# Computers

## Their History, Present Applications, and Future

Shirley Thomas

HOLT LIBRARY OF SCIENCE
SERIES II
15

Their History, Present Applications, and Future

# Computers

Shirley Thomas

Holt, Rinehart and Winston, Inc., New York

Shirley Thomas is the author of *Satellite Tracking Facilities* and the *Men of Space* series of books. Often called the First Lady of Space, Miss Thomas is a familiar figure at space symposiums and professional gatherings around the world.


Printed in the United States of America
18411–0215

# Foreword

It is curious that historians will often spend much time and effort to record various battles, political, economic, and social events of our civilization, but very few if any care to examine and document the "computer revolution" which is so rapidly changing the structure and attitudes of our society. It is much easier to document the physical facts such as the number of computers in use, the number of persons engaged in using or manufacturing computers, the billions of dollars spent annually, etc., than it is to document the mental changes which will probably be far more important in the long history of man.

Many changes are occurring in our mental outlook due to the availability of large digital computers. Comparatively few years ago 90 percent of the experiments done at the Bell Telephone Laboratories were performed in actual laboratories, and only 10 percent were done on computers. Probably before 1970 the situation will be reversed. Clearly our attitude toward experimental science is rapidly changing in many areas. In the area of space science, for example, thousands of trial flights are made on a computer for every one actually attempted. The advantages of computer simulation include lower costs, greater speed in getting answers by programming rather than building experimental equipment, the ability to do "ideal experiments," and the general all around flexibility of computers in the preliminary exploration of a new idea.

Computers also greatly increase the precision of our thinking, since they expose areas of ignorance and sloppy thinking whenever we sit down to write an appropriate program of instructions for the machine. As Professor Alan Perlis has observed, computers are causing us to view the world with eyes that search for algorithms to describe the processes we see rather than words to describe the facts we see. Thus the processes of precise thinking that are traditionally associated with mathematics are being used increasingly as the use of computers spreads.

I place such importance on the intellectual aspects of the Computer Revolution because I believe in the importance of ideas. We differ from the cave man not so much because we may or may not have better brains, but because we have discovered the social institution of organized thinking. It is this which, through the social institution of education, we pass on to the next generation; thus new ways of thinking are our most valuable possessions.

In a way it is not surprising that computers are closely associated with thinking. Man made the hammer to increase his muscle power, the microscope to increase the range of his 'sion, and the oscilloscope to give him a new sense. These are :h tools for the body. But he also invented the natural lanages we use to speak and write, the language of mathematics, , well as the modern electronic digital computer. Each of these is a tool for the mind. If one were asked to compare the importance of the invention of fire with the invention of language, most people would say that language was the more uniquely human. It is for these reasons that I do not feel apologetic for my enthusiasm for computers and for stressing the importance of the intellectual aspects of the Computer Revolution.

In this book you will find a careful, organized presentation of many facts about the Computer Revolution. Fortunately, the author does not confine herself to the current material facts, but discusses the past history as well as future possible developments. She is also well aware of the intellectual aspects of the changes that are occurring and mentions them when appropriate.

*R. W. Hamming*
*Bell Telephone Laboratories, Inc.*
*Murray Hill, New Jersey*

# Contents

# 1

# The Computer

A "thinking revolution" has transpired within the last decade. This battle has been won solely because men have devised the most potent weapon of the era, the computer. With it, they have achieved not only a faster way of performing calculations, but have evolved a modern approach to the organization of thought.

The dramatic developments of atomic power and rocket power have altered the course of civilization—yet, even these inventions were aided by, and may well be dwarfed by, the magnitude of the computer's influence. One obvious reason for this is the universality of application. Whereas very few people have direct need for a nuclear reactor or a missile, the day can be foreseen when all businesses and most individuals will avail themselves of the help of computers.

