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Behold the Computer Revolution

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MY WIFE IS MAD AT COMPUTERS. "Those awful machines," she calls them. "How they mess up our credit card accounts! Imagine sending a bill for $232.24 every month for four months after you've paid it!"

But I'm not mad. That mixup was settled after five months; and we never did feel as computer-harassed as some Americans, notably the Kansan repeatedly reminded that his department store bill was "overdue in the amount of $00.00." At last he too managed to pacify the computer—with a check for $00.00.

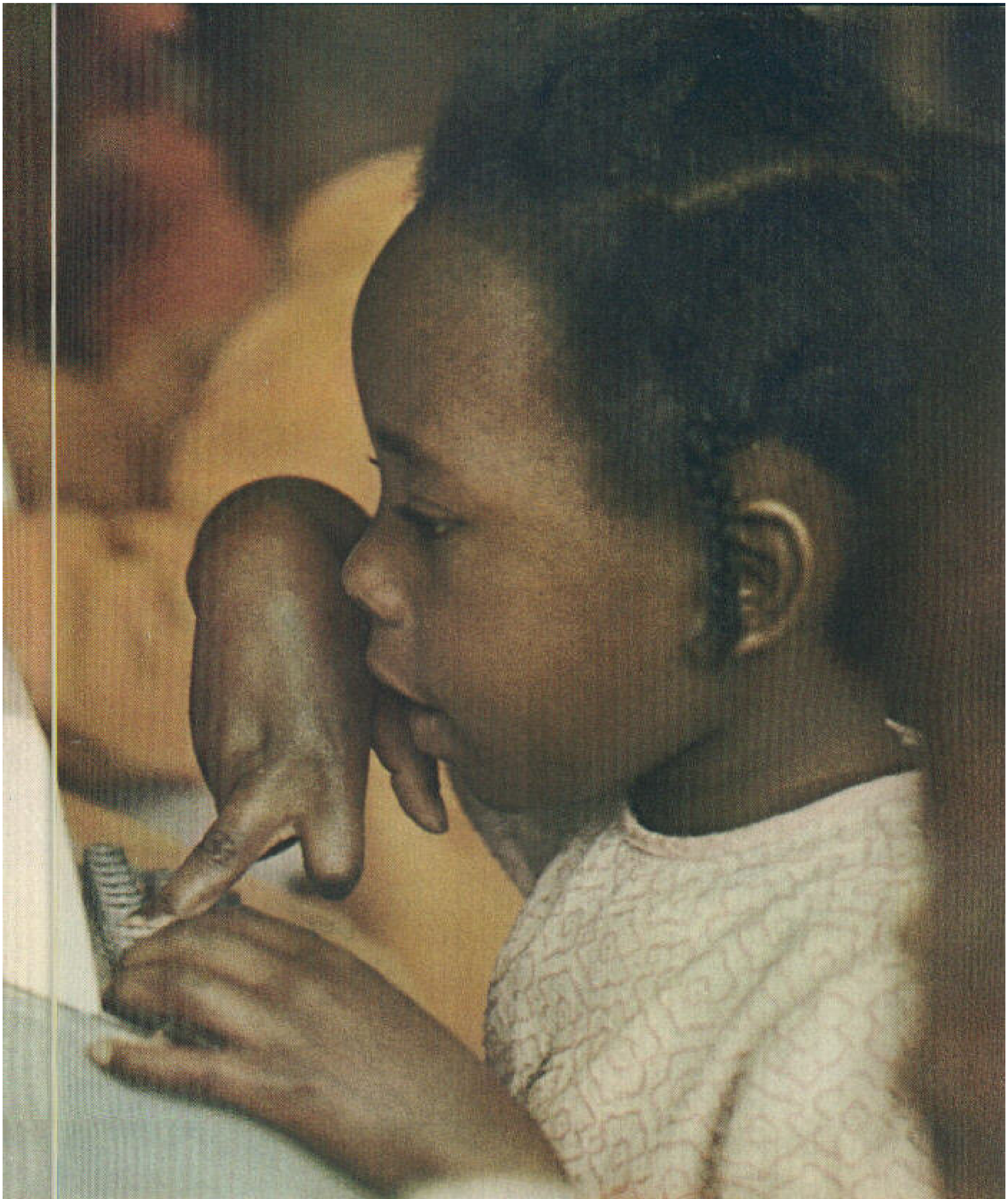
In a way, though, my wife is right. After a year of looking closely at computers—at what they are doing all over the country, what they are likely to do before long, and what their effects are expected to be upon us all and upon our descendants—I must say that these machines are indeed awful, in just about every sense the dictionaries assign to that word: inspiring dread, appalling, objectionable; solemnly impressive; commanding reverential fear or profound respect; sublimely majestic.

In the end I found my own ways of

At the consoles of such electronic wonders as this IBM 370, man achieves the power to master information on a scale that profoundly influences the course of science, business, government—even the arts. © N.G.S.

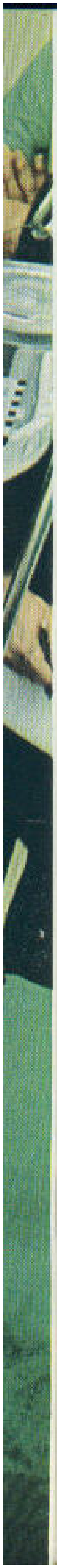
Bringing the blessing of education

Face to face with a classroom friend, six-year-old Shelia Brumfield raptly works her way through an arithmetic drill at a computer terminal in McComb, Mississippi. Taking turns with her classmates, Shelia identifies herself each day by pecking out her number and first name on the machine. Searching its electronic memory, the device



EKTACHROME BY BRUCE DALE © N.G.S.

locates her file, reviews her performance, and picks up with the day's practice problems. Work done, it grades the assignment and bids a printed "GOOD-BYE, SHELIA." Computer practice not only speeds the rate of learning, but also frees the teacher to explain new concepts. Launched as an experiment by the Federal Government three years ago, computer instruction has been enthusiastically adopted by the McComb school system as part of its curriculum.



thinking fundamentally changed. It began with my first inkling of how significantly computers are embedded in our everyday life.

I take my salary check to the bank. The check is imprinted with sharp-cornered numbers in magnetic ink that can be read by computers. A computer credits my account, and sorts all the checks received at my bank, for forwarding to the banks on which they are drawn. Another computer will charge my employer's account in *his* bank.

In this way our commercial banks handled 20 billion checks in 1969. As the Bank of America, the Nation's biggest, puts it, "Had we not started to use computers years ago, we soon would have had to hire every adult in California to help with our bookkeeping."

Machine Keeps Track of New Numbers

I pick up my telephone and dial a number.

An operator's voice cuts in and says, "May I have the number you are calling, please?"

I say, "555-7170."

"Thank you," says the operator. Now another voice tells me: "The number you have called, 555-7170, has been changed. The new number is 555-7535. . . ."

That second voice came from a computer. While I was saying 555-7170, the operator punched those numbers on a keyboard. She thanked me, pressed a key marked "Start," and the computer took over.

It reached into its memory, or storage unit, to match the old number with the new number. Then it fed the new number into an audio-response unit, which contains a vocabulary of prerecorded phrases and numbers from zero to nine, to assemble a message custom-made for me. That was the second voice I heard. The operator was through with me in seven seconds. She would have taken at least three times as long if she had had to do the whole job by herself.

Similarly, before the automatic dialing of long-distance calls, an operator had to write down the time and charges for each call. Now more and more computers keep track of that and send the bills, and the telephone companies get along with about 170,000 long-distance operators. To handle today's volume of long-distance calls in the old way would require nearly 750,000 operators—equivalent to all the unmarried women in their thirties now in the country's labor force.

At this point I paused to look into the nature of the computer itself.

Like all machines, it transforms things, as a lathe shapes a chunk of metal into a useful part, or a typewriter turns the touch of my fingers into words on paper.

The computer transforms information. This sounds simple, but it is in fact the basis of all its awesome power. How so? Because the information going in—in the form of numbers, letters, symbols, and even pictures—can be made to represent a tremendous variety of things. And the numbers, letters, and symbols coming out can be made to produce, often without human help, a tremendous variety of action, as we shall see.

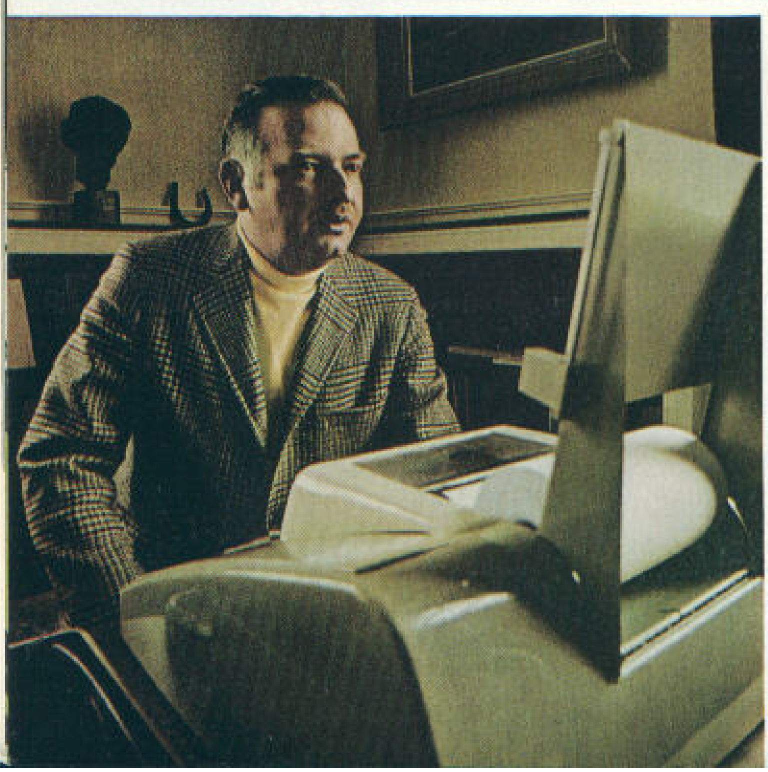
One more thing to remember: The computer transforms information by electronic means. To enable the machine to do this, the information, or data, going in must first of all be put into a form the machine can come to grips with. For most computers in use today, the data is rendered into the so-called binary code, in which any number, or letter of the alphabet, can be expressed in terms of just two digits, 0 and 1. (For example, the binary equivalents of the decimal numbers one through ten are: 1, 10, 11, 100, 101, 110, 111, 1000, 1001, and 1010.)

Inside the machine, those binary digits—0 and 1—are represented by switches that may be either off (for 0) or on (for 1). The machine, in effect, consists of hundreds of thousands of tiny switches. They are grouped

The patient that always comes back

Lifelike in its apparent distress, a plastic-skinned manikin known as Sim One—for simulated patient No. 1—serves as a durable guinea pig for an anesthesia student and his instructor, right, at Aerojet-General Corporation's Electronics Division in Azusa, California. Driven by a computer, Sim reacts to their ministrations by sleeping, coughing, vomiting, changing his breathing rate, even temporarily dying. As the student tilts the head to insert a tube into the windpipe, the instructor stands near a console that permits him to vary Sim's reactions. From the monitoring of intensive-care patients to the sending out of hospital bills, computers have swiftly become medicine's newest partners.

EKTACHROME (ABOVE) BY BRUCE DALE; KODACHROME BY EMORY KRISTOF © N.G.S.



They make computers work

◀ **Texas tycoon** H. Ross Perot eight years ago founded Electronic Data Systems, which specializes in computer work for other firms. Today, at 40, he is a four-hundredfold millionaire. Here, pressing buttons of a portable terminal that his firm designed, he transmits a coded message to a computer listening at the other end of a telephone line.

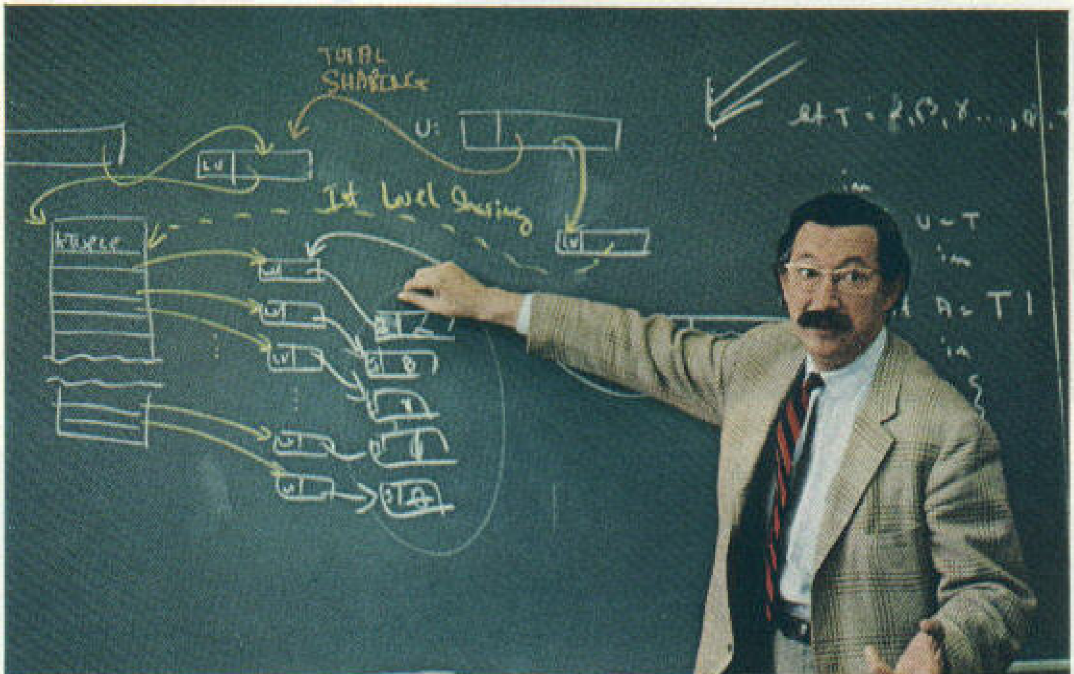
Theoretician Joseph Weizenbaum conducts a class at Massachusetts Institute of Technology. Rejecting the notion that the computer will dehumanize society, the professor of computer science foresees its use in the personalization of many activities, such as teaching. Professor Weizenbaum envisions computers producing magazines and newspapers specifically tailored to individual subscribers' tastes. ▶

Man behind the memory, Professor Jay Forrester of MIT pioneered the data-storage system used in the majority of today's computers (close-up, page 602). He has also applied the computer to industrial organization and to the problems of today's cities. ▶

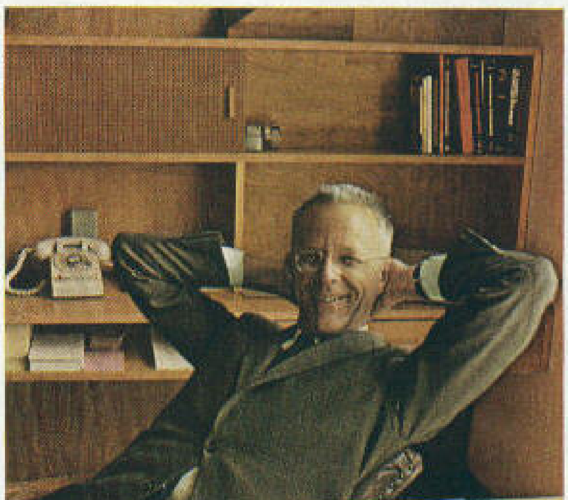
Part of a core memory device lies on his desk. To implant information, electric impulses feed in data as combinations of 0 and 1—the two binary code values used in most computers.

