "in terms of the basic system software—the operating system—we will continue to do that for the most part."

David C. Evans and Ivan E. Sutherland:

PATHFINDERS IN GRAPHICS AND REALTIME SIMULATION



Neither David Evans nor Ivan Sutherland set out to start his own company. They met in the early sixties while consulting for the same firm, and their association grew, Evans recalls, out of a mutual feeling that "though people listened to us and paid our consulting fees, they weren't really going to do what we wanted done." He likens their early role in recommending "person's-eye view" mechanical-engineering and pilot-training simulations to that of a doctor "who stopped somebody on the street who was perfectly well and said, 'now wait a minute, you look sick to me—I'm going to treat you.' "

The basic motivation behind the Evans & Sutherland Computer Corp was the need to develop the computer as a powerful, general purpose simulator, rather than as a machine that builds and maintains files. "What one does in the process of design, no matter what he's working on, is build various models and prototypes," Evans explains.

"There are two parts to this business," he continues. "One is the computer model—that's another way of talking about the simulator. The other is the graphics communications link between the computer and the human." Evans and Sutherland wanted to provide a way to build models and prototypes to test ideas before beginning the time-consuming process of making production drawings and building physical prototypes.

Long before he became interested in graphics, Evans had been thinking about the interaction between people and computers. He was frustrated with the mysterious black box that professional programmers held incommunicado. Then in the early fifties came the Bendix G-15, which he describes as the first personal computer. It functioned on interpretive programming, but its graphics capability did not surpass the typewriter's. Evans credits Federman's 1962 sketchpad as the prototype of modern graphics systems. But even that, he explains, didn't go far enough for problem solvers who "need to be closely coupled with computers."

Key additions to the company were Rodney Rougelot and Robert Schumacher, who now direct the company's simulation activities. These men had independently developed hardware based, realtime in-simulation projects for NASA and the military. Evans says that bringing them into the company to complement staff expertise was an extremely important event.

Today, the company is still based on two sectors—the simulator and graphics. The company offers a wide range of geometric modeling programs and graphics, with photograph-like, realtime images at the high end.

Evans looks forward to another big leap for graphics and realtime simulation and technology. To date, most simulation systems have been produced by single companies for their own use. "In the next few years," he predicts, "some general purpose integrated systems will be made. That will be a big change for us and for our kind of CAD/CAM. A big CAD/CAM industry is built around automating the drafting process."

William H. Gates:

DEVELOPER OF HIGH LEVEL LANGUAGES FOR MICROCOMPUTERS

Bill Gates' passion for computers was well established by the time he reached the seventh grade. That year, he and his ninth-grade friend Paul Allen used up their school's annual allotment of computer time writing a program to play Monopoly. While still in high school, Gates and Allen cofounded Traf-O-Data, a firm specializing in computer analysis of traffic patterns. They were also hired to computerize the electricity grid for the Bonneville Power Administration. A few years later, their enthusiasm and industry launched a multimillion-dollar company called Microsoft and helped to establish the microcomputer software industry.

Gates first encountered microprocessors while working for TRW during high school. Even then he thought of writing a BASIC for the microprocessor, but the 8008 instruction set was not powerful enough. In January 1975, when the 8080 based Altair microcomputer appeared on the cover of *Popular Electronics* magazine, Gates and Allen seized their opportunity. Gates explains, "BASIC was in some ways the obvious thing. It's interactive, it's easy to use, and we thought we could do it with very little memory."

The pair obtained an 8080 instruction set manual from Intel. Because they didn't have a microcomputer, they wrote on 8080 simulator to run on Digital Equipment Corp's PDP-10. Gates then worked on an 8080 BASIC interpreter that would run on the simulator. He confesses, "We had never seen an 8080 chip, ever. All we had was this blue manual." Then, with what must have taken a certain bravado, Gates and Allen called MITS, the makers of Altair, and said they had nearly completed a BASIC for the machine. The fact that they asked key questions like how to read characters into and out of the machine convinced MITS they were serious; arrangements were made for Allen to fly to Albuquerque, New Mexico, with a paper tape to load into an Altair.

En route, Allen realized they didn't have a bootstrap routine to load their BASIC into the computer. So he wrote one on the plane, then phoned Gates from the airport for his OK. At MITS, there was only one machine with four working 1k memory boards, so Allen entered his bootstrap loader via the front panel switches and read in the paper tape through a model 33 Teletype. BASIC ran on the first try.

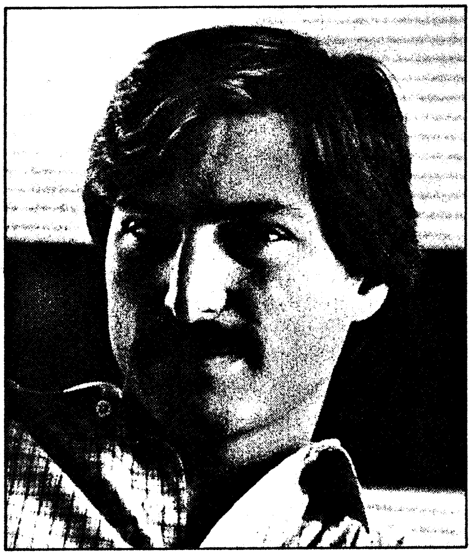
In 1976 Gates took a leave of absence from Harvard and Allen left his job as assistant programmer at Honeywell. Throughout that year, the two enhanced BASIC to run on a variety of microcomputers. Their first release was called 4k BASIC, which to Gates and Allen meant that it would allow the user to run a 50-line BASIC program using four of MITS' 1k memory boards. The interpreter occupied about 3.2k and did full floating point arithmetic.