Man is the best example of a general purpose computer. He has been "processing data," either consciously or automatically, since the Stone Age. His downfall almost came when the amount of data grew to such proportions that it swamped his ability to handle it. In the midst of this information explosion, the computer appeared to relieve him of mental drudgery. The computer is of major assistance in man's relentless assault on ignorance.

The invention of computers is a magnificent example of men rising to a challenge. First our nation was dominated by an agricultural economy. Then the industrial revolution changed our complexion. Within the last 25 years, the third major change has occurred; it is one in which science and technology have moved to a position of preeminence. The advancements in these areas of knowledge have added layers of complexity to every endeavor, and have expanded our capability and knowledge in all fields by incredible factors. Thus, a need arose for means to cope with problems, data, and communication concurrent with these advancements.

There has been the increasing danger that we might be engulfed by the mountain of paperwork that has attended every activity. But where an army of clerks would have been utterly defeated, the computer has clicked through to victory.

Knowledge of all kinds has increased in staggering proportions, particularly in recent years. Today, boys in the sixth grade know as much (or more) about science as did the great scholars of ancient Greece, and freshman college students know more physics than did Galileo.

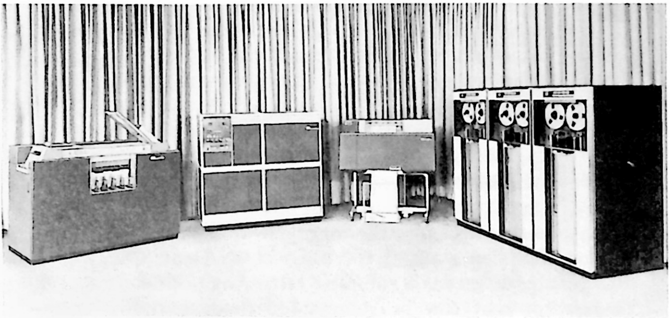
Computers have played a key role both in the acquisition of new knowledge and in its dissemination and storage for later recall.

Computers might be called the "brains" of automatic equipment—although the term induces certain fears. Whereas man ever feared that an automobile would render his legs less fective, he has been overly sensitive that a computer might urp the decision-making function of his mental powers. uckily, that science-fiction fallacy is being thoroughly dispelled, and computers are being appraised in their true light—as tools men can use to extend their mental capabilities.

The computer is truly man's most remarkable tool. Just as engines allow him to press buttons and vastly increase *physical* power beyond the range of his muscles, computers tremendously increase the capability of *mental* processes. At present, the machines perform a great many of man's mental activities; but man still has a corner on creative thinking and imagination.

In this age of innovations, a certain blasé attitude has developed—one that works in favor of the computer evolution; it has become very difficult to astound people, and, therefore, has become very easy to bring about acceptance of complex concepts. Quickly, people incorporate advancements into the routine of living.

This acceptance also spells dependence. Should all of the functions and productivity of computers suddenly be with-



*(International Business Machines Corp.)*

Fig. 1-1. The components of this IBM-1401 are typical of many computer systems; (left to right) card read punch, central processor, printer, tape drives.

drawn from the world, utter and absolute chaos would inevitably result.

Some years ago our government began funding the development of computers for its own purposes, particularly in the area of defense. Subsequent applications have spun-off from this effort. Scientific application expanded into business utilization. Lately, the machines have been adapted to non-numerical applications—ones that involve thought concepts instead of numbers. No longer is the computer restricted to scientific computation or bookkeeping; it is used, also, in processing information in a logical sense. The machines can be made to solve almost any problem that can be expressed in symbols.

The development has taken giant forward steps that even those doing research in the field did not anticipate. The computer has proved to be the "dark horse" of the technological race, and has won the sweepstakes of the century. By 1970, it is estimated that computer-affiliated activities—designing, manufacturing, programming, and servicing—will constitute the *world's leading industrial occupation!*

# 2

## Applications

Where and how are computers used?