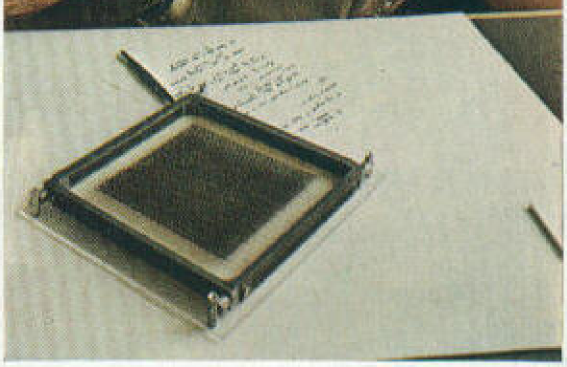
◀ **Time-sharing pioneer:** Dr. John G. Kemeny helped develop the technique of having a single computer serve many masters at once, storing the data of each until called on to process it. President of Dartmouth College, he mans a terminal in his office tied in with the institution's Kiewit Computation Center (pages 632-3).

Computer magnate Thomas J. Watson, Jr., serves as Chairman of the Board of International Business Machines, the world's leading computer manufacturer. He stands in front of an IBM 360. ▶



EKTACHROMES AND KODACHROME (BELOW LEFT) BY EMORY KRISTOF © N.G.S.

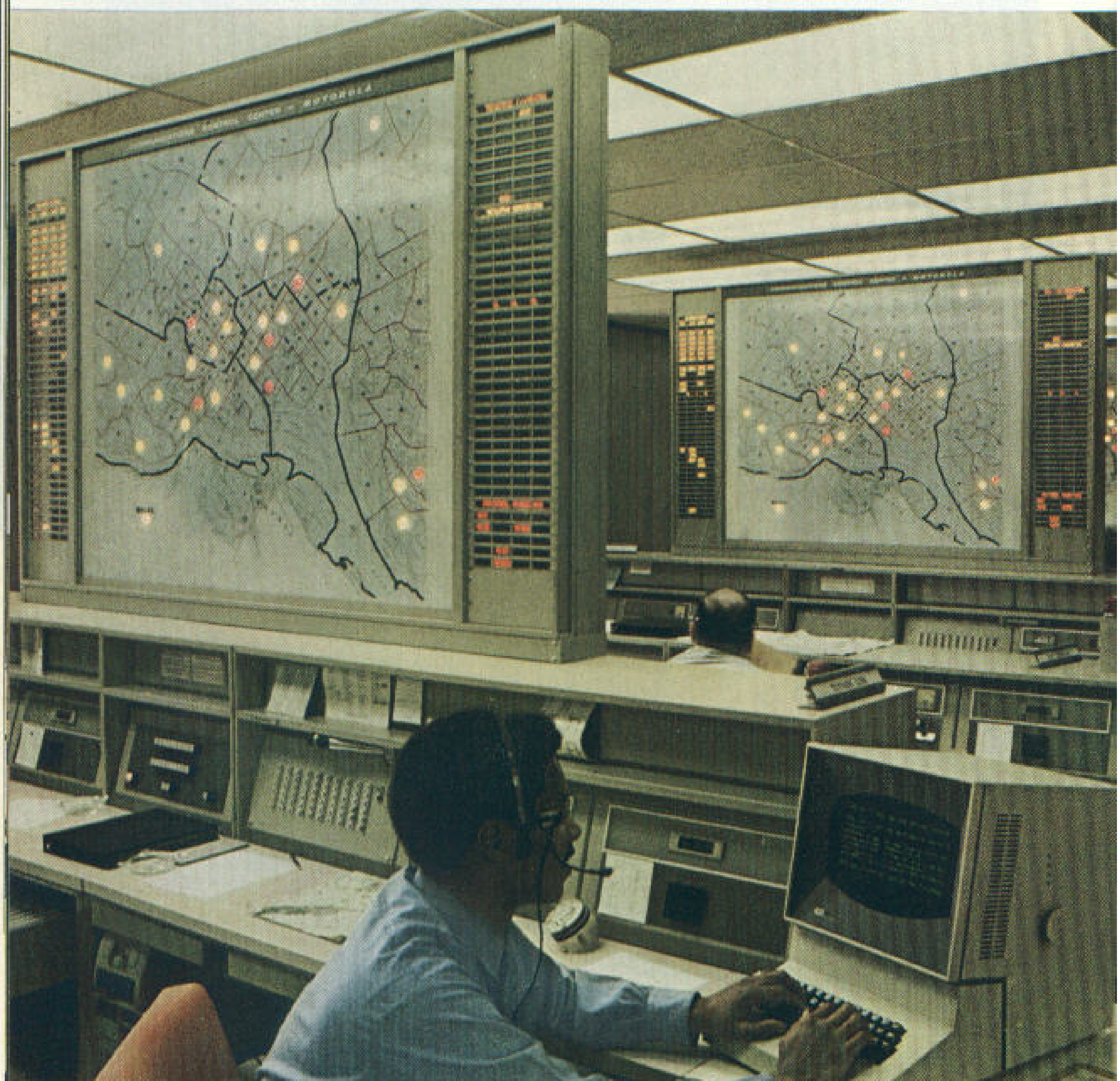




Computers against crime

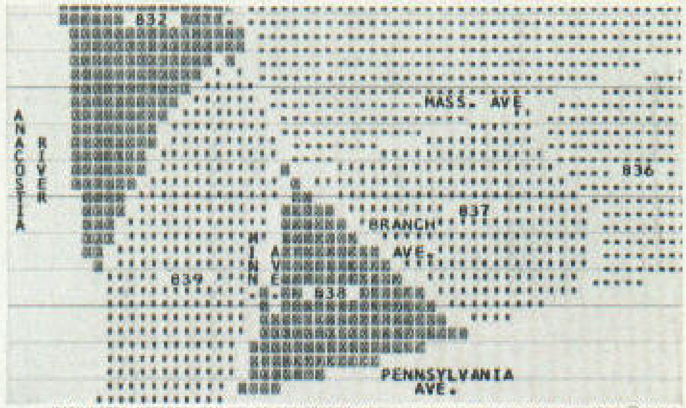
"Check D. C. license 999-398," radios a policeman in Washington, D. C., who spots a suspected stolen auto. His call goes to the city communication center, where lights on maps mark the patrol-car routes (below).

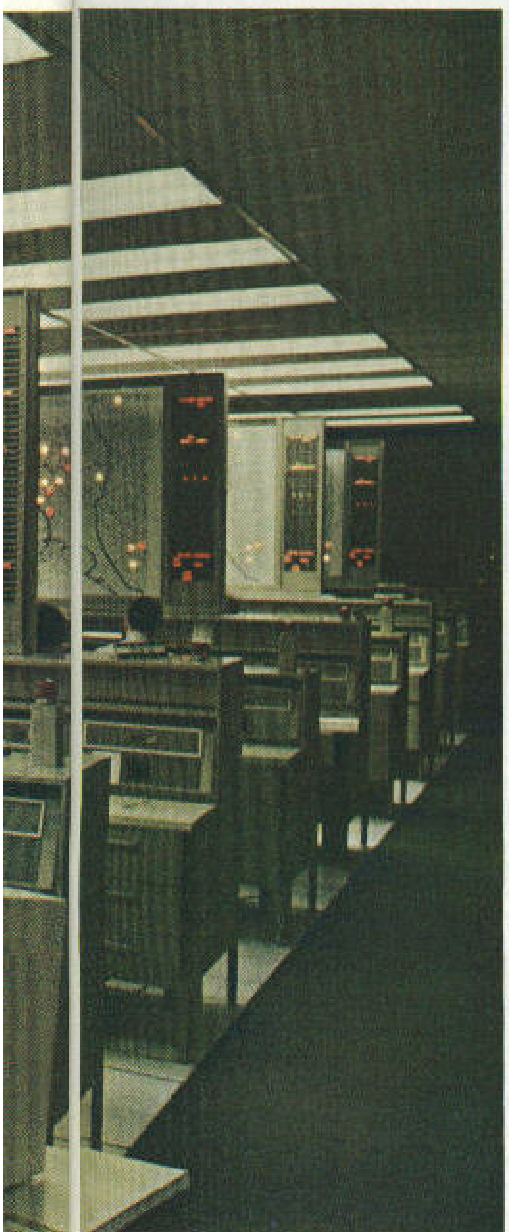
As an operator punches the license number on his keyboard, a computer instantaneously combs a vast criminal file on



objects and persons, constantly updated by Washington-area police units and courts and the D. C. motor vehicle department. The computer also queries the FBI's National Crime Information Center. Quickly it reports back on the display screen —in this case, no complaint.

As another anticrime aid, the computer prints monthly crime maps (right). Darkest shading shows high-crime areas, here within the Capital's 14th Precinct.





into five units: Input. Storage, or memory. Control. Processing. Output.

The input unit senses, or "reads," data in binary code from various sources, such as:

• Punched cards, each with hundreds of spots in which a hole may be punched. A hole may represent 1, no hole may represent 0.

• Magnetic tape, with more than a thousand spots per inch —a spot magnetized in one direction represents 0; a spot magnetized in the other direction represents 1.

• A keyboard. When a key is pressed, the letter or number it represents is automatically encoded into electronic impulses corresponding to 0's and 1's.

• A radar antenna, or a TV camera. The data they gather is also turned into electronic impulses, representing binary 0's and 1's.

Output Appears in Varied Forms

Once sets of binary electronic impulses have been put into the machine, they are ready to be manipulated by the almost indescribably complex interactions of the memory, control, and processing units—that is, to be added together, or to be subtracted from others, or to be sorted or compared with each other; in short, to be processed. Then the output unit delivers the results, which can be made to appear in a variety of ways:

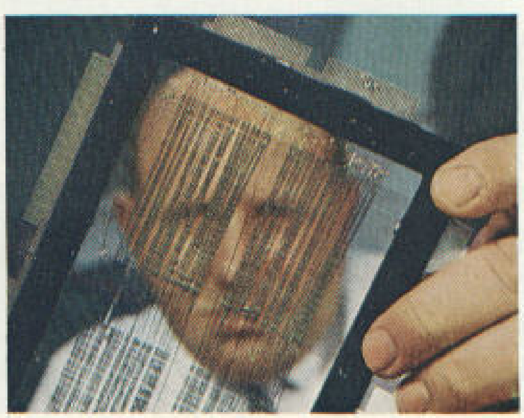
In binary code on punched cards or magnetic tape. Or decoded into decimal numbers and letters of the alphabet, and printed by an electric typewriter or other machine—such as the one turning out the mailing labels for 6,900,000 copies of this magazine. Or displayed on a cathode-ray tube similar to that of a TV set. Or put into words through an audio-response unit, such as the one I heard after dialing that telephone number that had been changed.

And because it's all done by what is basically the switching around of electronic impulses, the work of this most astonishing machine man ever built is known by the modest phrase "electronic data processing."

For a modest but far-reaching example, I drive to a Jr. Hot Shoppe in northwest Washington to get a Royalburger. The girl at the checkout register punches a key marked RBG and out pops my check: 55 cents. Her punching

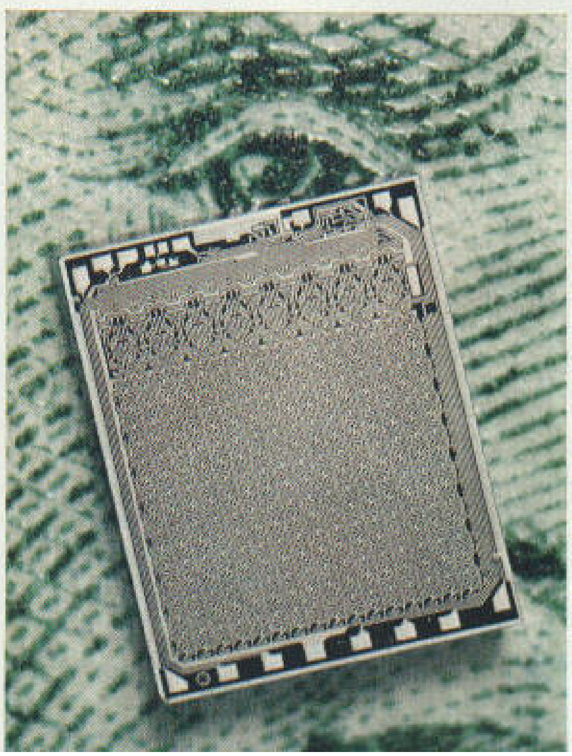
Anatomy of a computer

To create the computer's complex memory and nervous system, engineers turn to their indispensable assistants—other computers. Drawing with a beam of light, a computer-driven plotter traces the outline of a printed circuit on film at TRW Inc. in Los Angeles. The diagram will be reduced photographically to a 1/7-inch square, coated with conductive metals, and combined with other patterns to become an integrated circuit, or IC. These masterpieces of miniaturization, holding as many as 600 electronic components, give computers their compactness. They also reduce the distances electrical impulses must travel—a vital saving for a device performing a million operations a second.



Electronic memory of most computers dwells in thousands of iron-oxide rings strung on wires, as in this IBM grid (left). Magnetized rings may represent the digit 1; nonmagnetized, the number 0.

Minuscule circuitry is dwarfed by Thomas Jefferson's face on a one-cent stamp; both appear greatly enlarged at far right. Lacelike "wiring" connects 2,500 microscopic transistors, resistors, and diodes in this memory "chip," made by Fairchild Semiconductor in Mountain View, California.



automatically sends a series of electronic impulses to a computer memory.

Next morning, over a telephone line, a computer four miles away pulls in all the data stored the previous day, and the electronic data processing begins.

The computer adds the number of Royalburger patties sold the day before in all the Jr. Hot Shoppes. It subtracts that number from the number of patties in the supply center. It compares the result with the number of patties estimated to be needed today, and prints an order for the right number of patties to be brought to the center. The computer also prints a list of how many patties are to be trucked to each Shoppe.

"How many buns, too," adds a senior official of Jr. Hot Shoppes. "It's quick, it's economical."

And it's characteristic of much data processing done by the biggest organizations nowadays. Thus do the automobile manufacturers keep from running out of parts. So do Boeing Aircraft and the U. S. Air Force.

Crime Data Converges at the FBI

Now I stand in a quiet room in the heart of Washington. An electric typewriter, unattended, clicks softly and rapidly, and stops. This is the FBI's National Crime Information Center—essentially a computer linked to police in all 50 states.

An FBI inspector says, "Watch the typewriter. If you see the word 'hit,' it means somebody has found something that somebody else is looking for." I see a timely cross section of crime and apprehension.

11:38 a.m. New Jersey State Police report a hit on a Vespa motor scooter with Arizona plates. It had been stolen in New York....

11:56 Man wanted in Baltimore for unlawful flight. Computer acknowledges, adds that this man already is wanted in Virginia for breaking and entering....

12:01 Inquiry from Utah, giving engine number of blue '67 Chevy pickup truck. It's another hit. The truck was stolen in Texas....

The inspector explains that criminals have become disconcertingly mobile. "But as they rush across the country, a lot of them get caught in the middle, in Kansas, Nebraska, Texas. Say a trooper in North Platte, Nebraska, stops a man for making a left turn without signaling. Intuition tells him something's wrong; the man may be wanted, so he radios the information on the driver's license to his dispatcher, who types it on a keyboard, which

SHEPHERD *of a steelworks, an unseen computer watches over an automated inferno at the Granite City Steel Company in Illinois. Controllers, sharing air conditioning with the pampered computer, monitor panels showing temperature, dimensions, and speed of the glowing strip of steel as it goes through powerful rolling mills at center. Hidden sensors constantly scrutinize the process. Should the product stray from programmed specifications, the computer automatically carries out proper adjustments.*

EKTACHROME BY EMORY KRISTOF © N.G.S.

is connected to our computer here, and the trooper gets his answer within 90 seconds, before he has to let the man go.