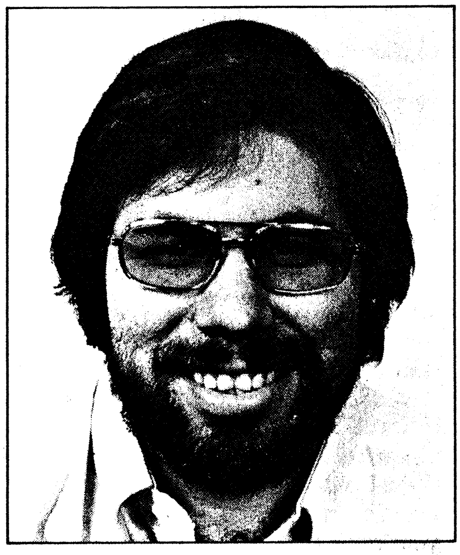
This soon led to a family of four upwardly compatible BASICs, including Disk Extended BASIC, whose operating system allowed use of disk I/O either from programs or from BASIC's command mode. Other Microsoft functions included peek and poke, to allow direct access to memory; edit; and trace. Incidentally, by way of a computerist's joke the command to turn on trace—TRON—became the title of a Walt Disney movie.

Microsoft has since added FORTRAN, COBOL, and Pascal. When 16-bit computers were introduced, the company followed with languages to run on them, as well as 16-bit XENIX and MS-DOS operating systems. In the eight years since it was founded as a partnership, Microsoft has grown to over 180 employees with sales of over $16 million—a testament to the founders' early recognition of what a microprocessor could mean.

Steven P. Jobs and Stephen G. Wozniak:

TRAILBLAZERS FOR THE PERSONAL COMPUTER INDUSTRY





The founding of Apple Computer is as much the story about chemistry between people as it is about technology. Many talented, enthusiastic individuals began microcomputer companies in the seventies, but none have sparked the kind of human/technology formula that Steve Jobs and Steve Wozniak did.

Jobs had been working in video design at Atari and Wozniak had been designing calculators at Hewlett-Packard when they started going to meetings of the Homebrew Computer Club. Together they designed a single-board computer hooked up to a TV and a keyboard. Immediately all their friends wanted one, so the two devised a way to make and sell a limited number in the form of blank printed circuit boards.

To their surprise, a local computer store ordered 50 units but wanted them completely assembled. First, Jobs and Wozniak had to convince two parts distributors to give them $25,000 worth of parts on 30-day credit. "Paying it back in 29 days," Jobs recounts, "started our attention to cash flow." What they created for the Byte Shop turned out to be both the first single-board computer and the first product shipped using 16k RAM chips.

With Jobs and Wozniak working on their mainstay, the Apple II, the burgeoning company needed venture capital and business management skills. A. C. (Mike) Markula was hired to help write a comprehensive business plan. "We always tried to hire people who were better at certain things than we are," Jobs says. "The key is a balance of chemistries."

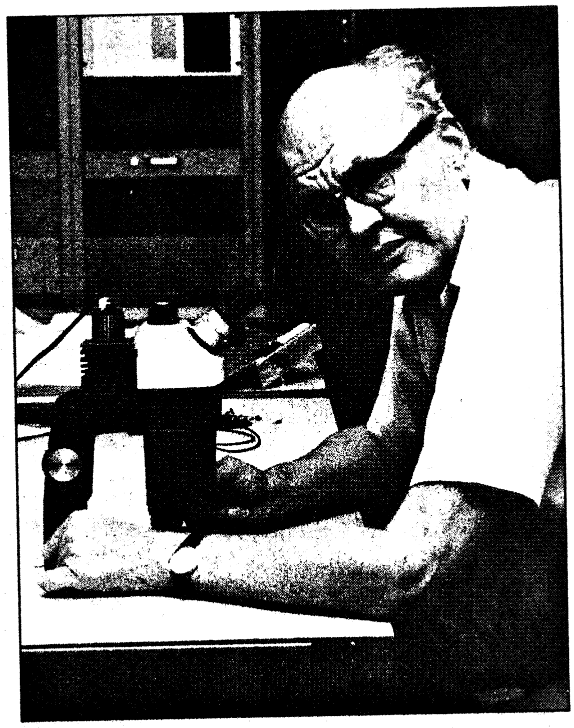
One hallmark of Apple Computer is that the founders, both talented engineers, did not try to retain total ownership and control; they gave stock to every employee they hired. "We would rather have 50% of something than 100% of nothing," Jobs observes. Today chairman of the board, Jobs expects the company to ship its millionth unit within the next year, when Apple will also probably join the Fortune 500. Wozniak, however, has gone off in a new direction: he recently organized the US Festival, the first of several rock concerts billed as a union of technology and music for the eighties.

As to where the company is going, Jobs notes, "We still haven't got to the point where we can give a computer to somebody and they can learn to use it in a short time." He wants to make a machine so human oriented that anyone could learn to use it within a half hour. Further down the road, he hopes, will be "a computer the size of a book."

To these ends, Apple has maintained a "loan to own" program. All employees, from janitor to top executive, can borrow a complete Apple system for one year, after which they own it. Apple's philosophy is that better products will come about if people feel that computers have been designed to meet their particular needs. After all, that's the human/technology formula that made Apple Computer in the first place.

Jack St. Clair Kilby:

INVENTOR OF THE INTEGRATED CIRCUIT



While most of his fellow engineers were vacationing in July of 1958, Jack Kilby invented the integrated circuit. In the succeeding 25 years, of course, chips from the silicon block have propelled electronics into virtually every facet of life on this planet—and beyond.