The scope is so vast that the answer might almost be, "Everywhere." Recently, the magazine *Computers and Automation* compiled a list of 600 areas of application, and even this was by no means a complete tally. Any problem, process, or concept that can be represented mathematically (symbolically) can be solved, controlled, or investigated by a computer.

The uses that usually pop up in the news are the unusual nd zany ones, and are no more than an amusing fringe to e real workload carried by the clicking boxes. For instance, Arizona State University the students of the card stunt committee now have 46 extra hours a week to devote to study, simply because a GE-225 computer figures out the displays that take place during half-time at football games. (Stapled to the seats in the stadium are computer cards, giving detailed instructions for each stunt.)

Computers have vast numbers of applications in process quality control; they are now being used to control such widely divergent operations as those of oil refineries, rolling mills, power generation plants, and cement factories.

These electronic wizards are involved in food—right from the phase of agricultural research, through the production, processing, and distribution. In order to feed the population of this nation 50 years from now, twice as much food must be produced. Computers will play a vital role in the planning to meet this challenge. It is envisioned that farm systems will operate entirely under electronic control. For instance, sensors attached to animals can indicate their conditions to computers, and printed reports could keep the farmer advised.

Even the cake mixes that we now get from our grocery shelves have the help of computers. The Pillsbury Company uses electronic assistance to calculate the mixture that not only provides best nutritional values, but also permits taking advantage of fluctuations in cost of the ingredients. Whereas a dietitian formerly required 4 hours for this task, the computer now whizzes out the answers in 40 seconds.

The computer is a remarkable "toy" with which games may be played. This simulation may take such varied forms as war gaming, political gaming, or management gaming. "Game" gaming came into recent prominence when it was announced that, for the first time, the gambling casinos of Las Vegas had found it necessary to revise the rules under which the age-old game of Blackjack would be played. This was made necessary as a result of the computer-compounded theories of probability, as expressed by Dr. Edward O. Thorp, Associate Professor of Mathematics, New Mexico State University, in his book, *Beat the Dealer.* (Thorp contends that the casinos' rule change is futile—that his system still will work.)

A complex system to handle traffic flow has been effectively demonstrated in such cities as Toronto. This problem is one that requires extensive individual study. The Bureau of Standards devoted 3 years to a study of a 9-block length of 13th Street N.W. in Washington, D.C. San Francisco has undertaken a study to analyze the traffic flow across the 6 bridges that span its Bay.

The flow of railroad cars across the continent is also tallied by computer. In the past, keeping an accurate tab on the entire number has been a slow and formidable task. But, now, the Denver & Rio Grande Western Railroad can within 30 seconds locate a single car from among the thousands traversing 2300 miles of track.

Electronic data processing is becoming one of the primary tools of highway design by mathematical simulation. Engineers can ponder their initial designs, revise, alter—without ever moving a shovel-full of dirt. The many varying factors that are to be considered in laying out a highway can be evaluated effectively by computer, using the mathematical tools of probability, statistical decision theory, and sensitivity analysis. Another advantage, not to be overlooked, is that a computer is devoid of political influences. It is not seeking votes when it makes a public works decision.

The secrecy born of competitiveness prevails over much of the computer utilization by the petroleum industry. However, a great deal is known about their extensive applications, ranging from tallying how many gallons of gasoline each customer buys each month on his credit card, to determining product mix for refineries. Analyses of aerial surveys, optimization of well-drilling programs, and the reduction of mass spectrometer data are also parts of the operation. A 1000-mile pipeline is controlled by one man at a computer in Texas. One company has tied its 30 computers, located in offices of many cities, to the large one at the corporate office; 'ıey chit-chat via direct line Telex.