"Or if he chases a car on the highway, he can check out the license plate while traveling only three miles. Could save his life, if he is told the man is armed and dangerous."

The anticrime computer's job is a matter of electronic matching. The Vespa hit at 11:38 was typed in thus: B505/AZ/67/MC. That stood for license plate B 505, Arizona, '67 motorcycle or motor scooter. Had there been nothing to match in the computer's storage, the machine would have typed back: NO RECORD. But the match was made, which triggered the outpouring of the stored information.

"We also put in stolen securities," the inspector said, "and boats, aircraft, snowmobiles. About two million records. By the way, Mr. White, what is your date of birth?"

I said May 11, 1925.

He typed DCFBIWA. NAM/WHITE, PETER. DOB/051125.

The machine typed NO RECORD, and the inspector bade me goodbye.

Computer Solves a Builder's Nightmare

I drove to the Potomac shore, to the Watergate complex—hotel, shops, offices, and apartments—four vast and unconventionally curvy buildings: a monument to computerization.

The reason is that so little is square about these buildings. All those curves, so harmonious to the eye, are far from symmetrical; an architect's dream but a construction man's nightmare. The project manager supervising the erection of two additional high-rise buildings says a computer is saving his sanity.

"Each concrete floor reaches out to a slightly different edge. Those glass walls are really hundreds of separate windows, set in hundreds of steel frames, each of slightly different breadth! To get the necessary specifications takes hundreds of thousands of calculations. Even if we could get enough engineers to do it, they'd each make little errors, and the pieces wouldn't fit properly.

"So—one computer figured it all. It sends specifications to the manufacturers for each window and frame. Each arrives labeled as to precise location. Excuse me."

He turns to a teletypewriter that spits out blocks of numbers.

"A lady who bought an apartment on the eleventh floor wants a wood-burning fireplace," he says. "Now the computer tells us how we can put in a chimney for her without messing up the apartments higher up."

To learn how one operates computers, I entered a special school in Washington. The teacher said, "We don't just feed data into the machine; we must also put in instructions. First we analyze the problem. Then we write a solution as a logical flow of consecutive steps."

And so we drew up a flow chart, a sequence of concise instructions; in this case, the purpose was to turn out a factory payroll.

IF HOURS WORKED GREATER THAN 40, GO TO OVERTIME.

IF SOCIAL SECURITY AMOUNT IS LESS THAN SOCIAL SECURITY LIMIT, GO TO DEDUCTION.

IF BONDS EQUAL $18.75, GO TO BOND—BUY.

And a lot more instructions. Finally: WRITE CHECK FOR NET PAY. And STOP RUN.

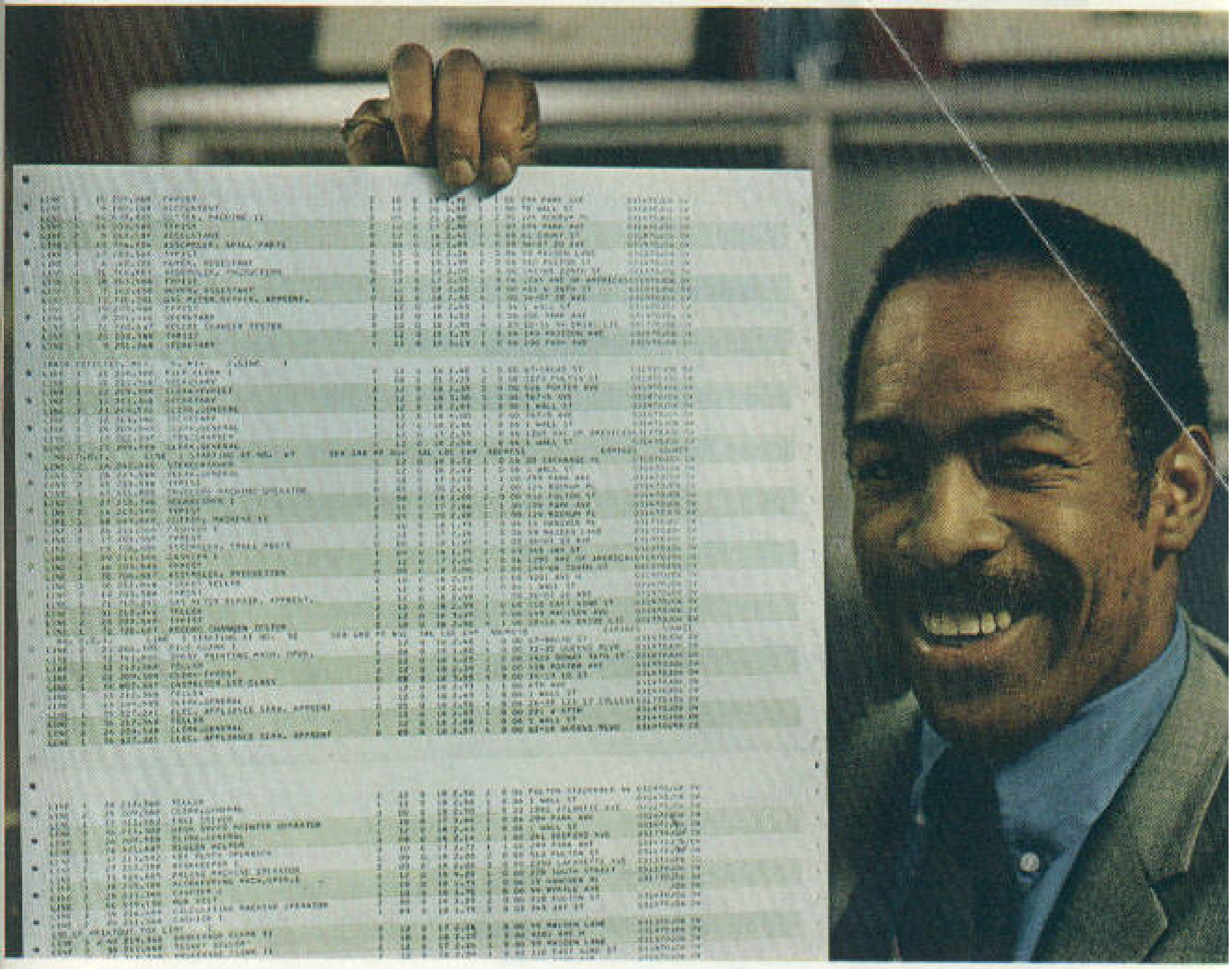
All these instructions would be encoded into series of electronic impulses and fed into the computer—to set a lot of the switches inside it, so to speak. Incredible, how much switching our instructions would unleash. To do the data processing necessary for the printing of each paycheck, circuits by the tens of thousands would be switched on and off, all within a single second!

And how marvelous that we didn't have to worry much about the inside of the machine: the mass of wiring linking masses of minuscule parts. But of course we weren't studying to become engineers. We were learning to write recipes for data processing; or, as the jargon has it, to write computer programs. I was becoming a programmer.

The teacher said, "Any well-defined procedure can be programmed." But how can one define the ever-changing factors in an industrial process well enough so that a computer can run an oil refinery? Or a steel plant?

The teacher said, "A properly programmed computer can control and modify its own operation." Many measuring devices keep watch on the process to be controlled. Their output is turned into electronic impulses. These are continuously fed back into the computer, which in turn sends out impulses of its own to continuously adjust the machinery necessary to refine crude oil into gasoline.

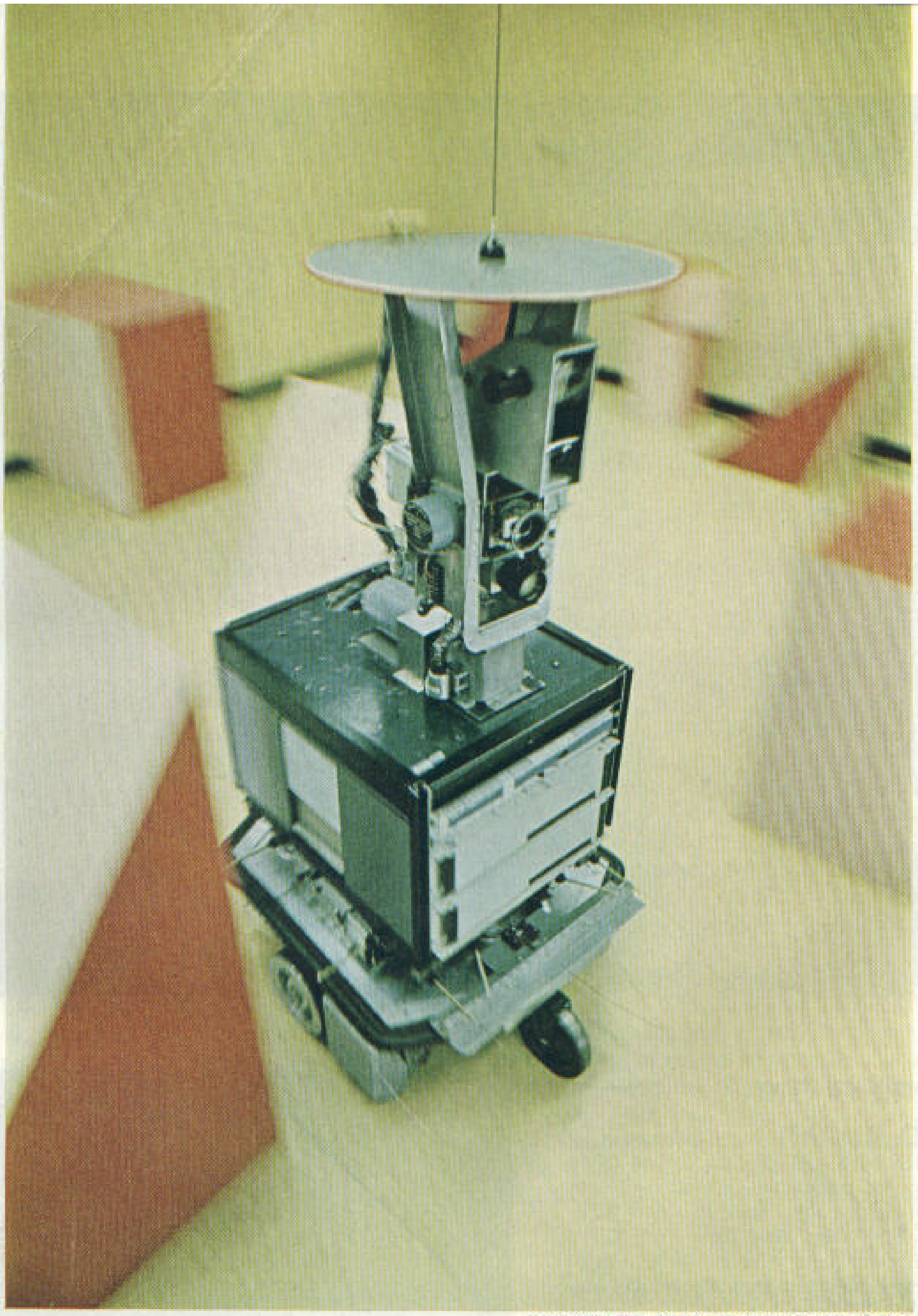
Or to mix the ingredients for steel in a furnace, and then flatten fat ingots into sheets thin enough to sheathe cars and refrigerators



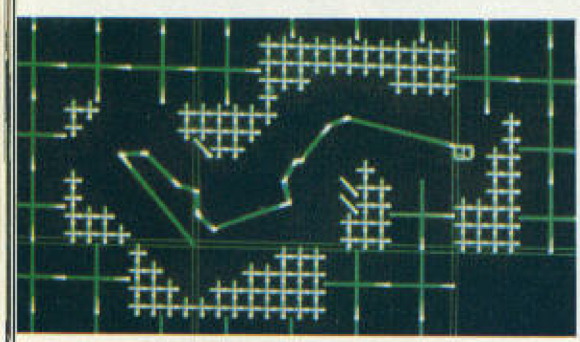
Friend of the job hunter

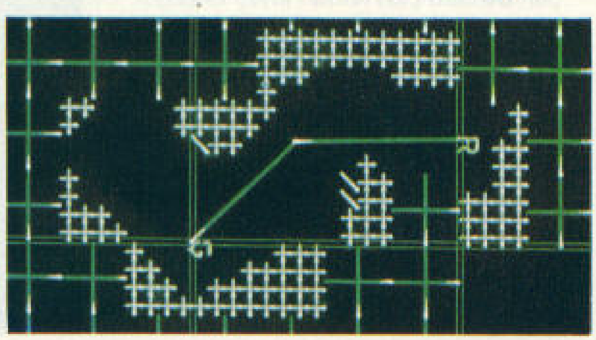
"If computers can match boys and girls for college dates, they can match job-seeking men with man-seeking jobs," said President Richard M. Nixon. And New York City's Manpower and Career Development Agency does just that. Robert W. McKinney, Jr. (above), a data manager for the Bedford-Stuyvesant area, displays a computer listing of available jobs. Applicants (right) will give counselors their requirements and qualifications. A counselor may then tell the computer that a 21-year-old male with a high-school diploma and a year's experience wants full-time work at $2.25 an hour in accounting. The computer replies that such a job is open at $2.41 on Court Street.

EKTACHROME (ABOVE) AND KODACHROME (TOP) BY EMORY KRISTOF © N.G.S.



EKTACHROME (ABOVE) AND KODACHROMES BY BRUCE DALE © N.G.S.





(pages 604-5). Or to launch one of NASA's rockets into space. That process—requiring so many things to happen so fast and so accurately—could never be managed without computers.

Before such a rocket can be launched, hundreds of programs must be written, containing hundreds of thousands of steps. That requires hundreds of programmers, and a lot of programmers can make a lot of mistakes. Errors, or bugs, are eliminated as programs are run for testing, or debugging. Just the same, an undetected bug disabled the $18,500,000 Mariner I, so that instead of flying to Venus it had to be destroyed barely five minutes after take-off from Florida.

Alas, how tricky it could be just to program a girl to cross a road! I had learned that from a film which, to illustrate the pitfalls of programming, shows her holding a walkie-talkie and doing only what she is told to do.

Take a step forward. Have you reached the curb? No.

Take a step forward. Have you reached the curb? Yes.

Stop. Look to the left. Is there a vehicle within 60 yards? Yes.

Is there a vehicle within 60 yards? Yes.

Is there a vehicle within 60 yards? Yes.

What went wrong? The girl was stuck because the programmer forgot that vehicles can be parked. He should have asked:

Is there a moving vehicle within 60 yards?

The reply would have been No, and the next instruction could have been *Cross the road.*

Something like this had happened in that department store's billing operation in Kansas, the one that produced bills for $00.00, remember? Something was missing from the flow chart for that program, a step saying "Test for zero. If yes, send no bill."

Now that I knew how demanding it can be to work with computers, and how frustrating, I could see why extra-bright programmers can earn $20,000 a year at age 25. Why they sometimes chew their nails and pencils around the clock, and snap at their wives when they finally get home. And why one night a programmer fired two bullets into a computer. Unemployment checks were late that week in the vicinity of Spokane, Washington.

Machines Keep Track of Fashion Trends

To celebrate my escape from programming, my wife and I sent a lot of electronic impulses flying. We headed for a suburban Washington department store, and she chose a dress. The salesgirl tore off a portion of the price ticket that had a mass of holes in it (page 613).