A down-to-earth man, Kilby admonishes fellow engineers to "deal with those challenges you are lucky enough to have an impact on." Part of his recipe for successful invention is to concentrate on the problem at hand and not be distracted by global issues. "I couldn't have invented anything if I first had to consider its cosmic implications," Kilby muses. "Vowing to live with total creativity," he adds, "would drive the best person nuts by noon."

Kilby joined Texas Instruments in the late 1950s when the Pentagon was funding micro-miniaturization research and development in electronics technology. Believing that better and more reliable products would result from improved manufacturing techniques, engineers concentrated on standardizing component form factors. Another popular tactic was to interconnect, through deposited conducting films, a set of elements that had been bonded to a substrate. This approach led to the hybrid integrated circuits still used in high performance applications.

To Kilby, a unique approach has always meant that "you won't be reworking the same solutions as everyone else, and hopefully you will be able to contribute something special." For instance, Kilby did not go along with the mainstream micro-miniaturization efforts. He felt that shrinking and standardizing components without revamping the manufacturing process would not improve reliability. His greatest single contribution in inventing the integrated circuit was to recognize that all components and interconnections could be made from the same basic semiconductor material. This shifted the focus of the problem from packaging to materials.

Once individual components could be produced from the same chunk of material, however, they had to be isolated and interconnected. Kilby outlined several possible solutions to the isolation problem, including the junction isolation technique popular today: cascading n- and p-doped areas so the interconnected areas form diodes to block unwanted current flow.

Subsequently, Fairchild's Robert Noyce developed some different techniques for integrated circuit fabrication. Noyce's key improvement was to grow an oxide layer over the surface of the chip to protect the circuits it contained, then evaporate an adherent pattern of metallic interconnections on the oxide.

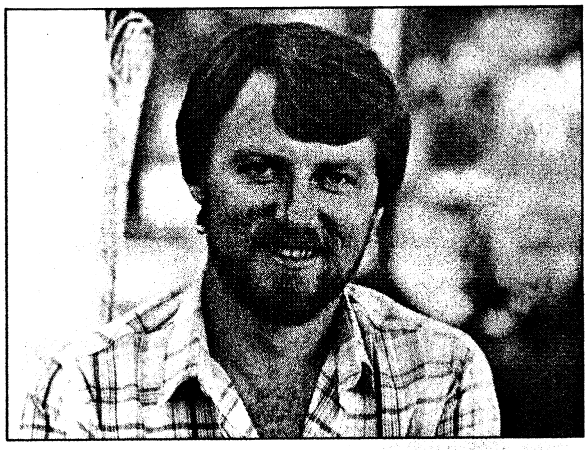
"Defining the problem in appropriate terms is at least as much a part of an invention as the physical embodiment that one finally produces," Kilby reflects. "More to the point are clear statements of the problems and an in-depth understanding of the resources that my company was willing and able to commit to solutions I might propose."

Comfortable in his Spartan laboratory at Texas Instruments (where he has been officially on leave since 1970), Kilby is busy with the company's solar energy conversion project. He has designed a unique solar collector that will recharge automatically. The approach: immerse millions of doped silicon bits in an electrically conductive solution. Doping converts each bit into a diode, which can then generate electric current.

Kilby is acutely aware of the compressed time scale of electronics technology. The first transistor was invented in 1947, the silicon transistor in 1954, and the integrated circuit in 1958. He suspects that the next methodological leap will absorb much of the present progress. "Twenty-five years is a long time between drinks in this business," he reminds us. "We're about ready for another something big."

Gary Kildall:

CREATOR OF A UNIVERSAL OPERATING SYSTEM FOR MICROS



Gary Kildall's invention of the CP/M operating system demonstrates the synergy that characterizes most advances in the computer industry. Although the impetus for creating microcomputer software came from early processor chips, today's perennial CP/M could not have come about without developments in small disk drives and controllers—and a person to catalyze the infant technologies.

After Kildall graduated from the University of Washington, he was looking around for something to do. "I ran across an ad for an Intel 4004—computer-on-a-chip, $25," he recalls. "Well, that's a pretty good price. I'd been working with an IBM System/360 that cost a couple million dollars, so it was a nice discount." Kildall wrote a few programs for the 4004, including an assembler simulator, a floating point package, and some transcendental functions. Intel was interested in the transcendental function package and signed Kildall on as a partime consultant.

Next he wrote a cross-emulator for Intel's 8008, the first 8-bit microprocessor, then a high level compiler called PL/M for the 8008 and the new 8080. This compiler, however, ran on DEC's PDP-10 and had to be booted to the new Intellec-8 development system. Kildall decided the development system needed a resident PL/M compiler that would let it operate standalone.

The problem was that the only backup storage available for the Intellec was agonizingly slow paper tape. "It took 30 minutes to program a 256-byte PROM," he explains, "and 10 minutes to erase it." Kildall needed a convenient storage device and a software environment that would allow PL/M to be used as a totally resident compiler. Paper tape would not do the job.

Kildall was not deterred. He got a test floppy disk drive from Shugart Associates, but could not afford the $2000 for a controller. Failing at several attempts to devise his own, Kildall asked his friend John Torode (who later founded Digital Microsystems) for help. Together they wirewrapped a working controller that enabled them to load an early version of what later evolved into CP/M, initialize the disk, and put a prompt on the screen.

Fortunately for Kildall, Intel lost interest in the resident compiler project (although it later developed its own operating system, ISIS, for the Intellec). So Kildall was on his own with a still rather primitive operating system when a company named IMSAI asked him to develop an operating system for its 8080 based microcomputer. Ensuing developments turned CP/M into a product that easily adapts to almost any 8080 or Z80 hardware system.

IMSAI had been shipping computers and promising delivery of an operating system at a later date. Kildall took the job of adapting the whole operating system to each new machine. Soon he realized that the hardware dependent portions could be confined to a standard basic I/O system (BIOS), which could then be modified without affecting the rest of the operating system.