When the computer's talent for composing music was ;paraged, Paul Armer of The RAND Corporation became .e electronic artist's champion by saying of the critics, ". . . they belittle efforts at musical composition by machine because the present output compares miserably with that of Mozart or Chopin. How many *men* can produce music that compares favorably?" [1]

This tolerant point of view should prevail when appraising the artistic output of A. B., Auto-Beatnik, a push-button poet created by R. M. Worthy of the Librascope Division of General Precision, Inc.:

*Whales*

The iron mother's bouquet did rudely call,
Yes, I am as fine as many murmuring crates.
People was braver than snowy hay.
It was dirtiest who bleeds behind the piano.

Though A.B. is not strong on grammar, "he" certainly conjures up a mood!

In utter contrast to this gimmick is the very serious use to which a computer has been put by the U.S. team negotiating

(MIT)

Fig. 2-1. At the Massachusetts Institute of Technology, Ercolino Ferretti is creating electronic music by computer.

tariffs in Geneva, Switzerland. Previously, it had required months to properly evaluate European proposals. By means of the "electronic diplomat," the forecast can be made in only hours.

Whereas the first utilization of computers was heavily oriented to science, this has tended to level off. There is now twice as much application in business, and it is steadily increasing. Businessmen are realizing that the computer is not a means of doing the same job with fewer employees, but that it actually embodies an entirely new approach. Those who do not appreciate this philosophy are likely not putting their equipment to completely efficient use.

There have been far too many instances of infatuation—of business leaders becoming enthused at this intriguing machine and installing it in their organization without justification. When the operation is simple, the computer may very well be too costly, both in investment and effort. As a dynamic computer expert at the Bureau of Standards so graphically phrases it, "It is very foolish to kill a flea with a cannon. Many people, ignorant of the wonderful possibilities of the computer, use it for problems that could be better done with ordinary equipment."

But in the business applications where the computer has been judiciously applied, and where the full power of this tool has been felt, the results have been astounding. A Labor Department survey indicates that the largest classes of users are the automobile manufacturers, electrical industries, insurance companies, and financial organizations. Uses by these and other groups are enlarged upon in the remainder of this chapter.

## Wall Street

In the years since World War II, this nation has undergone a drastic transformation in countless ways. One of the most striking of these is in the investment habits of the people. Between 1952 and 1959, the number of investors doubled. Today, more than 17 million people are shareholders in our private enterprises.

The Securities and Exchange Commission requires that all brokerage houses must figure and post every transaction of the day before they may open for business the following day. As growth rapidly expanded the operation, this became a frighteningly huge task on days of heavy buy- and sell-orders.

It became abundantly clear that conventional bookkeepers on high stools could not reasonably cope with such volume—even when armed with adding machines and desk calculators. Automation was needed in the houses that handle the bulk of the business.

Merrill Lynch, Pierce, Fenner and Smith, the nation's largest brokerage firm, now has half of the area in its main office packed with $4.5 million worth of computer equipment. The tasks these machines perform replace the efforts of a small army of people, yet the operations can hardly be considered fully automatic since over 200 persons are required. Machines provide not only the speed demanded for handling the company's half million accounts, but also they can achieve far greater accuracy than with the old method.

Francis I. duPont & Company was an early Wall Street user of computers; in the mid-1950's the company programmed (see *Glossary*) a machine to maintain the accounts of purchases on margin. The balance must be maintained daily on each account in this credit-type of buying, since the constantly fluctuating stock quotations determine the buyer's equity. DuPont now has 1 large and 4 smaller IBM computers that combine to process all daily records—including those of taxes and the thousands of commissions.

For every giant company that can readily bear the investment in either the purchase or rental of such equipment, there are many smaller firms that are also in need of improved data-handling facilities. To accommodate those companies that are not in a position to bear the heavy cost of installing their own facilities, RCA has established a multi-million dollar Systems Center on Wall Street.

This type of operation will most surely become a pattern in countless areas, since it reconciles the fact that many businesses need expensive equipment—but only for short periods of time.

The New York Stock Exchange itself has followed the lead of the houses; in the fall of 1962 an announcement was made of a contract to effect complete automation by 1965.