That night many such stubs would go through a reading machine; it would transform the data on the stubs into holes in punch cards, ready for the computer.

Next morning the dress buyer would have a report from all the store's branches, showing just what dress styles were selling best, so she could reorder fast.

I stopped at the store's theater ticket counter. Any seats for the musical *1776* in New York tomorrow? The girl punched a keyboard, and the answer flashed right back on a little screen like that on a TV set: N101 and 102, fourteenth row, center. I said all right. The girl punched another key and our tickets were printed out then and there.

The morning after the show, I kissed my wife goodbye, picked up the phone, and asked an airline for a seat to Dallas. I couldn't see the reservations girl, but I knew what she was doing: punching keys, looking at a little TV screen, then punching in my flight number, date, destination, and name.

And something in addition. Did I want steak or lobster for my dinner? Steak! I was off to see H. Ross Perot, the celebrated computer tycoon, in Texas (page 598).

Mr. Perot had responded to a widespread

Shakey the robot With a whir and a wobble and a chirp from its radio transmitter, a man-high mechanism named Shakey prowls a room at Stanford Research Institute in Menlo Park, California. Challenged to discover a path through a maze of obstacles, Shakey starts out at the left side of the electronic map at far left. Following a dead-end path, it gropes forward, senses obstacles with its cat-whisker antennas, and ultimately zigzags to the goal. Asked to show how it would return, Shakey's computer intelligence—a PDP-10—recalls the obstacles encountered and draws for the robot a correct path, shown as R-to-G on the right-hand map. Scientists at the institute think machines like Shakey could someday explore dangerous environments such as those man might encounter on Mars.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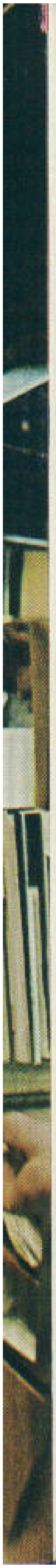


need. Many a businessman eager to benefit from computers had learned the hard way that one can't simply buy the machines, plug them in, and expect them to do just what the salesman promised. A procedure might take only an hour to run, but the necessary programming might have taken a year.

Even little changes in a program consume much time and nervous energy. And a switch from one computer system to a newer one? Programmers quitting in a huff! Accounts mixed up by the thousands! Chaos! No wonder many corporations find it best to let somebody else do their data processing for them.

$1,000 Check Turns Into Millions

Many men have discerned this need and scores have invested to profit by it, but none with the touch of Mr. Perot.

On his coffee table I saw a $1,000 check framed in silver. "With that I started Electronic Data Systems," he said, "in 1962, when I was 32." Eventually his company issued shares to be sold to the public. These soon rose in value, to such an extent that the shares he had kept for himself were now worth several hundred million dollars.

The brightly lit hall where I watched his computers at work looked like any other computer center: False floors, to accommodate thick cables connecting those massive steel cabinets, in pale blue and pale gray. Reels of magnetic tape, spurting and stopping, quietly, behind plates of glass. Machinery printing out 1,100 lines a minute. For an insurance company, a bank, a brokerage house.

Mr. Perot said, "My secret is to hire men who are smarter than I am." Ten of his employees had become millionaires too.

Next to dazzle me with computer doings was a pigtailed first-grader named Shelia, in McComb, Mississippi (pages 594-5). I watched her at the keyboard of a Teletype machine as she hunted and pecked with slender fingers.

The machine typed: $6 - 5 =$ __

Shelia pecked in: 1

Machine: $4 + 3 =$ __

Shelia made it: 7

Then came the thing that impressed me so.

Machine: $5 + 2 = C + 3$

$C =$ __

Shelia, quickly: 4

I have since been assured that this is not an uncommon accomplishment for first-graders—that's the sort of math they are taught nowadays. But not many as yet are drilled daily by computers, as were all the pupils in the seven elementary schools of the McComb school district. It was an experiment then, piped in over telephone lines from Stanford University in California. Today the McComb schools have a mini-computer of their own.

The machine summed up. 16 PROBLEMS WITH 94 PERCENT CORRECT IN 168 SECONDS. GOOD-BYE, SHELIA. PLEASE TEAR OFF ON THE DOTTED LINE.

"The machine doesn't allow the mind to wander," said the district superintendent. "Some teachers were opposed. They thought it was just play. But our test results show significant improvements in the children's mathematical abilities. So what if it's fun?"

I noticed that among Shelia's classmates none got quite the same problems. A little boy named Ralph was given only the simplest additions. To $22 + 33 =$ __ he replied 6. The machine typed, NO, TRY AGAIN.

Ralph thought and thought.

TIME IS UP, ANSWER IS 55.

Ralph said, "It's a good thing; it tells you when you're wrong."

The machine does a lot more than that. As soon as a pupil types in his first name and identity number, it finds his file and provides a drill custom-made on the basis of his previous performances, geared to his own pace of learning. Teachers get daily summaries, reporting on each pupil's progress, and periodic printouts of grades, saving paper work. If special counseling seems advisable, the child's file is instantly available for review. The teachers still teach. The machine provides drill.

Oh, oh, no more drills today. All the machines are out of order. A day later, they type out an explanation: STORMS HAVE BEEN RAGING IN CALIFORNIA . . . POWER FAILURES . . .

Quick tallies on the Big Board As traders mill about, an official reporter of the New York Stock Exchange hastily jots on a computer card the details of a sale—the stock, its price, and the number of shares traded. Inserted in the electronic reader beside him, the information will flash almost instantly on 9,000 Exchange tickers and display boards around the world. EKTACHROME BY EMORY KRISTOF © N.G.S.

WEAKENED CIRCUITS WITHIN COMPONENTS THAT MAKE UP A COMPUTER . . . IT TAKES LONG HOURS AND CONSTANT PROBING TO TRACK DOWN AND REPAIR THEM ONE BY ONE . . . .

Those are the ills computers are heir to. There are more. Excessive humidity can make them go haywire. So can the vibration from heavy traffic. And particles of tobacco ash can mix up the impulses stored on magnetic tape and produce errors.

Exasperated Student Gets a Warning

As I traveled on, I was impressed by the variety of sophisticated programming done for the benefit of students nowadays. I sampled the computer-assisted instruction available to all the midshipmen at the U. S. Naval Academy—physics, electrical engineering, economics. And I took a geography lesson myself at Dartmouth College.

Please keep in mind that there is no human being at the other end of the line, just a well-programmed computer.

HI, I AM CALLED MISS TELETYPE—WHAT WOULD YOU LIKE ME TO CALL YOU?

PETER.

HELLO, PETER! TOGETHER WE WILL LEARN THE LOGIC OF LOCATING A SET OF CLIMATE DATA ON THE GLOBE. . . .

I was given climatological definitions, plus information about average monthly temperature ranges and average rainfall for a real but unidentified place—interspersed with questions I was to answer in my own words.

Step by step I located the place in the Northern Hemisphere, in the upper mid-latitudes. I did fairly well but not for long.

BE SERIOUS, PETER.

I confess that I became unduly exasperated. I typed in an intemperate word. Miss Teletype reacted immediately.

GOODNESS—SHAME ON YOU!!! WATCH YOUR LANGUAGE OR I'LL CUSS BACK AT YOU.

I was ashamed. I buckled down.

VERY GOOD.

EXCELLENT, PETER.

PERFECT—THAT WASN'T HARD, WAS IT!

SO LONG FOR NOW, PLEASE GIVE ME A CALL AGAIN—SOON.

I paid my respects to the professor who had programmed Miss Teletype. "It's not all that hard," he said. "You know—you present things logically, you try to anticipate what might happen."

An even more graphic lesson awaited me at the Massachusetts Institute of Technology. The associate dean of engineering took me to a desk equipped with a TV screen, a keyboard, and a so-called light pen all connected to the same computer.

"Take the pen and draw on the screen," he said. "Lines of light will appear on the screen, in the path of the pen. Please draw a child's set of building blocks. When you are satisfied, press this key—your drawing will be stored in the computer's memory."

I was creating a model, so to speak, of a set of blocks. It was in the form of information stored in the computer, representing algebraic formulas based upon lines and curves. No need to worry about the mathematics, though; the computer's program took care of that.

"Now watch," said the dean. "I can command your blocks to become larger or smaller. I can change their shapes. And rotate them, to view them in different perspectives. I can arrange them as I like; I can erase them." He did all that, moving the light pen, pressing keys. I had never seen a fancier toy.

Computer Models Help Decision Makers

"In the same way," said the dean, "we can create a model of something we really want to build. A school building perhaps, or a traffic interchange. Then we type in information on the physical site, on design requirements, and human considerations, on many factors affecting our project. The computer calculates these, and we can modify the model accordingly—add parts, delete parts, change some.

"We look at various stages of modification. We measure the effects and the costs. We are simulating things that might happen—to find the best choice, to make the best decision."

In other words, figuring out a lot of things a lot faster than many men could with pencils?

"I think your analogy is unfair to the computer," said the professor. "We have a brand-new capability here, to do things we couldn't do before, to explore so many possibilities. To let the truly creative man use his mind freely. An incomparable tool of exploration."

Modeling! Simulation! Much aircraft designing is done that way nowadays (page 615). An engineer with a light pen draws a cross section of a wing. Then, in effect, he turns his computer into a wind tunnel, subjecting the wing to simulated stresses.

He changes the shape and dimensions of the wing, and when the results look good to him, he presses a key. Thereupon a computer-controlled plotting machine will draw a blueprint of what he designed. Then the computer could produce a tape, to control a machine to build that wing for a prototype.

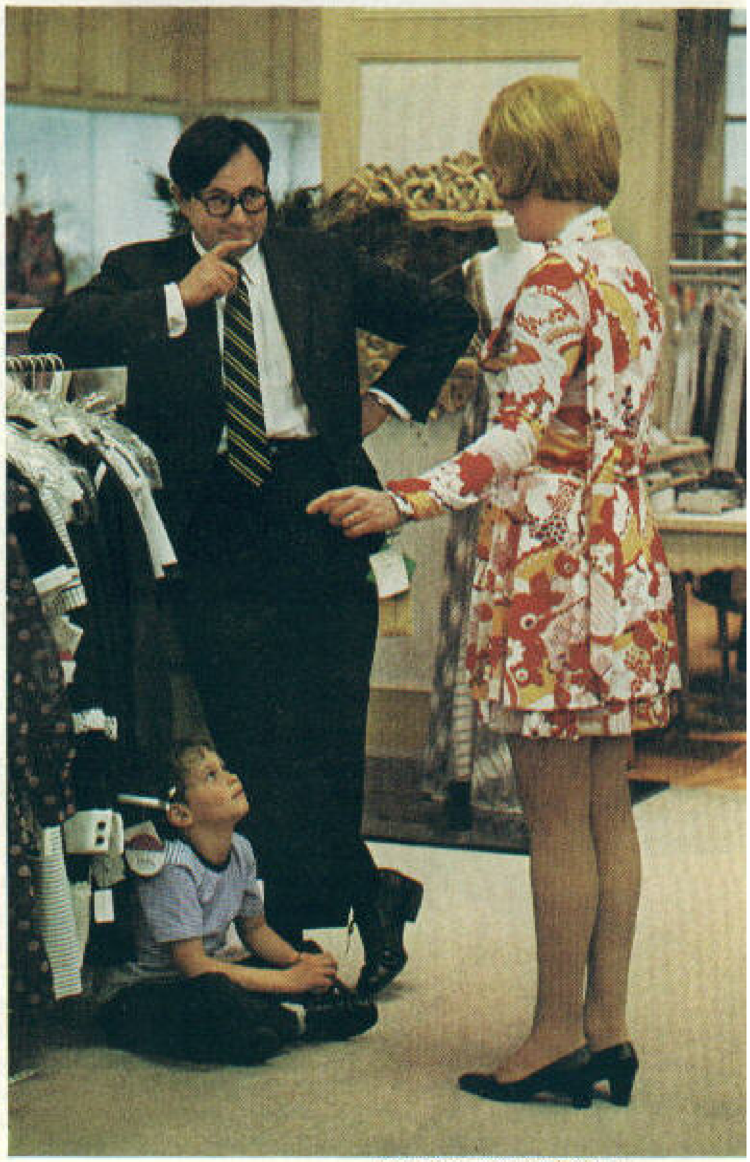
Modeling and simulation get astronauts to the moon.* In training, they see the effects of their piloting simulated as they practice in a mockup.

For months the spacecraft's flight is mathematically simulated in computers; during the actual flight the model is corrected once every second. This freshly calculated navigational guidance can be beamed up, as needed, from NASA's central computers.

Never was space flight simulated more triumphantly than during the anxious hours of the Apollo 13 mission. While Astronauts James Lovell, Fred Haise, and John Swigert hurtled through space in their damaged craft, other astronauts huddled inside the computerized command-module and lunar-module simulators in Houston, doggedly trying out procedures for returning Apollo 13 to earth under circumstances never before encountered and never really foreseen in complete detail. Finally the procedures thus checked and double-checked were radioed up to the real Apollo 13, and applied successfully.

I found less hectic varieties of simulation far and wide. Scientists in Connecticut observe

*See in NATIONAL GEOGRAPHIC: "The Flight of Apollo 11," December 1969; and "Tracking America's Man in Orbit," February 1962, both by Kenneth F. Weaver.

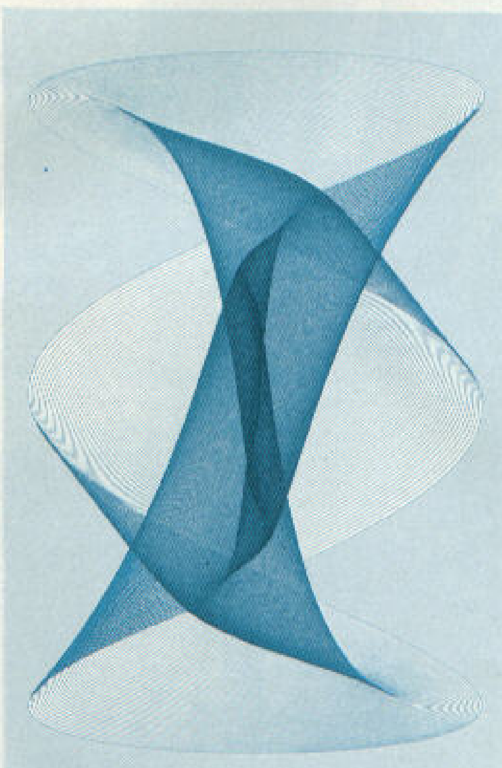


Helping tend the store

With typical male skepticism, the author and son Norby, 6, kibitz as Mrs. White shops for a dress at a suburban Washington, D. C., store. Should she buy, a salesclerk detaches the price tag, marked like those on bathing suits above. During processing that night, large holes will guide the card through a reading machine as small perforations reveal price, style, and other data. Noting this and some 12,000 other computer-recorded transactions for the day, a machine will print by next morning an accurate picture of sales, showing buyers what items to restock.

ARTWORK (ABOVE AND BELOW) BY CALCOMP, ANAHEIM, CALIFORNIA

"The Fisherman": A computer, programmed to draw a human face, guided a plotter that turned out this portrait with Oriental features.



"Oscillating Wastebasket": A student at the University of Toronto programmed the computer that produced this abstract composition.

the spread of blight in a mathematically simulated field of tomatoes. From an analysis of rock data, a geologist at the University of Michigan simulates erosion, to show in successive computer-printed profiles how the Colorado River cut the Grand Canyon.

Scores of major companies use simulation. If car production drops, what's the effect on the steel industry? How high can copper prices rise before it is wise to switch to aluminum wire for winding transformers?