At the urging of Jim Warren, founder of West Coast Computer Faires, Kildall developed an end-user package and released CP/M version 1.3 into the technical hobbyist market. This started what he calls the "cyclic effect of writing application software for the operating system, which then promotes the operating system, which then promotes the applications software." The triad formed by customer, applications vendor, and operating system supply/support operation has become the foundation of Kildall's company, Digital Research.

CP/M's versatility catapulted from what was essentially a small job control language to a compatible operating system that spans 8- and 16-bit processors. Moreover, it is available on a variety of mass storage devices and is even spreading into multi-user and multitasking versions. In fact, Kildall's early vision of processor-resident software has been carried to its logical conclusion: the CP/M-86 kernel on Intel's 80150 chip. How does Kildall see CP/M's chances of survival as the computer industry evolves? "It will do very nicely," he predicts. "It's just a very good way of organizing data."

Robert N. Noyce and Gordon E. Moore:

LEADERS IN MEMORY AND PROCESSOR TECHNOLOGY

For the last 26 years, Bob Noyce and Gordon Moore have shown the computer industry what it means to "recognize a good idea when it comes by," as Noyce puts it. From the earliest developments in transistors, both men have contributed to the evolution of semiconductor technology—the prime mover behind the story of the computer industry.

In 1956, Bill Shockley, winner of the 1955 Nobel prize for co-inventing the transistor, hired Noyce and Moore. Physicist Noyce and chemist Moore joined Shockley's small team of scientists to explore silicon's semiconductor properties. While there, Moore established diffusion and metallization techniques new to transistor technology.

The next year, Noyce, Moore, and six others left the Shockley laboratory to start up Fairchild Semiconductor, where Noyce soon developed silicon mesa and planar transistors. Noyce began to conceive of the integrated circuit while implementing Moore's diffusion and metallization techniques in planar transistors. He describes this invention as "recognizing a good idea when it came by." Extending photolithographic techniques used in transistor production, Noyce used aluminum to connect n and p regions, and silicon dioxide to insulate the individual components. Fairchild soon became the first company to produce commercial integrated circuits based on Noyce's isolation and interconnection techniques.

By 1968, the idea of creating their own large scale integrations moved Noyce and Moore to branch out again and cofound Intel. Although the two men planned to develop other circuits from the start, they saw semiconductor memories as a "stepping stone" to perfect the process and achieve early market penetration. With the development of silicon-gate MOS technology, in which cofounder Andy Grove was instrumental as operations manager, the company produced the first semiconductor device considered for main storage applications: the 1k-bit MOS dynamic RAM.

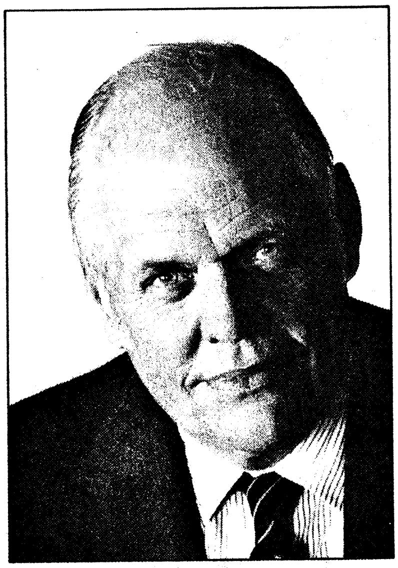
Moore's famous rule that integrated circuit complexity doubles each year continues to be true. Unfortunately, Noyce notes, design costs go up in proportion to the number of transistors. Therefore, when a Japanese calculator firm approached Intel for a custom chip set in 1969, the company declined the proposed design as too complex to be cost effective.

During the review process, however, Noyce encouraged another "good idea," which ended up leading integrated electronics into a new era. Instead of designing a series of separate circuits to meet special applications, a young Intel engineer, Ted Hoff, suggested they "make a little general purpose processor and program it to look like a calculator." This innovative thinking resulted in Intel's 4004 architecture, which was actually a 4-chip set: central processor, ROM, RAM, and shift register. The central processing chip became the renowned "microprogrammable computer-on-a-chip," later dubbed the microprocessor.

The microprocessor set two processes in motion: the spiraling complexity of large scale integration, and the shifting of functional design into software. Noyce believes there is still a long way to go in both areas. Commenting on the first, he notes that reducing linear dimensions by a factor of 10 is "certainly in the cards" and will cut areal dimensions by a factor of 100. Since speed increases linearly as dimensions go down, he concludes, "there is a lot to be wrung out of the speed issue in just straight MOS."

Kenneth H. Olsen and C. Gordon Bell:

FORERUNNERS IN DEVELOPING AND PRODUCING MINIS



Ken Olsen left the rarefied atmosphere of MIT's Whirlwind computer project in 1957 to lease 8500 square feet in a converted 19th-century woolen mill. His goal was to make smaller, cheaper, and more flexible transistorized computers that would meet a wide range of applications for the mass market. Ultimately, Olsen's commitment to a small interactive computer set the foundation for the minicomputer industry and the concept of distributed data processing.

Olsen convinced General Georges Doriot, head of American Research & Development Corp, to give him $70,000 seed money, and launched his company making digital logic modules as discrete circuit boards. By 1960 these modules were combined in Digital Equipment Corp's first computer, the PDP-1 programmed data processor. This machine accommodated an astonishing range of peripherals, including one that changed the way the world viewed computers: the CRT screen. In just a few years, Olsen's staff had designed the realtime processing capabilities associated with room-sized computers into one that would operate outside the sterile, air-conditioned chambers mainframes required.