The computer-based IBM Teleprocessing system speeds trading information from the floor of the Exchange by means of 19 optical data "readers." These compact units, standing 40 inches high by 1 foot square, take only a little over a second to read ordinary pencil-marked cards that report sales and quotations. (This method is a striking advance over the prior method of transmitting the information by pneumatic tubes and voice.)

Then, in split seconds, the computer center in the Exchange will dispatch the information by printing the sales totals on the thousands of Exchange stock tickers through the nation (new models operate almost twice as fast as former ones). At the same time the "Voice Assembler" will respond to inquiries from subscribers to the Telephone Quotation Service. This remarkable unit composes its messages from 126 sounds—

words, syllables, digits, and letters—pre-recorded on tracks of a revolving magnetic drum. The sounds are played back in the proper sequence to compose responses to as many as 400,000 phone queries each day.

To close the loop of its operation, the computer center sends back constant reports on all of this information to the Exchange floor; this system has the capability to handle trading volume in excess of 16 million shares a day. Further, it can be programmed to perform other functions. As Mr. Keith Funston, President of the New York Stock Exchange, says: "We are providing here an electronic system to which extensions can be added in many directions in the future as conditions and scientific advance warrant."

## Banking

All forms of finance are well-suited to computerized operaɔns. In fact, this seems the only means by which the 15,000 ˈanks of our nation could have surmounted the paper barrier. In 1940, we scribbled 3 billion checks; now we yearly exchange our money with about 20 billion checks! (And each one of these pieces of paper may go through as many as 20 operations.) Electronics can perform each step—such as sorting, reading, balancing—in a few millionths of a second.

Bank of America, the world's largest privately owned bank, pioneered computer applications. In 1950, the facilities were being strained by the explosive growth of California; needs were being created that were not being met by available business machines. So, S. Clark Beise (Bank President, now retired) presented the problems to Stanford Research Institute. The goal was a challenge, even to that capable group—to define an electronic system that would handle the many operations of commercial accounts, would prepare statements, yet would not change the style of checks that people were accustomed to using.

A means of reading the checks proved the most formidable of the research problems. Many methods were discarded before the one now known as MICR, Magnetic Ink Character

Recognition, was evolved. The peculiarly shaped numerals and symbols that MICR reads, now a familiar sight in the lower left corner of all checks, are printed in an ink that contains ferrous oxide; when passed under an energizing device, the printing becomes magnetized and can be read electronically.

MICR was refined and improved first by General Electric's Computer Division, then by other manufacturers. In 1959, the American Banking Association brought about the adoption of MICR as the standard type for all of its member banks. In that way, even though banks might adopt individual systems, at least they could all communicate through this common language.

Bank of America adopted ERMA, Electronic Recording Method of Accounting, the system developed by the Stanford Research Institute. GE was selected to manufacture the equipment; they in turn bought the patent rights, and contributed improvements over the prototype. There are 13 ERMA Centers to service the nearly 900 branches of the Bank of America.

For this company, use of the equipment has effected a saving of about 40 percent in the cost of processing checking accounts. However, the initial investment in such a system as ERMA is great. Comments Mr. Volney Pratt, Vice President of the First National Bank of Oregon, "For some part of each normal working day we have about $1,800,000 worth of electronic hardware looking for a way to be profitably occupied."[2] Cooperative processing centers have furnished the answer to this dilemma. During the hours that the equipment is not in use for banking procedures, it is made available to other business organizations.

While manufacturers are busily devising improved methods of check handling, the future thinking of some leading bankers indicates it may not be needed. It is foreseen that there likely will be a sharp drop in the numbers of checks written. A plan could be formulated by banks whereby they become a service operation to their depositors. Under this plan, bills would be sent to the bank and would be paid by the bank from the individual's account. The depositor would not even be bothered to collect and deposit his paycheck; his employer's computer would simply instruct his bank's computer to credit his account in the amount of the wage. For those who get a certain satisfaction from the feel of crisp bills in their hands, this might prove a deprivation—though the efficiency of such a method can't be contested.