And how was the duck shooting last year? How is duck breeding coming along in Canada? From such information the U. S. Fish and Wildlife Service creates a model to simulate duck populations for the coming season, to decide how many hunting days to permit.

It would take all the pages the GEOGRAPHIC publishes in a year just to list all of today's computer applications.

Science Projects Stored for Reference

Back in Washington, I visited the Smithsonian Institution's computerized Science Information Exchange. Researchers send in brief summaries of their projects, to be stored on magnetic tape. Any scientist can order computer print-outs describing research underway in his field, so that he won't start to do what somebody else is already doing.

The director said he had about 100,000 active projects on tape, lots of them employing electronic data processing. "I suspect that using computers in research is becoming as common as using the microscope."

Computers monitor experiments. They analyze, tabulate, and sift findings, thus fostering the discovery of newly appreciated relationships and proving new theses. Not only in the physical sciences but also in biology, in archeology (see the article beginning on page 634), and in the humanities as well. Through analysis of the recurrence of certain words, a computer furnished convincing evidence that 11 Federalist Papers widely thought to have been written by Hamilton were by Madison.

By now I longed for a rest from computers. But I couldn't avoid the newspapers, with their daily diet of computer-related items:

- Computers in hospitals analyze electrocardiograms and brain waves; they monitor patients' progress by continuously measuring heart and respiratory functions, temperature, and blood pressure.
- Computers in state and municipal employment agencies match job applicants with job listings that are truly up to date, so that a

man won't go after a position that was filled two days before.

• Computers control traffic lights at city intersections, changing the signals in tune with the over-all traffic situation that very moment, as scanned by many sensors.

I also read that computer-made music is booming (pages 628-9). So is business in computer-written horoscopes. For $20, one gets reams of advice and predictions—every bit as reliable, it seems, as any other horoscope. Computerized dating services flourish too. People love them, even though a computer once matched brother and sister.

And crime? Two bright young men from North Carolina are in jail now, but for a time they were riding high with an anti-poverty agency in New York City. They made a computer turn out thousands of checks to nonexistent youths working at fictitious jobs. Then they had a lot of those checks cashed, collecting several hundred thousand dollars.

High Hopes for the "Beep-boom" System

I took to the road again, to discover what electronic data processing is doing to warfare.

The general who heads the U. S. Army's Computer Systems Command gives me a glimpse of the automated battlefield of the future, where far-off detection devices, or sensors, feed data to tactical headquarters by radio.*

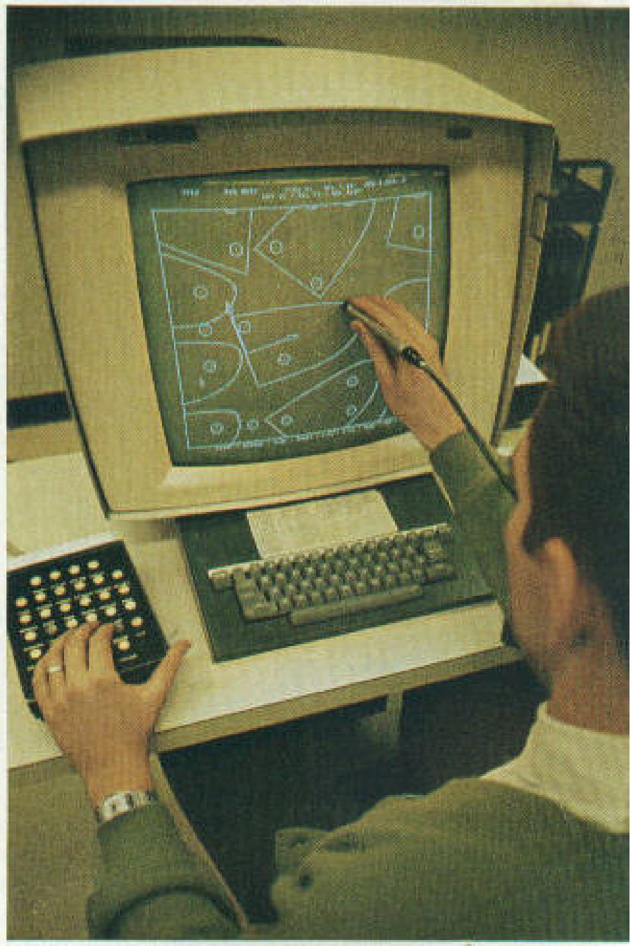
"Some sensors go 'beep.' The computer evaluates what set them off, say enemy tanks of a certain size. It picks out the right artillery pieces, orders the right fuses, aims, fires! No time wasted. We call it 'beep-boom.'"

This new system will soon be tested on maneuvers, and the general worries lest I jump to misleading conclusions.

"Remember, the decisions are still up to the commanders," he says. "A computer program has value judgments built into it—it says when certain conditions are met, go this way. But a commander can punch different criteria into the program. And he stays always in command because we put him either on-line, as we say, meaning the chain of action passes through him, or we put him off-line, meaning he acts as a monitor. If the commands coming out of the computer look good to him, he lets them be carried out. If not, he overrides them, with a button."

How can electronic data processing assist a commander under attack? During a Navy demonstration at the Fleet Anti-Air Warfare Training Center in San Diego, I watch the weapons coordinator on an aircraft carrier make up his mind as enemy planes close in from different directions, faster than the speed of sound. Which of the enemy planes presents the greatest threat?

The coordinator sits at a console of the Navy Tactical Data System, which is fed by various sensors—the radars of friendly ships and planes. He presses a button and tiny pointed symbols jump onto a display screen: the hostile planes. Round symbols show friendly ones.



KODACHROME BY BRUCE DALE © N.G.S.

Wielding a light pen, a console operator outlines aircraft parts on a computer-linked cathode-ray tube at Lockheed-California Company in Burbank. Striving to get the maximum number of parts out of a metal sheet, he uses his keyboards to maneuver the pictures and insert them in a computer memory. This information will guide a machine in cutting out the parts.

*See "Remote Sensing: New Eyes to See the World," by Kenneth F. Weaver, GEOGRAPHIC, January 1969.

With his palm, he rolls a black rubber gadget protruding from the console like half a tennis ball. As he rolls it, a bright blip moves correspondingly on the screen; he rolls until the blip coincides with the closest hostile plane, presses another button, and the system "hooks on" to that plane.

He presses a third button. Rows of white digits appear in his read-out panel, giving information about that plane. Its present course. Altitude. Speed. Time to target, if it keeps going this way. A green digit flashes a computer-calculated "threat number" . . . 2 . . . 3 . . . 6. . . . The highest would be 7.

He checks on other enemy planes before making recommendations to the skipper. Other buttons will unleash the defense, the Phantom jets, the Terrier missiles. . . .

In the future, should a real battle be in the offing, the admiral in another ship may be able to press buttons to cut in with commands of his own. So may the Chief of Naval Operations in Washington. So may the President of the United States, wherever he may be.

That's the idea of the World Wide Military Command and Control System. When completed, it will be the biggest computer network ever built. I saw something like that already in operation—inside Cheyenne Mountain, near Colorado Springs, Colorado. This is NORAD, the North American Air Defense Command, a most awesome electronic data processing complex, employing 15 computers and 34 generals.

President Himself Can Go "On-Line"

Information constantly feeds in from radars around the globe. Masses of intelligence and weather data are stored and constantly updated. The job, says a U. S. Air Force general in NORAD's Combat Operations Center, is to process all this data rapidly; to display the gist concisely; and, if necessary, to trigger nuclear weapons for air defense. Subject to decision from the President, of course. If necessary, the President would be right on-line.

"The only nation in the world that can launch an all-out nuclear strike on us is the Soviet Union," says the general. "And so our biggest radars look more than 3,000 miles over the horizon and into the Eurasian landmass, from England, Greenland, and Alaska. They pick up a rocket launch. Is it a test? Or a space shot? Or an attack on the North American Continent?

"Within a minute the computers calculate the trajectory and display the answer. If it should be an attack, they predict the impact area. We'd get 15 to 25 minutes' warning. A target in the north would get less warning than one in the south."

The general goes home and a U. S. Army colonel takes over the operations console. "There are thousands of commercial planes in the air all the time, and we don't want to see those," the colonel says. "But if one isn't in a position where his flight plan says he should be, the computers pick him up. That's an 'Unknown.' A red light goes on, and if we can't identify him fast, we send up fighters to take a look.

Radar Watches Soviet Planes

"Of course," adds the colonel, "we routinely keep an eye on a few 'Specials' we're interested in." He lights a cigar and reclines in his swivel chair. Sixty-three buttons glow to the left of him, eighty to his right (page 626). He presses one.

On his screen appears an outline of eastern North America and part of the Atlantic. Near Newfoundland glow two dots with tiny tails. He presses again. Letters and numbers appear alongside the screen. "NN370, the Russian Aeroflot flight from Murmansk to Gander to Havana. NN245 is going the other way, Havana—Gander—Moscow." Another button brings up a little triangle off Cape Hatteras: VE01, a Russian fishing trawler.

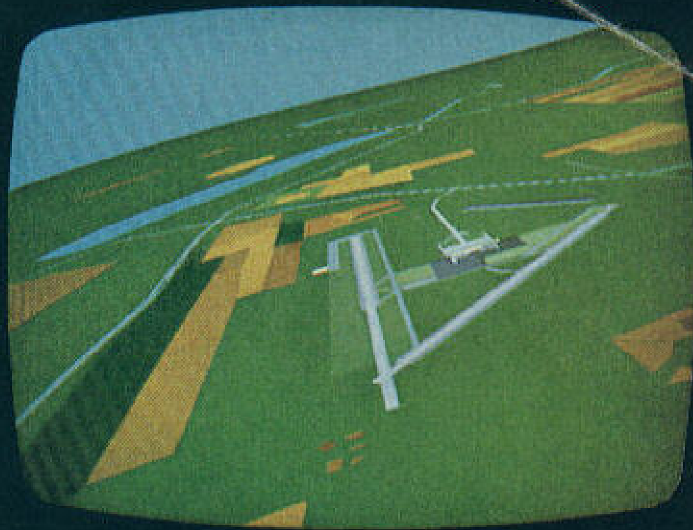
The colonel presses the button marked "World," and another button. I see the path of a Soviet Cosmos satellite. A blip marks the spot where it was a second ago. The colonel says, "We track every man-made thing in earth orbit."

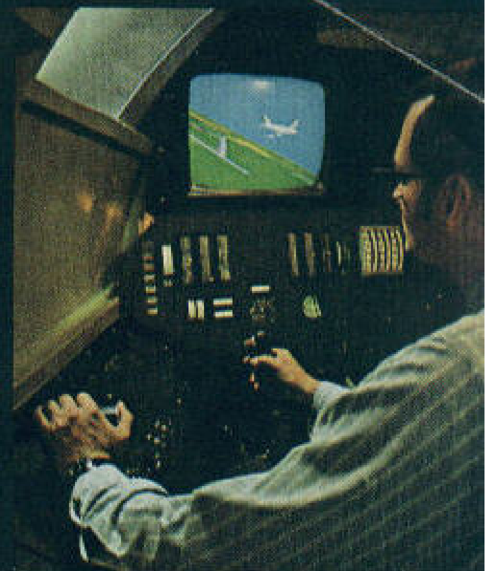
It was an uneventful night. Cosmos 221 over New York. Cosmos 236 over Anchorage, Alaska. The airborne command post of the Strategic Air Command near Kansas City.

Then a red light went on. An Unknown popped up over California, going east.

It turned out to be United Airlines Flight 14, a DC-8 scheduled from Los Angeles to Kennedy Airport, New York, with 50 passengers and a crew of 7. It had been hijacked and was heading for Havana.

I headed back to MIT, whose researchers developed so much of today's computer gadgetry. What's in the future, for nonmilitary men like me?





EKTACHROMES BY BRUCE DALE © N.G.S.

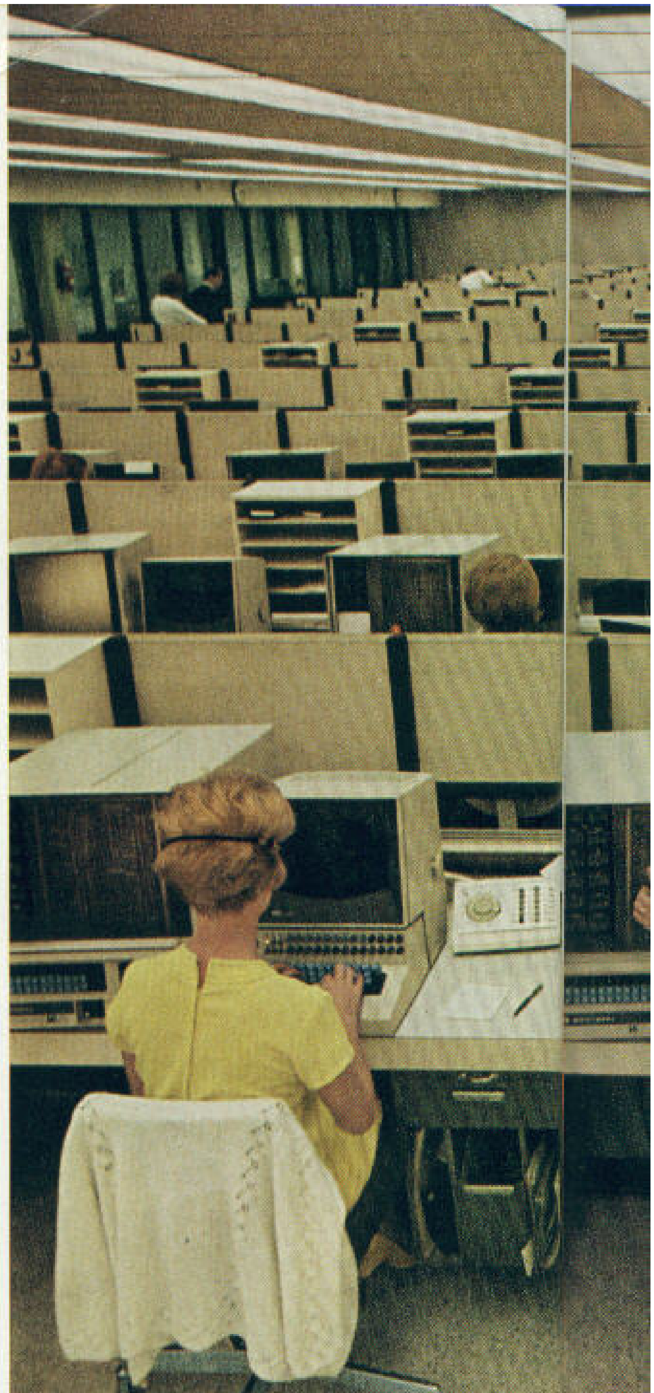
AIRPORT THAT NEVER WAS: *As if seen from a cockpit, a computer-drawn runway looms realistically a mile and a half ahead (top left), at 600 feet (center), then a mere 25 feet away (bottom). Finally the "plane" rolls smoothly to a stop—or crashes into black oblivion.*

These vivid scenes flash on the screen of a new computerized flight simulator (above). General Electric engineers designed it to train pilots without the cost—or peril—of actual flight. Here a pilot veers the simulator as another jet appears to streak across the screen before him.

Keeping America on the wing

In this cavernous reservations center in Miami, Florida, Eastern Airlines ticket agents take bookings at 150 consoles. When an agent types a customer's travel inquiry to this or any of ten other regional centers, a computer flashes back flight schedules, seating, and meal service. The passenger makes his selection, and the computer subtracts a seat from Eastern's availability list. With this system Eastern keeps track of more than two million reservations simultaneously.