Gordon Bell joined the company as manager of computer design in 1960. Three years later he led the development of PDP-5, which achieved the first dramatic price drop in computers by minimizing register architecture through the use of core memory. In 1965 the PDP-8, the first mass-produced minicomputer, revolutionized the computer industry. Moreover, an attendant development brought computer power out of the sequestered mainframe environment forever—distributed data processing.

From the start, the company's real business was defined as "the creation of new markets." As president, Olsen took unorthodox steps to ensure a diversified product base that would keep that creative process going. Salaried salespeople, who have no reason to favor any market sector, represent a product line ranging from single-board computers to large, timesharing systems like the VAX-11/780 and DECsystem-10. In this way, the sales force blankets emerging market needs and forms an important link to the research and development staff.

Decentralized management techniques create a productive, employee-conscious work atmosphere. "I believe the worker always knows more about his job than his boss," Olsen affirms. In fact, the business revolves around developing the product lines. According to Win Hindle, vice president of corporate operations, the rule of thumb is "he who proposes does."

Bell took a 6-year leave of absence from Digital Equipment Corp to teach at Carnegie-Mellon University. Now vice president of development and engineering, he believes that "large groups are always less efficient than small ones." Bell organizes his 5000-member engineering staff into teams of about 30.

Looking back over 25 years of phenomenal growth and productivity, one can trace Ken Olsen's and Gordon Bell's success to two major sources: energetic pursuit of new markets and farsighted management policies. The underlying motivation is that money isn't everything. "Since people want to work," Olsen asserts, "all you have to do is treat them well."

David Packard:

A NATIONAL AUTHORITY ON TECHNOLOGY AND ITS IMPACT

In 1939 the world had not even heard of electronic computers, nor would it for another 10 years. Nevertheless, that year David Packard and his Stanford University classmate William Hewlett built an instrument that became the foundation of a company that now has an important place in the computer world.

The instrument was a resistance-tuned audio oscillator called the 200A. In retrospect, the image of Hewlett proudly presenting his new device to a meeting of the Institute of Radio Engineers seems to foreshadow Steve Wozniak standing before the Homebrew Computer Club with his just-completed Apple I.

One of Hewlett-Packard's first customers was Walt Disney Studios, which used a modified version of the 200A to develop the sound system for the film *Fantasia*. The company grew rapidly in the electronic instrumentation industry, first producing vacuum tube voltmeters, then expanding during World War II into other areas of measurement with the introduction of a microwave signal generator. After the war, the company added high speed counters and calibrated oscilloscopes to its product line.

Rapidly evolving instrumentation produced large amounts of measurement data that had to be analyzed to yield meaningful results. Moreover, with several instruments measuring different aspects of the same system, a means was needed to control and coordinate overall operation. This spurred the company to two pivotal developments. In 1966 came Hewlett-Packard's first instrumentation computer, followed by the Hewlett-Packard Interface Bus, later adopted as the IEEE 488 or GPIB standard.

Six years later, the company produced the world's first handheld scientific calculator, the HP-35. Then came the HP1000 and HP3000 in 1976, which marked the company's commitment to building business computers in a big way.

From over 40 years of involvement in electronics and 3 years as Deputy Secretary of Defense, Packard has gained a perspective on both the potential and the problems of the industry. He believes that electronics—and that includes computers—"has provided a unique opportunity for individual enterprise." Further, he says, "many of the most important inventions have been made by individuals, sometimes working alone, sometimes sponsored by a university or an industrial company."

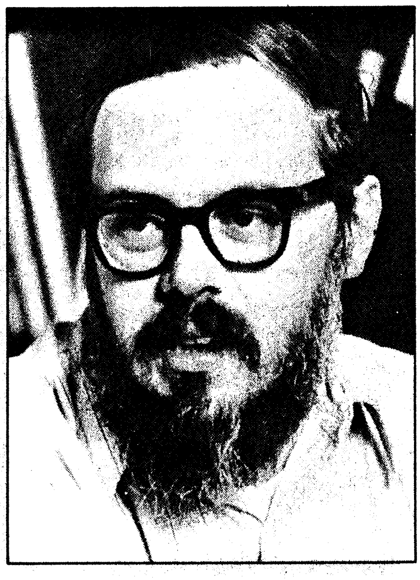
Packard notes that "the growth of our industry has been built on a continually expanding base of scientific knowledge." He is therefore very concerned with the state of scientific education and basic research in the United States. Packard recently served on Governor Jerry Brown's commission for the advancement of high technology in California. Among the major recommendations of the commission were increased emphasis of basic science education in the schools and promotion of basic research.

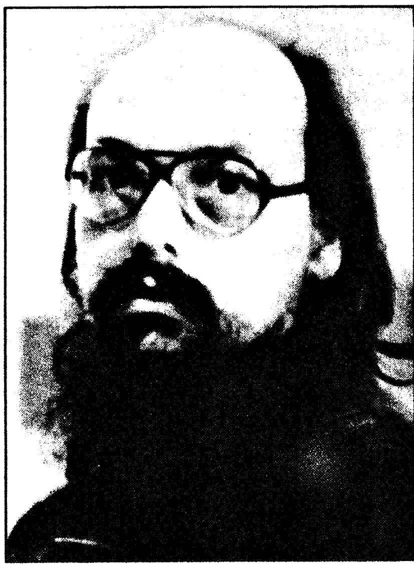
Packard encourages the industry to renew its commitment to excellence. "We should not worry so much about how much money we can make next month," he says. "Instead, we should concentrate on how we can do a better job next month and every month thereafter. Then we won't have to worry about making money or competing with the Japanese."

He sums up on a positive note: "The most satisfying thing is that the opportunities for a young person looking forward to a future in electronics are just as attractive, perhaps even more so, today, as they were for Bill Hewlett and me in 1939."