## Insurance

Since computers thrive on a diet of paper, it was obvious that the insurance companies would feed them well. Purveyors of policies, long addicted to punched cards, seized upon electronic data processing with the early machines. Metropolitan Life Insurance Company began investigating e use of magnetic tape electronic equipment in 1948. In d-1954, as soon as any suitable equipment was available, company acquired it for use in the Actuarial Division. Metropolitan Life and General Electric were among the first business users of electronic computers.)

As could be anticipated, substantial investment had to be made before appreciable savings were realized. Also, it was found that effective use of the equipment required changing basic insurance procedures and thousands of individual methods. But after a test period, Metropolitan embarked on a full-blown operation and, in retrospect, offered these fundamental conclusions: (1) The required consolidation of operation, along with reduction in the routine duties, brought about a realignment in employees. There was a large reduction in the number of lower level, unskilled persons and a relative increase in the number of experienced clerks needed. (2) The computer is so important to the company's overall operations that it requires top executive attention and consideration.

Virtually all insurance companies have now followed the pioneering path of Metropolitan Life. It has not been possible to standardize the operation of insurance companies as extensively as was done with banking. But individual companies can make excellent use of electronic assistance in computing the variables and constant changes in the policies. Electronic systems, in which are stored the data from which premiums are figured, print out the notices. Electronic processing methods figure actuarial tables and devise plans suited to particular classes of insurance. But the combining of all these functions to create a fully automated system has required ingenuity and the most advanced techniques; the optical scanner has been, perhaps, the biggest single contributor. With this unit, letters and numbers can be read off the documents and fed into the computer.

Travelers Insurance Companies recently contracted with UNIVAC for one of the largest single computers ever installed. The giant system, which will require several years to complete, will enable offices in the field to query the Hartford-located center regarding details of its policies, and receive replies on a "real-time" (almost instantaneous) basis. Rotating magnetic drums will store an enormous 3.5 billion characters of data on fire and casualty insurance policies.

## Newspapers

There is no insurance for the success of a system. The companies that have pioneered in the use of computers have taken a gamble. It has not always paid off. When the Phoenix, Arizona *Journal* first started publication in 1962, an attempt was made to prepare the copy and prepare the billings of the entire classified section by computerized operation. It was a new paper, and it was blazing trail on a new technique. Results were far less than expected.

But this experience did not halt the efforts of other newspapers that already had research underway. The benefits promised were far too great a lure, and there had been no major advance in the art of printing newspapers since the advent of linotype machines some three decades ago. The next papers to try computers were the *Los Angeles Times*, the Perry newspaper chain in Florida, and the *Daily Oklahoman-Times*. None of these attempted to combine the billing function with the composition, but they concentrated on computerized typesetting. The first newspaper to set all its editorial and classified copy by a computer was *The Daily-Oklahoman-Oklahoma City Times,* on March 5, 1963, using IBM equipment.

The *Los Angeles Times* was the first newspaper to go into steady production, on December 1, 1962. Although each operation varies, the procedure at the *Times* is typical: The reporter writes a story on a special electric typewriter that produces both the typed sheet and a paper tape. Any changes or corrections are marked on the typed sheet, then another tape of these corrections is cut. The tape of corrections is fed into the computer memory, then the original story is fed in. The computer inserts the corrections. This is performed at the rate of 1000 characters per second.

At the same time, the computer is preparing the story into the proper length of lines for the newspaper columns. This involves a great amount of hyphenation—dividing of words. In some languages, established rules would be the answer, but the English language is quite complex, and has exceptions—also, exceptions to exceptions. So hyphenation has been the big question mark in newspaper application of computers.