Confirming a reservation at Chicago's O'Hare International Airport, a United Air Lines agent types out the passenger's name and flight number. Instantly United's computer center near Denver, Colorado, responds, and the waiting line moves swiftly. Computerized ticketing spreads to new fields, from theaters and baseball games to campsite reservations.



"Computerized individualization," says Professor Joseph Weizenbaum (page 599). He gazes out his window, onto Technology Square.

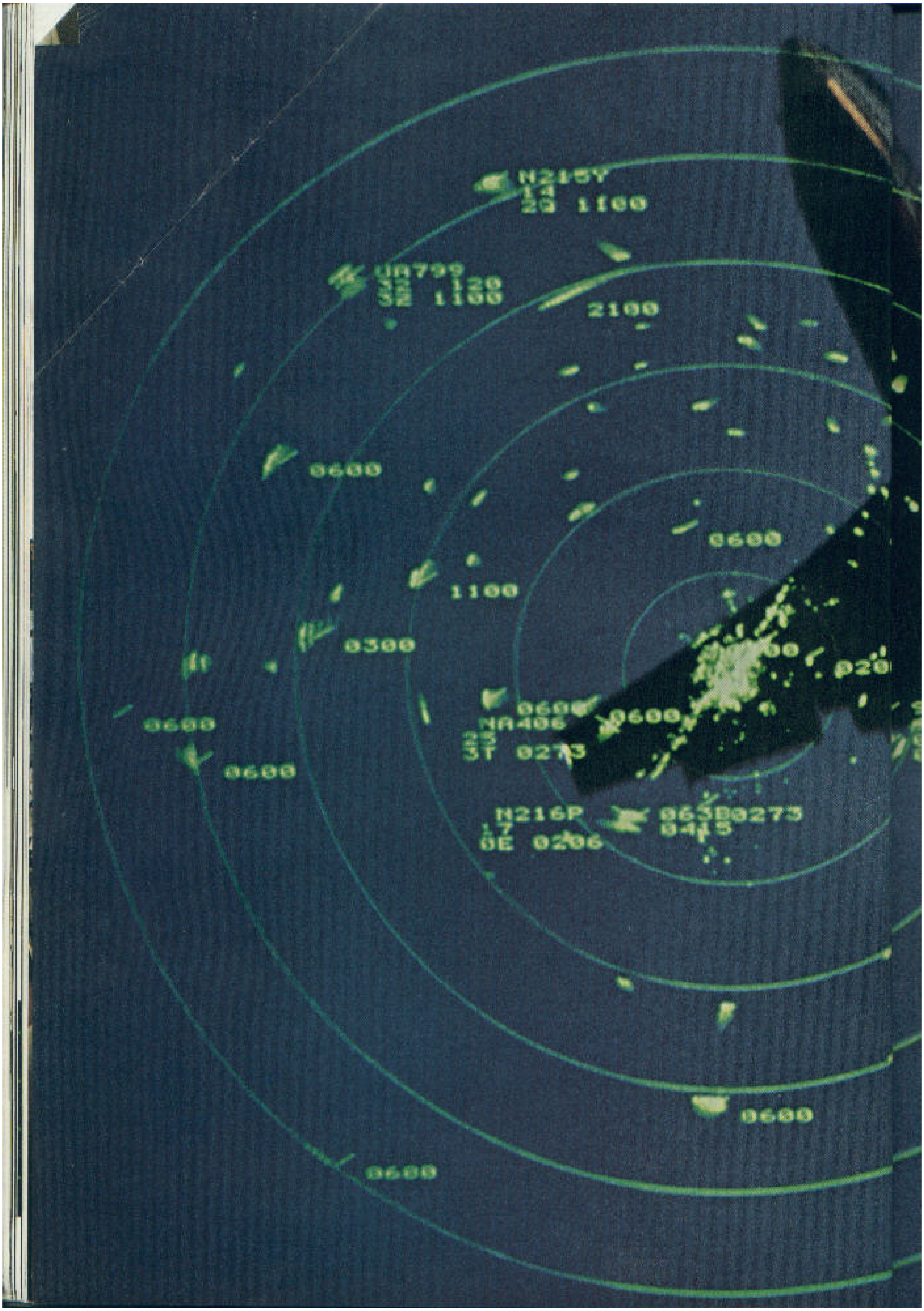
"I am talking about techniques of mass production applied to produce things that are more or less custom-made. Do you care about skiing or coin collecting? Your weekly magazine will bring you a lot of ski and coin news, in addition to general news. But that same week your neighbor's copy of that same

magazine will have a lot of news yours doesn't have—about stamp collecting and fishing, if that's what he cares about. For the computer that won't be much of a problem.

"You could have a rug made to your own design with a fault woven into it, for individuality, but made by machine on a production line with thousands of other rugs. A computer program can do that.

"Or a suit can be cut for you along with thousands of other suits, but to your measurements, fed in from a plastic card. You'll keep the card, for other suits later on. You can see the beginnings of what I mean, right now, in the automobile industry...."

Sure enough, at the Oldsmobile assembly plant in Lansing, Michigan, not one car coming down the line looks like the next. Sedan, convertible, hardtop, topless chassis for a hearse; Aspen Green, Sherwood Green, Burnished Gold, Galleon Gold, Azure Blue, Twilight Blue, Reef Turquoise—all mixed up, all ordered individually. Big engine, bigger engine, biggest; two-way power-adjustable



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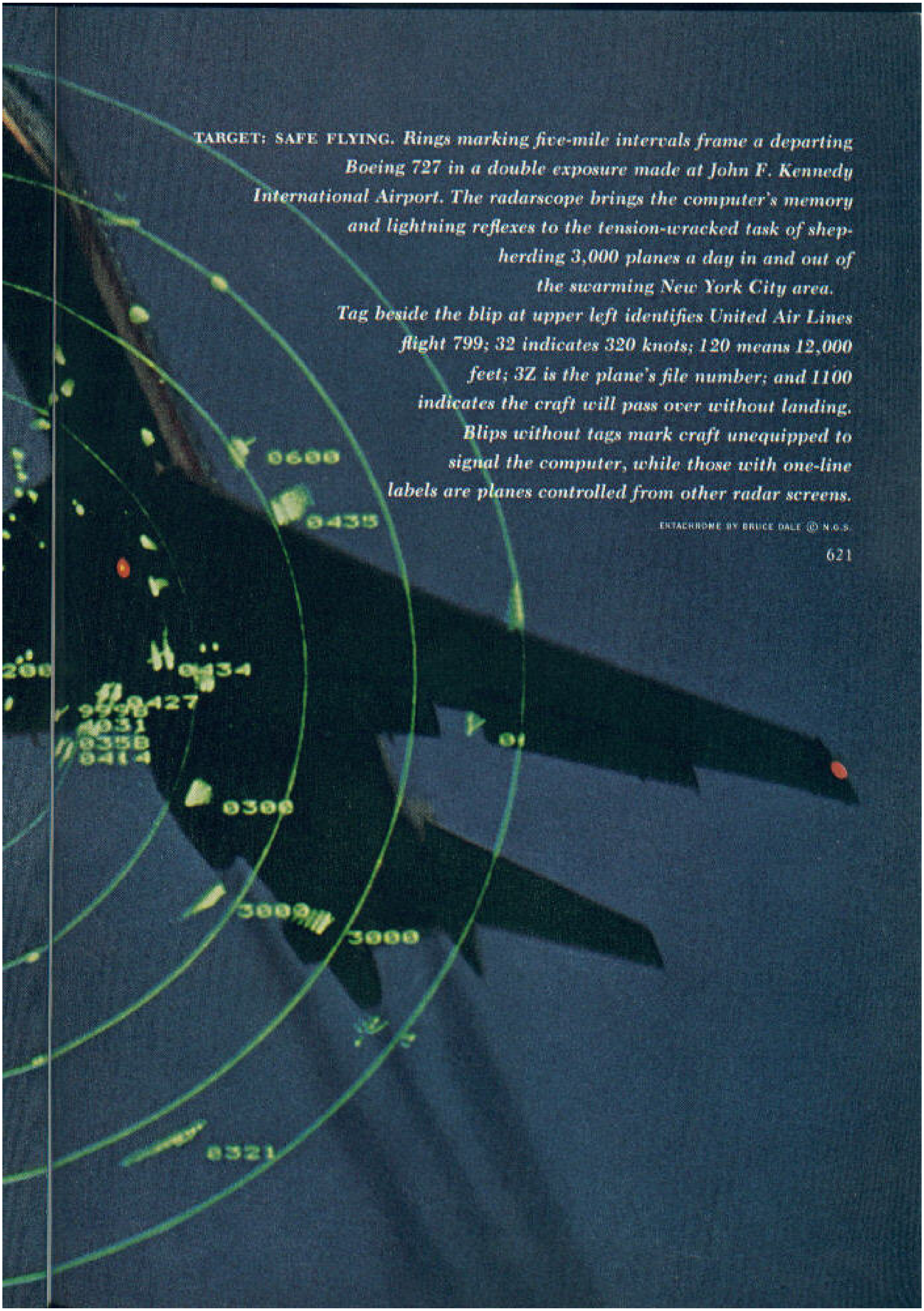


TARGET: SAFE FLYING. *Rings marking five-mile intervals frame a departing Boeing 727 in a double exposure made at John F. Kennedy International Airport. The radarscope brings the computer's memory and lightning reflexes to the tension-wracked task of shepherding 3,000 planes a day in and out of the swarming New York City area.*

Tag beside the blip at upper left identifies United Air Lines flight 799; 32 indicates 320 knots; 120 means 12,000 feet; 3Z is the plane's file number; and 1100 indicates the craft will pass over without landing. Blips without tags mark craft unequipped to signal the computer, while those with one-line labels are planes controlled from other radar screens.

seat, six-way power-adjustable seat; eight types of steering wheels. . . . The computer arranges for the right parts to reach the right assembly-line station at just the right moment.

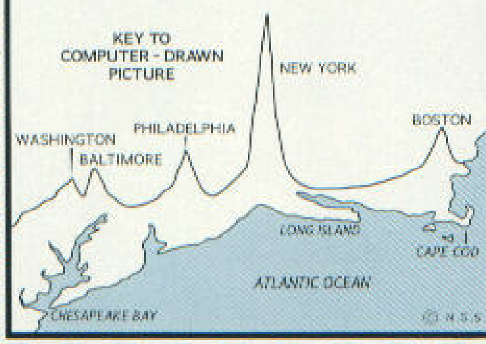
How many 1970 Oldsmobiles could conceivably be made here, without any being exactly like the other? The programmer winces; not every option can go into every model. He takes eight hours to prepare a program, and 18 seconds of computer time. The answer is 61,758,733,548,151,070,414.

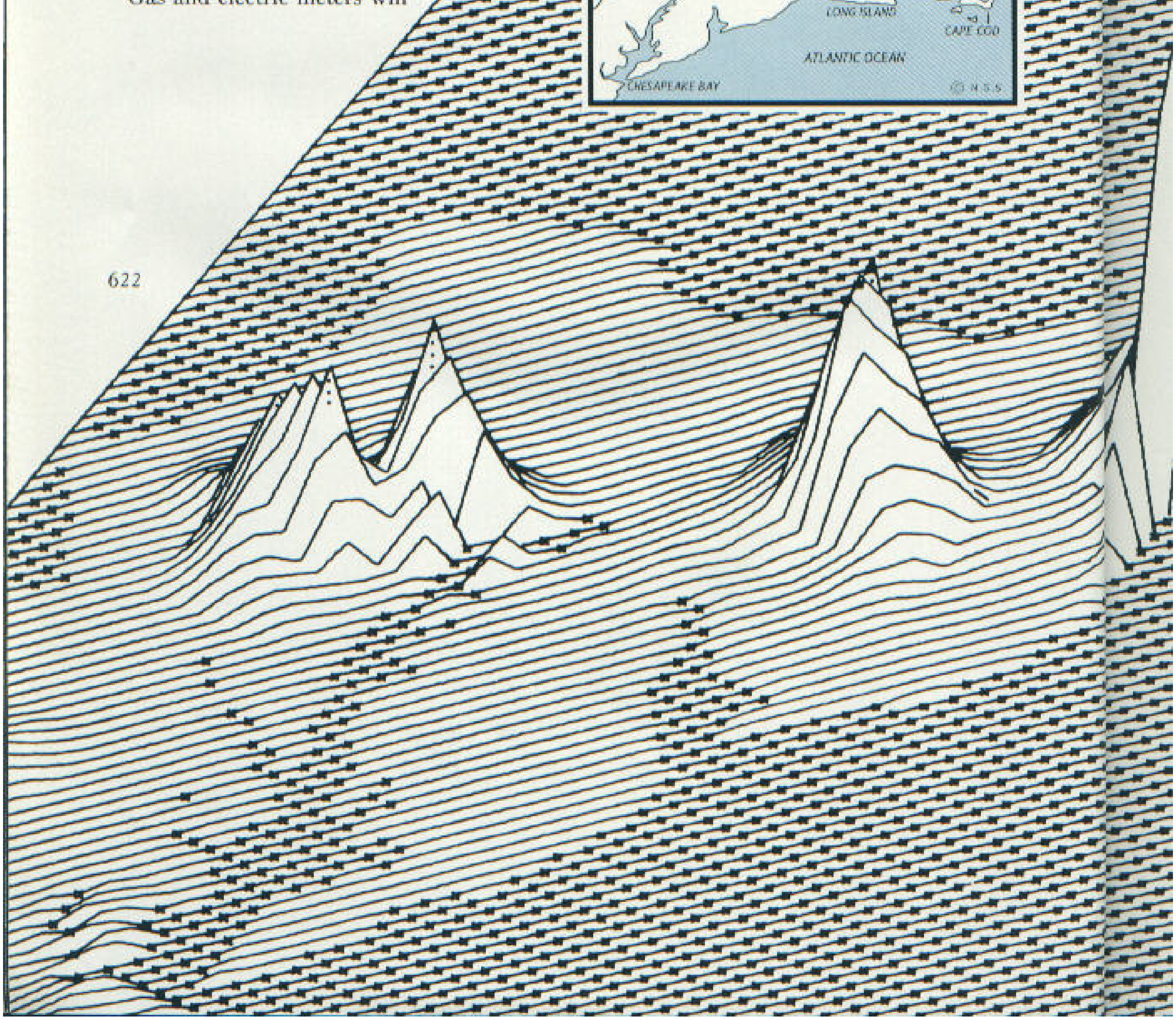
What else lies ahead? A lot of computerized paying of bills. Say you keep an account in the bank and make a purchase in a shoe store. The clerk takes your bank credit card, inserts it into an attachment on his Touch-Tone telephone, and punches in the amount. The bank automatically deducts that from your account, and credits it to the account of the store.

Gas and electric meters will

People-picture of megalopolis

Fed a meal of geography and census figures, a computer prints out a diagram of the northeastern United States showing population densities as mountain peaks (identified in the inset sketch). The graph demonstrates how the computer can transform naked numbers into meaningful displays.