Dennis M. Ritchie and Kenneth L. Thompson:

DEVELOPERS OF POWERFUL YET COMPACT SOFTWARE





Dennis Ritchie and Ken Thompson balked at losing their "convenient computing environment" when Bell Labs abandoned its interest in MULTICS, the large scale, multiplexed information and computing service it had been developing with General Electric and MIT. "We didn't want to lose the pleasant niche we occupied because no similar ones were available," Ritchie comments.

Even while they were working on MULTICS, Ritchie and Thompson realized that many of the improvements they sought for the programmer interface would be more effective on a small computer. Motivated by his own need for a software engineering tool, Thompson ferreted out a discarded PDP-7 with graphics display to write his own operating system. Throughout 1969 he worked out, "on blackboards and scribbled notes," the basic file structure at the heart of UNIX.

Each file in the UNIX operating system, Thompson explains, is "a collection of bytes with no special format." A simple structured architecture lets users process multiple tasks simultaneously because "they don't have to use a lot of special jargon to get each job done." In addition, each I/O device is associated with a device file that is treated like any other file. Portability was an early target; Thompson maintains that only 10% of an operating system—the actual I/O connections—has to be machine dependent.

Also key to this small (100k-byte) system's enormous appeal is the fact that it is written in a high level language—another boon to portability. Ritchie began to work on the C language in 1971, when he and Thompson acquired a PDP-11. Ritchie notes, "UNIX and C were developed at the same time they were being designed." For system programmers, C is extremely versatile because it combines features of high and low level languages. On the one hand, programmers can label data symbolically and easily add to or modify the modular structure. On the other, they can address memory directly without assembler code.

By 1973 Ritchie rewrote the UNIX kernel in C and introduced multiprogramming. That step, he observes, "convinced us that C was useful as a nearly universal tool for system programming, instead of just a toy for simple applications." Other virtues of the ubiquitous UNIX system include hierarchical file directories; operational transparency; and stream processing via software pipes, which turns one program's output into another program's input without temporary storage.

Small size, high level language, and machine independence have spread UNIX's power over a wide range of computer systems, including the Amdahl 470; BBN C/70; DEC VAX 750 and 780; Honeywell Level 6; Intel 8086; IBM 370, 3033, 4300, and Series/1; Perkin-Elmer 832; Univac 1100; and Zilog 8000. The use of UNIX in applications as diverse as process control, software development, and word processing—in addition to the continual introduction of variants since its inception—testifies to the foresight of Ritchie and Thompson. The coauthors have mixed feelings about the emerging alternates, however. Portability has been a top priority from the start, and different versions could defeat that goal.

Alan F. Shugart:

DEVELOPER AND PRODUCER OF COMMERCIAL DISK DRIVES

Our number crunching society would have ground to a halt long ago without a simple way to input, output, and store information in volume. Outstanding among his peers in the development and production of disk drive technology is Alan Shugart, founder of Shugart Associates and cofounder of Seagate Technology. Just as important as his business acumen, moreover, is his pivotal role in the design of the first random access mass storage system, the 8″ floppy disk drive, and the 5¼″ Winchester.

Shugart's work on disk drive technology began with the RAMAC project at IBM. The amazing thing about this random-access mass storage system, he recalls, was its capacity. "People wanted to know who in heck was ever going to fill up 5M bytes. Figure it out: somebody was going to have to punch all those records."

Released in 1955, RAMAC stored data on a stack of over fifty 24″ hard disks—but it had only two heads. To change disks, the heads had to be unloaded and withdrawn, then moved to the newly selected platter. "We didn't know anything about flying heads," Shugart comments. "You had to pump compressed air up to the head and it came out the bottom and made a precisely controlled air bearing."

It was also at IBM that Shugart developed the 8″ floppy drive, which he later introduced as a commercial product. He credits the semiconductor industry with providing the impetus for this invention. "The floppy disk was originally developed as a removable device for storing microcode, for putting microcode into computers," he explains. Microcode in the System/360 had been stored in nonvolatile hardware ROM. When the System/370 was designed in the 1970s with semiconductor memory, IBM had to devise a way to load microcode memory, which lost its data when the power turned off.

Diagnostic program loading, Shugart continues, was a logical enhancement. "Once you've made the decision that the floppy disk is going to be a microprogram loader, it's a short step to discover that it would be really nice to log things on that floppy disk and add a write function." He sees the big technical achievement as the diskette itself, that "flexible media rotating inside the envelope with material glued to the inside of the envelope that would continually wipe the media."

In 1973, Shugart left IBM to form Shugart Associates. Developing the market, he remembers, was the toughest part of his venture as an independent manufacturer of commercial disk drives. He hoped to build 50,000 drives. "Nowadays you see jillions of stepping motors and jillions of heads. In those days, you didn't have jillions of anything," he recalls.

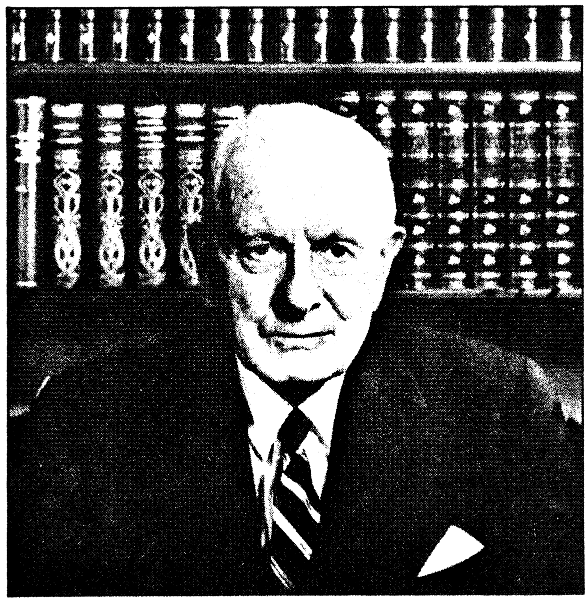
Volume production is the key to Shugart's small-disk-drive ventures. Simplifying design and improving manufacturability and quality control has always been a top priority for him. "You have to approach any high volume business like ours as a yield business."