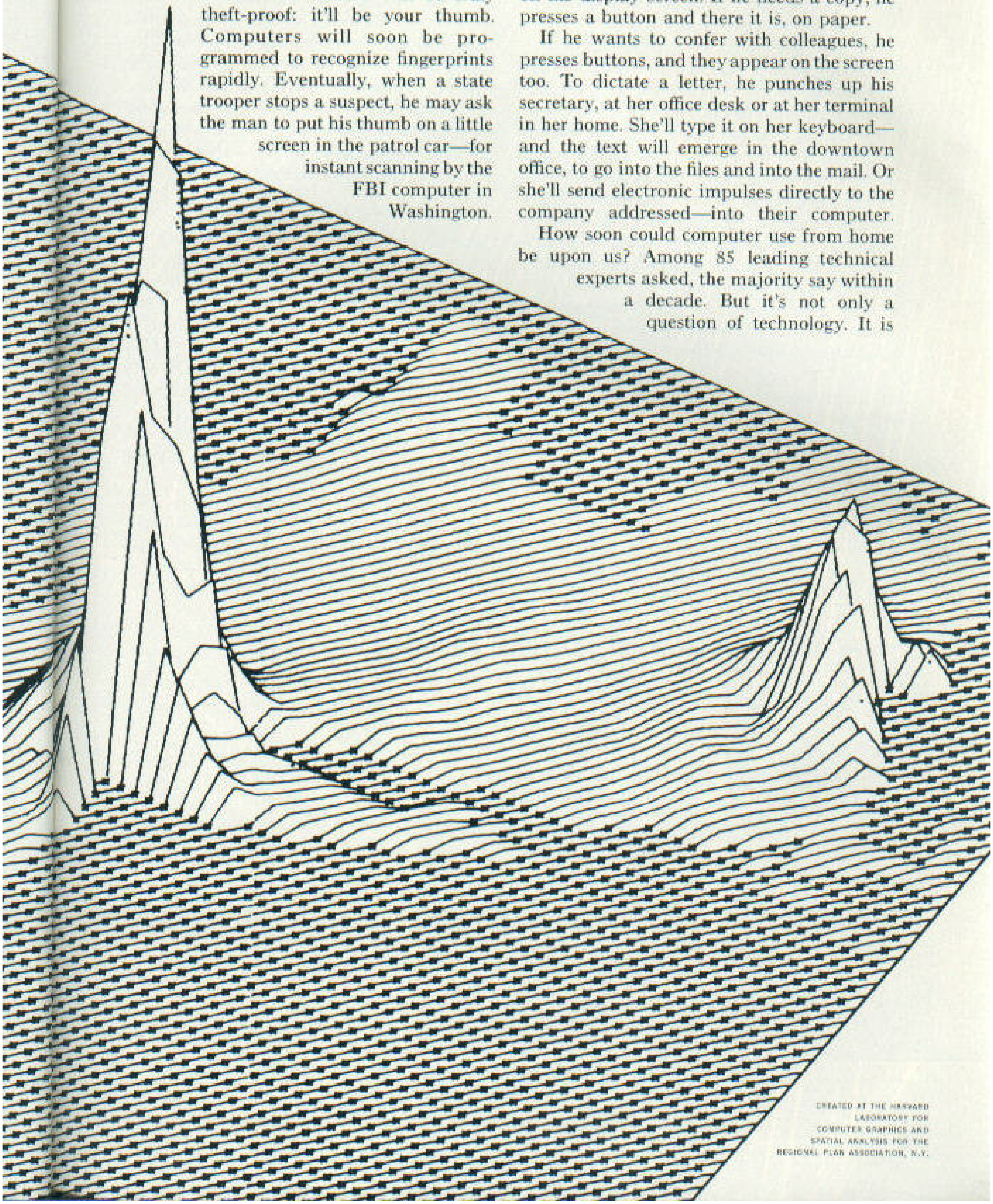
be linked to telephone lines, so that computers read the meters from afar and send out the bills. They could also be connected to banks; customers would then find utility charges on their monthly bank statements.

Your credit card will be truly theft-proof: it'll be your thumb. Computers will soon be programmed to recognize fingerprints rapidly. Eventually, when a state trooper stops a suspect, he may ask the man to put his thumb on a little screen in the patrol car—for instant scanning by the FBI computer in Washington.

Perhaps someday the desk worker fed up with traffic jams in the city will do his job at a computer input-output station at home: If he wants to see documents from company files, he punches his keyboard and they appear on his display screen. If he needs a copy, he presses a button and there it is, on paper.

If he wants to confer with colleagues, he presses buttons, and they appear on the screen too. To dictate a letter, he punches up his secretary, at her office desk or at her terminal in her home. She'll type it on her keyboard—and the text will emerge in the downtown office, to go into the files and into the mail. Or she'll send electronic impulses directly to the company addressed—into their computer.

How soon could computer use from home be upon us? Among 85 leading technical experts asked, the majority say within a decade. But it's not only a question of technology. It is



CREATED AT THE HARVARD LABORATORY FOR COMPUTER GRAPHICS AND SPATIAL ANALYSIS FOR THE REGIONAL PLAN ASSOCIATION, N.Y.

also a question of economic practicality, and I trust no predictions on that.

On the other hand, computer technology may yet outstrip the experts' expectations. Computer performance, in terms of capacity and operating speed, continues to grow by a factor of ten every two and a half to three years. Had the speed of manned flight increased at such a rate, an astronaut could have orbited the earth nine years after Orville Wright wobbled aloft at Kitty Hawk.

The fact is that the first "electronic digital computer, with a variable program stored in its memory"—to use a proper definition—was not in operation until 1950. At present some 70,000 are in use in the United States and another 20,000 abroad, chiefly in Europe and Japan. Technologically, 99 percent of these computers are obsolescent, and even engineers are awed by what is already being tested.

For data storage, not magnetic tape but holograms, or laser pictures.* For processing, not wires for electronic impulses to travel in, but laser beams. Not a million processing steps per second, but a billion per second.

Such advances permit vastly increased amounts of data storage. Such speeds will enable a computer to serve hundreds or thousands of users and still respond as rapidly as it now serves 30. Those machines might cost a lot more, but their output, unit by unit, will become cheaper. Many new applications will be economically feasible.

And so I may yet have a chance to sit home and punch my push-button telephone to ask a computer for the best car route to the beach on Labor Day, and see the directions spelled out on my TV screen. Or see my wife pushing those buttons to order bargains from the department stores, with the charges automatically deducted from my bank balance—without mistakes! But to extend such services to millions of households might put such stress on the telephone network that it would have to be rebuilt, a matter of a decade at least.

Biggest Computer Grows in Pennsylvania

Architect of what may become the most powerful computer yet is Dr. Daniel L. Slotnick of the University of Illinois in Urbana. Here was brought forth one of the classic computers, the first ILLIAC, in 1952. Dr. Slotnick's baby is the ILLIAC IV, being built in Paoli, Pennsylvania (page 631). Would it really equal the capacity of all other computers in the world combined?

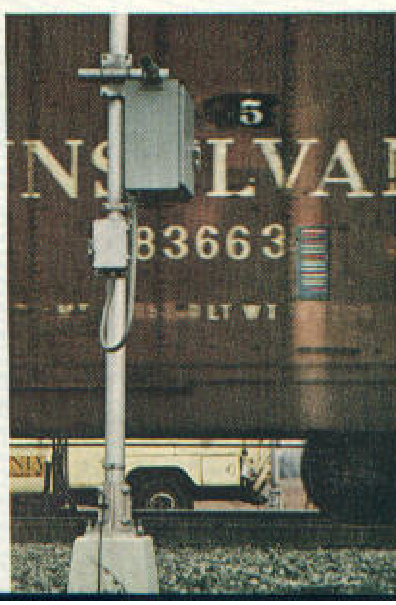
"That would be one hellish calculation," said Dr. Slotnick, "but it's probably not far from right."

Marvelous, 256 processing elements, a billion operations per second. Who needs all this computer power? The U.S. Atomic Energy Commission, for one. It seeks the biggest and most advanced computers, to design nuclear

*See "The Laser's Bright Magic," by Thomas Meloy, NATIONAL GEOGRAPHIC, December 1966.

EKTACHROME (RIGHT) BY BRUCE DALE; KODACHROMES BY EMORY KRISTOF © N.G.S.

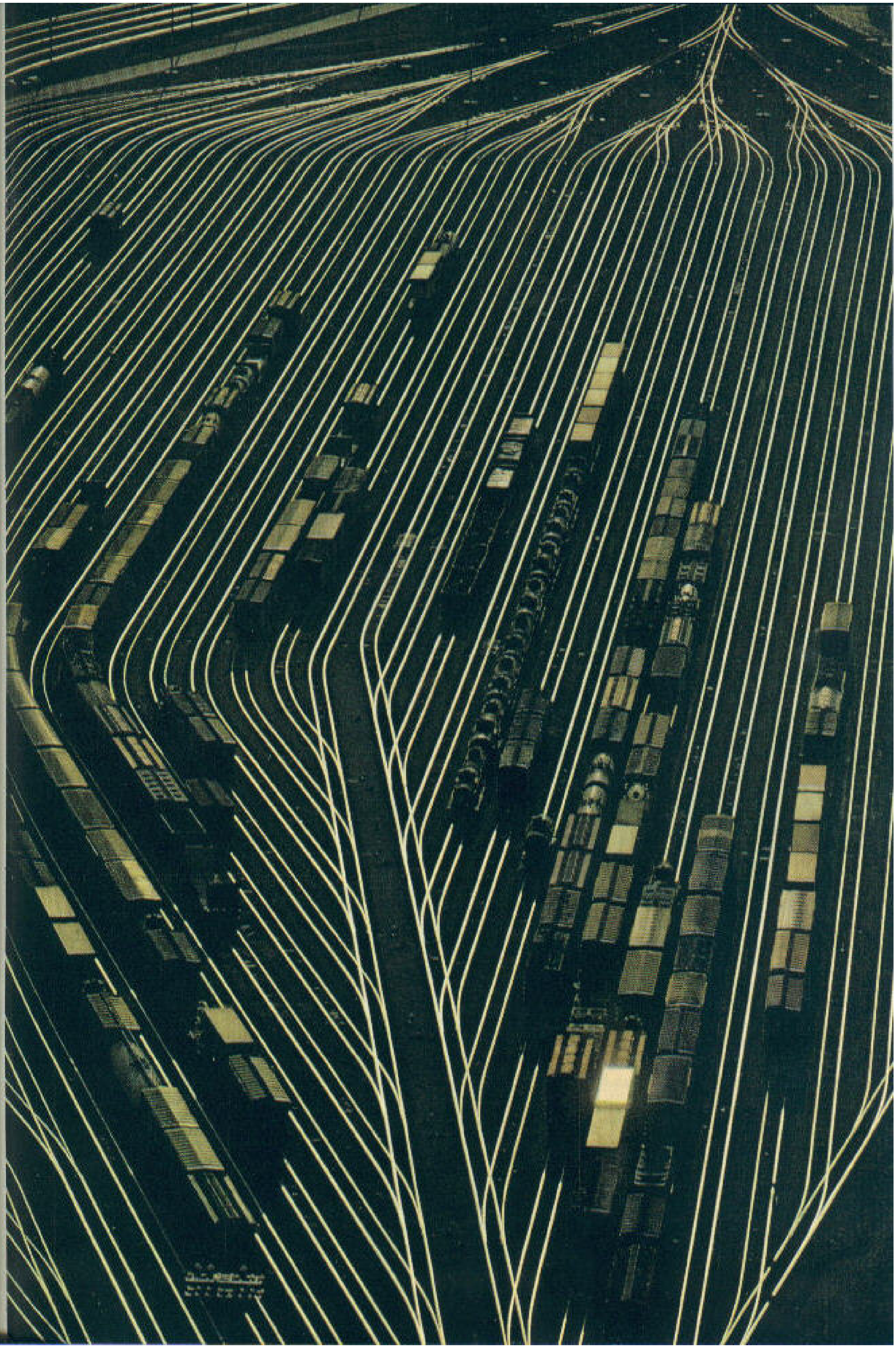
Working on the railroad . . .



Golden strands in the glint of sunset, steel tracks of the Santa Fe railway lace an electronic switching yard in Kansas City, Kansas. The tracks fan out from the hump, an incline that feeds cars onto the proper tracks for assembly into trains. Once the domain of the switchman, such yards today take orders from computers.

The machine stores in its memory a list of what cars to shunt where. After yard engines have pushed cars up the far side of the hump, the computer activates the proper switches, then brakes the cars for safe link-up.

Yardmaster (far left) will take over at his manual control panel if the computer fails, or if an unidentified car reaches the hump. Railroads also increasingly adopt ACI—Automatic Car Identification—in which a sensing beam reads a moving freight car's coded label (left).



EKTACHROMES BY BRUCE DALE (ABOVE) AND JOHN LAUNOIS, BLACK STAR © N.G.S.

. . . and for defense

Deep inside a Colorado mountain, an officer of NORAD—the North American Air Defense Command—scans the orbital path of a Russian Cosmos satellite. Glowing buttons offer an array of computer-generated displays. Here the United States and Canada sift reports from a worldwide network of sensors to track hundreds of aircraft simultaneously, along with every manmade object in earth orbit. Whenever a rocket is launched from the U.S.S.R., a NORAD computer calculates its course, to learn if an attack is imminent.

weapons and to make calculations for peaceful atomic uses. Could Dr. Slotnick cite a homelier application? He said: "Weather forecasts, one to two weeks ahead, accurate beyond anything now possible. Ideally we'd have readings taken at some 8,000 points around the globe, at 10 levels above each point, and 4 different measurements at each level. Altogether, more than 300,000 measurements. ILLIAC IV could digest all that, fast."

Bigger, faster, increasingly interesting. But as I toured the laboratories, what intrigued me most was the programming done to develop so-called artificial intelligence.

Robots Can "Learn" by Experience

At the Stanford Research Institute in Menlo Park, California, I watched a computerized robot moving about and making decisions on its own, "learning" as it went (page 608). Such machinery, I was told, might precede men in exploring the bottom of the sea, or the planets—their microphone ears hearing things in frequencies humans cannot hear, their television eyes seeing things in the infrared portion of the spectrum. . . .

How does a machine learn? By trial and error.

I had found that out at MIT too—from a 25-year-old Missourian, Richard Greenblatt. He had written a chess-playing program for a computer employed by MIT's artificial-intelligence team.

"In any given situation, some moves look more promising than others," he said. He drew me a "decision tree," showing various branches, or possible moves.

Having made a losing move, he explained, the program will clip off that branch. And so it will sooner or later wind up with the optimum path. "Now I don't feed in moves any more," he said, "I feed in principles. The learning process is already built in. While it's playing, I don't feed in anything, of course."

In 1967 this had become the first computer to win a tournament game. Now its official rating was close to the median for tournament players in the United States.

Could I play?

"Sure," said Richard. "We had a professor here the other day who said computers can't think. It beat him."

It beat me too, with its tenth move. Could I take my last move back, and play on?

We went to twenty moves, to thirty. More and more young men gathered around. Forty moves, fifty. I got out of a trap rather elegantly, I thought. I looked around and was surprised. Why was everybody rooting against me?

Queen from Queen's Bishop 8 to King's Rook 8! The machine had nailed me with its fifty-ninth move. There was a great sigh of relief. Richard said, "You lasted longer than most people who come in here."

His program can be adjusted to look two moves ahead, or four, or six. It cannot possibly look ahead to the outcome of all possible moves—that would be a number with more than a hundred digits. No computer envisioned today would be capable of such a thing.

But the thought of things that computers may do before long gave me pause. Says Dr. Herbert Grosch, a senior researcher in the Center for Computer Sciences and Technology at the National Bureau of Standards:

"Many machines now can derive totally unexpected information through procedures the builder cannot fully predict. An advanced machine, programmed to evaluate its own performance by given criteria, may determine that some criteria are worthless and others more important than indicated in the initial programming. The human programmer has no way of knowing about these shifts in criteria values. He only knows that he gave the machine the capacity to make them."

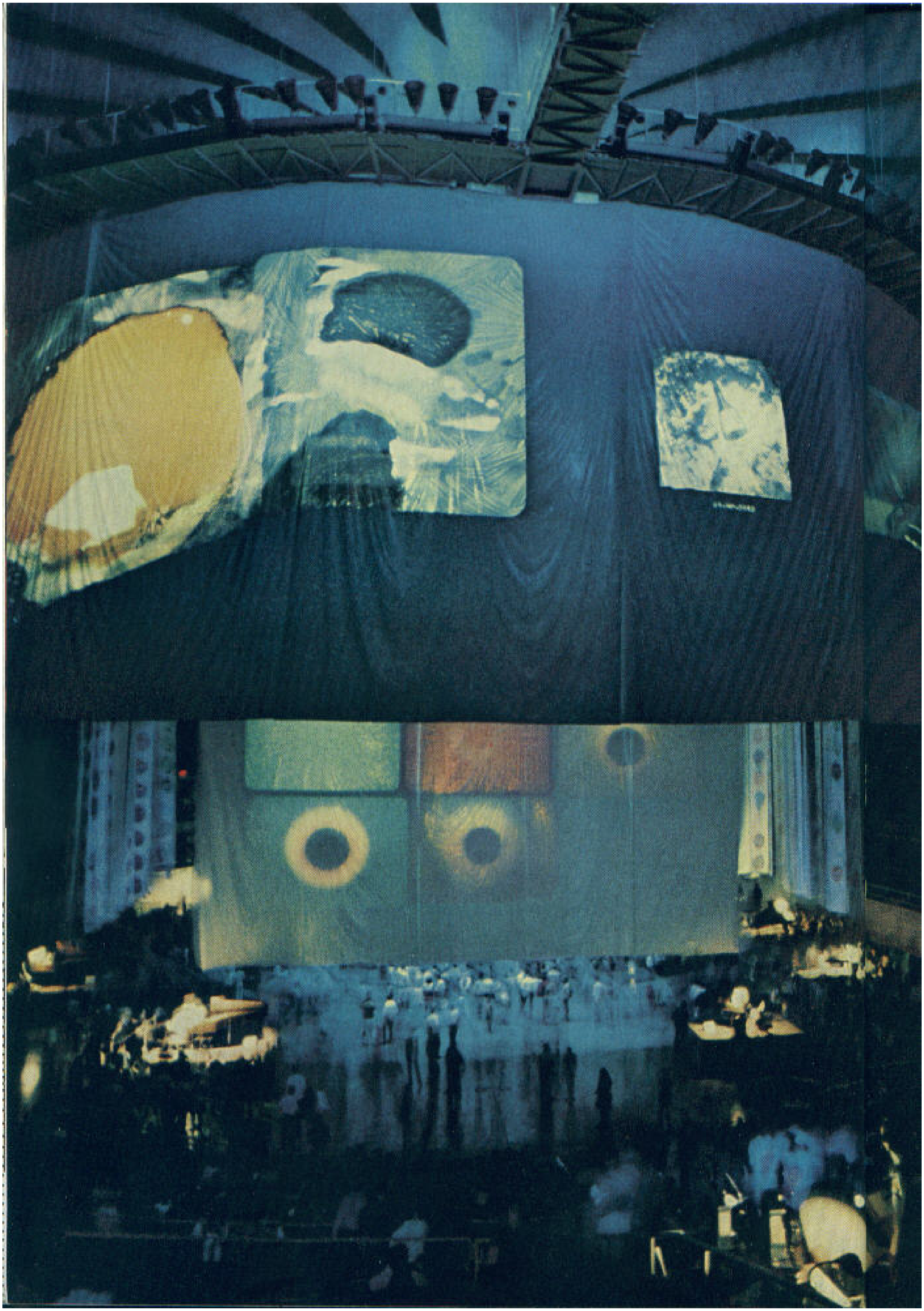
Computers May Act on Moral Values

Even today's computer technology—primitive in view of what is likely to come—permits the design of machines that adapt to a changing environment, repair themselves, and make new parts as needed. Moreover, serious men with impressive credentials in data processing do not think it at all unlikely that someday computers, supplied with feelings and even moral values, will make decisions based on those feelings and values, as well as on what their sensors perceive.

Right now there is growing concern that computer technology can damage individuals, and curtail the personal liberties of all.

U. S. Senator William Proxmire of Wisconsin warns that as credit-bureau files on some 120 million Americans are computerized, and linked into nationwide data banks, questionable information and data-processing errors are traveling faster and farther than ever.

"You could lose your credit, your insurance, even your job, because of such an error in a



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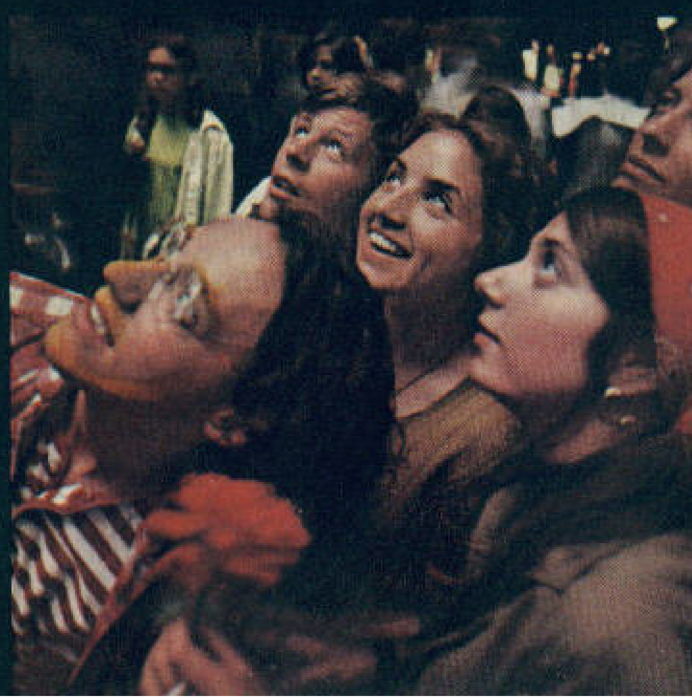
Students swing to machine-made sound

Like the inside of a gigantic jukebox (left), the University of Illinois Assembly Hall churns with garish lighting during a five-hour marathon of computer-created music. Presented by composers John Cage and Lejaren Hiller, the concert features the din of 51 loudspeakers pouring out notes that were both scored and taped by machines. Seven harpsichordists simultaneously played computer-written music.

One listener lies trancelike in a blur of swirling comrades (above); slide displays enthrall others (below).



The master file . . . A worker gathers reels of magnetic tape in the computer library of the Social Security Administration in Baltimore, Maryland. The tapes will go into one of the daily computer runs that calculate payments and keep up records on the 193,000,000 people who hold or have held Social Security numbers. Each capable of recording a maximum of 1,600 magnetized spots to the inch and stretching 2,400 feet, the agency's 170,000 tapes make up one of the world's largest collections of computerized information.

EKTACHROME (ABOVE) AND KODACHROME BY BRUCE DALE © N.G.S.

credit-bureau file. You say, 'Not a chance in my case.' Don't be so sure; it has happened."

The National Academy of Sciences, mindful of computerized data banks being set up at every level of government, is sponsoring a nationwide study of the problems thus posed for individual privacy and due process of law.

How does a citizen know what information about him is going into a data bank? He doesn't know. Some is highly personal. Say you want to buy a house and apply to the Federal Housing Administration for a federally guaranteed loan. Your file will contain a credit-bureau investigator's report of whether your marriage is in trouble—because, says FHA, divorce is a leading cause for defaulting on housing loans, and what's wrong with weeding out the worst of the poor risks?

What if in the future FHA should exchange tapes with other agencies, as has been suggested? Then somebody else's idea of your domestic life might be all over the place.

How could you correct inaccurate information about you once it was in the government data banks? As things stand now, you couldn't. An error in a personnel file, put in from some extraneous tape, could cost a civil servant a promotion. Or keep a man from getting a job. Chances are he would never know why.

Machines Hold Power for Evil and Good

Directing the Academy of Science's study is Alan F. Westin, Professor of Public Law and Government at Columbia University. He says: "Man has progressed over the centuries from the status of a subject of a ruler to that of a citizen in a constitutional state. We must be careful to avert a situation in which the press of government for systematic information and the powerful technology of computers reverse this historical process in the second half of the 20th century, making us 'subjects'

. . . and the "wizard" ILLIAC IV, when completed, will perform a billion operations a second and may rival in capacity all other computers combined. Here an engineer checks function lights of a 60-foot-long section at the Burroughs Corporation in Paoli, Pennsylvania, where three years have gone into its engineering. The 25-million-dollar machine may produce highly accurate long-range weather forecasts, a task involving torrents of data and variables that would overwhelm present-day computers.

again." He adds, "Perhaps the greatest legal device to facilitate the movement from subject to citizen in England was the writ of habeas corpus—the command issued by the courts to the Crown to produce the body of the person being held, and to justify his imprisonment.

"Perhaps what we need now is a kind of writ of 'habeas data'—commanding government and powerful private organizations to produce the data they have collected and are using to make judgments about an individual, and to justify their using it."

What if computer-equipped authority, insufficiently restrained, should turn hyper-inquisitive someday? If every purchase one makes, down to the last 10-cent newspaper, is recorded by a computer, showing where it was made and at what time; if millions of telephone conversations can not only be recorded daily but instantly scanned to pick out key words considered alarming by the surveillance officers. . . . The implications surpass the horrors of George Orwell's *1984*.

Dr. Jerome B. Wiesner, Provost of MIT, has said that the computer's potential for good, and the danger inherent in its misuse, exceed our ability to imagine. Wouldn't that be the worst it could do—to become an instrument of tyranny, propelling mankind into a new Dark Age?

Flying north over the snowy fields of New England, I thought of the best it might do. It might induce men to take a fresh look at the world. Let's call this the systems view, and let me explain how it was explained to me.

To make a useful computer model of a complicated process at work, one must first gather a mass of facts about that process. About the life cycle of the lobster. About the growth and decay of the cities. About the dynamics of the American economy, for the model now being built for the governors of the Federal Reserve System.

The finished model should help one decide what to do if one wants more lobsters, or healthier cities, or a healthier economy. But the greatest value of the model lies not in such specific guidance, but in the insight one gains in making the model, in what one learns while going after the factors that make up a complicated, ever-changing process.

In short, the common way of thinking in terms of simple cause and effect—the Newtonian, mechanistic view—is replaced by new awareness: of many causes, constantly producing varied effects, in what really are highly complicated and dynamic systems.

My little boy gets into trouble in kindergarten. There's rioting in Chicago, a coup d'etat in Cambodia. I used to have pretty simple explanations for these occurrences. But no more.

It looks as if computers will become so common, so taken for granted, that we no longer will talk much about computers but rather about computing, in the sense that we no longer talk as much about automobiles as we talk about driving somewhere. When that day arrives, when we see the world in terms of systems, we may discover that an intellectual revolution has come, comparable to those wrought by Galileo and Darwin.

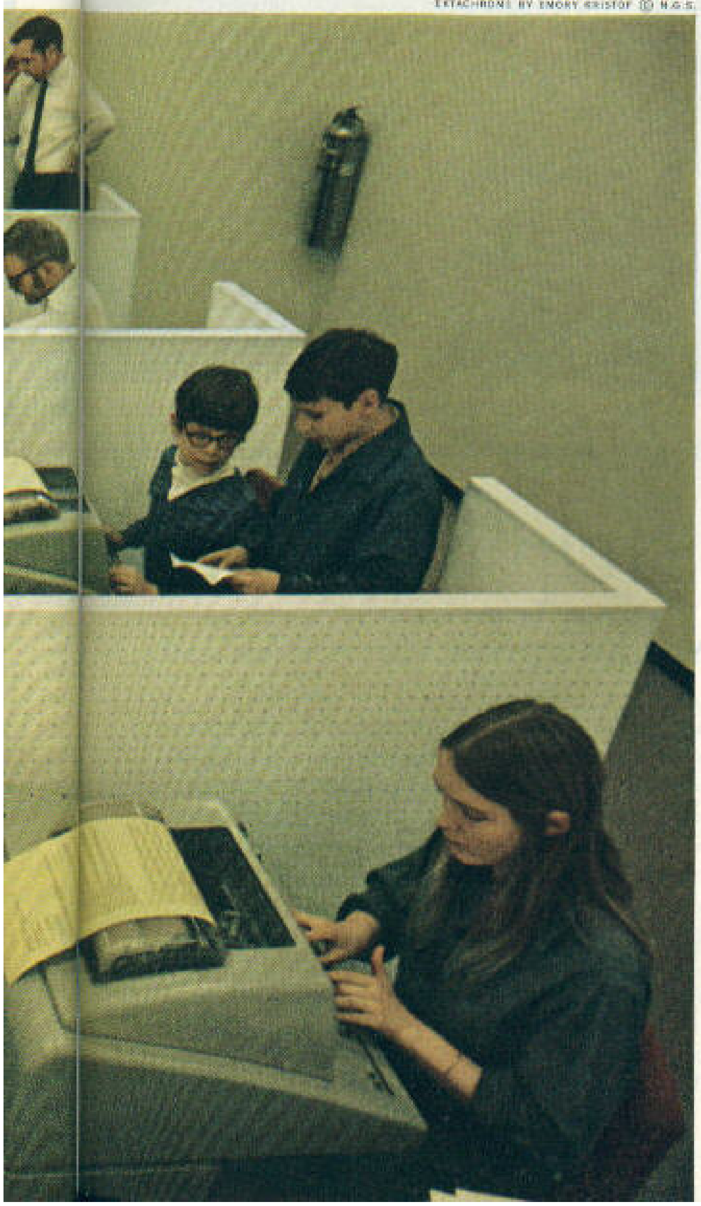
I landed at Hanover in New Hampshire, drove once more to Dartmouth, and found that this revolution may be closer at hand than I had thought.

Dr. John G. Kemeny (page 598), the mathematician who earlier this year became Dartmouth's thirteenth president, has a computer

Push-button world

Object of endless spoofing (right), the computer nevertheless stands secure as a shaper of the future. One glimpse ahead can be seen at the Kiewit Computation Center at Dartmouth College, where students fill computer terminal stalls. Because Dartmouth shares its facilities with other schools, the pupils represent all ages and confront the computer with questions involving everything from physics and mathematics to computerized checker games and the odds on the next football game. Thus youths acquire "hands-on" experience with the most amazing machines ever built.

"I have to leave the room. Which button do I press?"



terminal in his office, near a bust of Einstein, whose assistant he was. He told me:

"Nine out of ten of our undergraduates sit down at a computer terminal as naturally as they would go to the library to look up something in a book. Our freshmen start writing programs after two one-hour lectures. We don't teach them about computers, we teach habits of inquiry."

Snoopy Emerges From a Computer

That evening on campus, in the Kiewit Computation Center (left), ten of the sixteen terminals were occupied.

One sophomore had a girl with him. He was running a program printing out a picture made up of teletypewriter characters, a picture of the dog Snoopy.

"It snows your date," said a freshman. He was modeling a course for an Apollo flight.

Another worked on a Physics I problem, to see what would happen if another moon entered earth's orbit and crashed with the one already there. No, he didn't know much math, he was planning to major in English. But here he was, crashing moons around.

Said a professor, "Once the kids get their hands on the thing like that, they're no longer in awe of it. And they learn how enormously they can increase their powers."

Tens of thousands of kids, perhaps hundreds of thousands, will get their hands on the thing within one generation. I'll be awfully curious to see what they'll do with it.

THE END