Finis Conner, a close associate at Shugart, watched the mini-floppy market explode and recognized the opportunity for small, high capacity hard disk drives. In 1979, Shugart and Conner formed Seagate Technology to manufacture 5¼″ Winchester disk drives. Their reasoning, Shugart explains, was simple: "If you could get a hard disk drive at 15 times the capacity that was only 3 times the cost, every desktop computer with more than one floppy would be a candidate for your product." This theory led to the creation of a whole industry.

Shugart believes that advanced techniques such as vertical recording will have to overcome the technical hurdle of putting the material on the plated disk before anyone will commit resources to volume production. Optimistic about the future of magnetic storage, he predicts that it will continue to be the preferred technology. "We're in absolute infancy," he remarks. "The market will drive a small Winchester to 100M bytes. Now we're looking at 20M bits per square inch. I don't see an end for magnetic recordability."

Thomas J. Watson, Sr:

FATHER OF THE WORLD'S LARGEST COMPUTER COMPANY



THINK. Along with his many major accomplishments as president and chairman of the board of International Business Machines Corp, Thomas J. Watson, Sr is famous for introducing that motto to data processing industry salesmen—and to the world. First as general sales manager of National Cash Register Co, then in 1913 when he took charge of the Computing-Tabulating-Recording Co, which later became IBM, he hung framed placards of this motto in sales offices, lobbies, and nearly everywhere else where they could stir a person to THINK.

Described by both friendly associates and not-so-friendly competitors as the "world's best salesman," Watson probably did more to promote the computer industry than any other individual. Unquestionably, IBM was at the forefront of the technological revolution that made the computer one of society's most important devices. Every industrial plant—and every household—is intimately influenced by the computer, whether or not one is on the premises. Watson sold the computers. Others produced inventions, still others designed equipment from those inventions, but Watson educated the business world to accept and use that equipment. He turned a highly technical product into a simple device that could be used by multitudes of nontechnical persons: people who don't care how the product works or what is behind its covers. To Watson's probable chagrin, they don't even THINK about it.

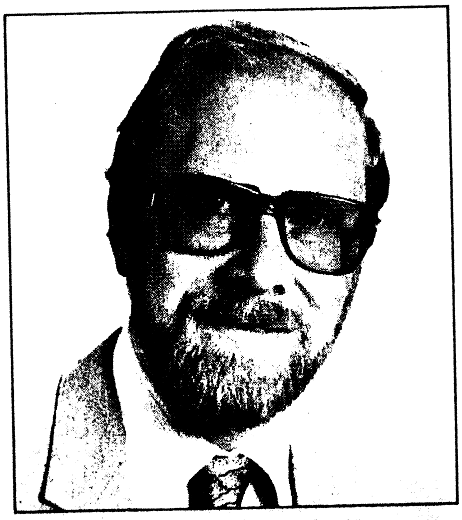
Watson believed that three factors were crucial to improving existing models of business machines and developing new ones: education, research, and engineering. One of his first steps as president of IBM was to procure loans to finance expansion—with precious little collateral. He boasted that he got the money by making his best sales pitch. His fortitude paid off, however, and *Forbes* magazine recognized his achievements by awarding its 1934 cup for "the best job of modernization in American industry" to IBM.

The company's gross sales increased from $2 million in 1914 to over $33.25 million in 1949. In the words of the *Saturday Evening Post*, this, too, is attributed mostly to Watson's "ingenuity in creating new markets, perfecting of educational-sales techniques, and stubborn strength for hard work."

From the time he became president of IBM's predecessor, until shortly before his death in June 1956, one month after he turned over the chief executive role to his son, Watson ruled IBM. He was described as a corporate tyrant who could not accept criticism. Supposedly, to second-guess Watson or to change his directives guaranteed dismissal from the company. If there were errors in judgment—and of course there were—under Watson's rule IBM managed to overcome them, and in many cases even disguise them as triumphs.

Yet Watson is also described as a sympathetic administrator who had far more consideration for his employees than he is credited with in his public image. During his tenure, Watson initiated many benefits for IBM employees. John Henry Patterson, president of NCR, had early impressed Watson with the notion of "company spirit." While president of IBM, Watson extended this idea to the concept of the "industrial family," whose first obligation is to the customer; next to the workers, who deserve proper compensation for their contributions; and finally to the owners, who require profits.

Watson coined IBM's second most famous slogan, "World Peace Through World Trade," to challenge the international community. His official biography quotes him as advocating "the exchange not only of goods and services but of men and methods, ideas and ideals." In 1939, as honorary president of the International Chamber of Commerce, Watson proposed that all countries "collaborate with their respective businessmen in a study of economic and financial conditions with respect to sharing alike world resources" as a way to prevent wars. Among his many awards was one in 1940 for his contributions to the advancement of American foreign trade. In the same year, he was cited at the New York World's Fair during Court of Peace ceremonies "for his important contributions to the laying of a solid foundation" for future world peace.



Niklaus Wirth:

CREATOR OF STRUCTURED PROGRAMMING LANGUAGES

Niklaus Wirth has spent the last 20 years paring programming language structure down to its essentials. Emphasizing high design standards, he refuses to be satisfied with unwieldy systems "that are large only because they are ill-designed and not because they perform well." Better tools have smoothed the way for tremendous progress in software design, and Niklaus Wirth includes "vehicles for thinking about our problems" in the tool category. "Structured languages have a key function," he notes.

Wirth turned his studies from electrical engineering to computer language design while doing PhD work at the University of California, Berkeley. Although he had long been interested in computer architecture, he decided first to learn about how computers were used. Wirth wrote the Euler language while in graduate school to distill "the principal ideas behind structured languages." Then, as assistant professor in Stanford University's newly formed computer science department, he designed PL360 and, with Tony Hoare, developed Algol W.

In 1967 Wirth returned to his native Switzerland with "the feeling that I really ought to have a decent structured language available for doing what I was interested in—mainly compiler and system programs." The next year he joined the faculty of the Eidgenössische Technische Hochschule (ETH) in Zurich, where he refined his ideas about structured programming into a new language, Pascal. This language was written with two objectives: to satisfy system programming needs and to write "a clean language with clean concepts for teaching."

Around 1974 Wirth marked the emergence of multiprogramming concepts and wanted to get hands-on experience. "The effort to crystallize some sensible programming rules," Wirth recalls, "boiled down to designing certain structures into the language." He designed Modula, incorporating the essential programming concepts into a minimum core.

Modula-2 was drafted from this minimum vehicle. It follows Pascal's principles of structured coding, strong type checking, and flexibility. Moreover, it improves on Pascal with added facilities for system design, such as independent modules, separate compilation, and concurrency.

Recently, Wirth has challenged the industry tenet that software should be written to fit existing computer hardware. "Everyone knows that advances in VLSI technology have resulted in inexpensive processor chips, while software design is the expensive, difficult-to-design component for computers," Wirth observes. "But few people have translated this into designing hardware to fit software instead of vice versa."

In 1977 Wirth's chance arrived. "I was lucky," he begins. "I was always intrigued by the idea of designing a computer, and this coincided with our need at the institute to get some expertise in hardware design." Richard Ohran, then assistant professor at Brigham Young University, approached Wirth about earning his PhD at the institute. "We agreed," Wirth recalls, "that he would learn about software and he would teach us about hardware. When we started, we didn't have a soldering iron or a chip."

The two men set up a hardware laboratory at the institute, where Wirth drew up the major architectural concepts for the Lilith software engineering workstation. In Lilith, Wirth synthesized his ideas about linking computer architecture to software design. "Software can be designed more easily on the machine that is suited to software design," Wirth explains. Lilith is a 1-language machine that directly executes the Modula-2 compiler's p-code. "There is no assembler for Lilith, and we don't want one," Wirth affirms.

Now head of the computer science division at ETH, Wirth reports that Modula-2 has replaced Pascal in all high level teaching and research. When asked to weigh Modula-2 against Ada, he chuckles. "Well, you cannot replace Ada because it isn't here yet. That's a major advantage of Modula-2." In addition, Modula-2 is simple. "The more complex the problem," Wirth warns, "the better you must understand your tool."

The decisive factor in future advances, however, will be people, not tools. "In software design, nothing can replace a creative person's thinking," Wirth contends. "I don't think that we have to expect gigantic steps through new tools. The ultimate improvement will rely on better discipline and higher professional standards."

MERITORIOUS NOMINEES

Thomas R. Armstrong (Paradyne)
For pioneering work in the development of high speed modems.

James L. Buie (TRW)
For the development of reliable high performance integrated circuits.

Fernando J. Corbato (Massachusetts Institute of Technology)
For building the first timesharing system and a major library of scientific software.

George Cogar (Cogar)
For designing and manufacturing advanced computers and memory systems.

Harold Garland (Cromemco)
For spearheading the personal computer industry by designing and marketing bus compatible microcomputers.

Hal Georgens (Data Electronics)
For advances in data storage and backup for small computer systems.

Grace M. Hopper (U.S. Navy, Retired)
For creating the first English-like high level language and some early compilers.

Thomas Horgan (Inforex)
For pioneering commercial key-to-disk data entry.

Charles H. House (Hewlett-Packard)
For contributions to the art of logic analysis and development of the first state analyzer.

Samuel N. Irwin (Sycor)
For the development of the first commercial intelligent terminals based on microprocessors.

Alan Kay (Xerox)
For simplifying the man/machine interface and making computer software more friendly.

Leonard Kleinrock (University of California at Los Angeles)
For pioneering work in information transfer using packet switching.

Raymond Kurzweil (Kurzweil Computer)
For research into pattern recognition and development of the first text-reading machine for the blind.

Thomas B. Martin (Threshold Technology)
For pioneering the commercial applications of speech recognition.

John A. McCarthy (Stanford University)
For research into artificial intelligence and development of a high level language for symbolic representation.

Robert Metcalfe (Xerox)
For inventing a widely used technique for data communications in local area networks.

Charles H. Moore (Forth Inc)
For creating a popular high level language, and for other contributions to software quality.

David L. Noble (IBM)
For developing the first floppy disks and drives, thus lowering the costs of mass storage.

Adam Osborne (Osborne Computer)
For designing the first complete portable computer, and for major contributions to software development.

Seymour Papert (Massachusetts Institute of Technology)
For research into computer systems for education, and development of a compatible programming language.

Chuck Peddle (Commodore)
For developing and marketing a popular microprocessor chip for small computers.

Lawrence G. Roberts (GTE Telenet)
For pioneering work in packet-switching technology and systems for data communications.

James Treybig (Tandem Computers)
For development of commercial computers and data communications systems offering nonstop operation.

Maurice Wilkes (Cambridge University)
For substantial advances in computer architecture through microprogramming and related techniques.