Florida newspapers solve it by storing a magnetic tape dictionary in the computer memory, and looking up each word that must be hyphenated; the *Daily Oklahoman-Times* hyphenates by a table of probabilities. But the *Los Angeles Times* uses an ingenious method that was developed by Dow Parkes, *Times* Computer Researcher, which is based on word logic. This involves scanning key letter sequences to determine if they follow the rules for four basic types of hyphenation; if not, the computer asks itself as many as 150 questions to determine the nature of the exception. All of this is performed in 15/1000th of a second, and the results are 99 percent accurate! The body type for an entire newspaper page can be type-set in 1 minute and 10 seconds.

The *Washington Post* is now using this same system, since it was made available by the *Los Angeles Times* through RCA. The RCA-301 electronic data processing system that the *Times* leases, costs $4665 per month, plus 3 percent to allow random use of the 200 hours allotted. (RCA now has available a smaller version, the 30-Newscom, for $1985 per month.) Says James Grider, *Times* Production Superintendent, "The benefits we have realized are, of course, faster type production, shorter deadlines, and financial savings."

IBM equipment for automatic typesetting is now on order by the *New York Daily News, Washington Evening Star,* and *South Bend Tribune.* As pioneering efforts of a few expanded into the beginnings of a trend, the Research Institute, Inc. of the American Newspaper Publishers Association began conducting computer seminars to alert their members to developments in the field.

Three rather startling concepts appear in the future planning of newspapers by computer: (1) No metal type will be employed. The computer will compose the page, then project it on the face of a cathode ray tube, and copies will be made directly by means of an electrofax or xerox type process. (2) A reporter will not have to type his story, but can merely "talk" it into the computer. (3) Newspapers will not be printed and delivered into homes. Instead facsimile or video recording units in each subscriber's home will print out individual copies.

A quiet upheaval is taking place in the field of newspapers because of electronic advances; and it can only add up to the faster and more accurate dissemination of news.

## Information Retrieval

Men are making news and creating new data today in what truly amounts to an "information explosion." Only the most ingenious application of every far-out technique can possibly hope to cope with a situation that is just slightly less than chaotic in many areas. There are more scientists alive now than in all previous civilization, and they are utilizing all advanced tools to produce data—material that should be available to aid the pressured efforts of others who are treading the same scientific waters.

The tales of costly duplication of research and production are legend; for instance, there is the reported case of the corporation that paid $18 million for an item that was later found to be available in the free market. Of course, much in the way of space or defense research has been labeled "duplication," when in truth there were parallel efforts deliberately planned as back ups. The technology is straining so hard against the very fringes of current knowledge that it is sometimes judged necessary to instigate dual efforts toward solving the same problem. However, it has been estimated that 50 percent of the money spent for research could be more efficiently utilized, or not spent at all, if the available pertinent data could be located.

It is by no means in science alone that the accumulation of information has innundated workers in the field. Indeed, the technological revolution has served as stimulus to every field of learning. The "knowledge business" accounts for about one-third of our gross national product.

An Electronic Syntopicon, created jointly by the American Library Association Encyclopaedia Britannica, Inc., and Remington Rand, previews tomorrow's research library. When a key word is punched in, the machine will print out a sizable assortment of quotations on the subject. By culling the pertinent thoughts from the writings of many authors, it thus takes a step beyond furnishing a bibliography on the subject. To comprehensively accomplish this, from existing and constantly expanding literature, is a staggering task; for instance, there are now over 100,000 technical periodicals in world publication. Yet, if efficient information retrieval can be accomplished—even at the cost of billions, how could the saving in man-hours be reckoned? How could the accompanying advance in knowledge be evaluated?

There is no giant breakthrough of equipment required. The process involves no calculation, but it does employ the logic capabilities of the equipment. To be a master librarian, the computer needs nimble fingers, a quick brain, and a gargantuan memory. That is, these are the requirements of the presently accepted method. But it would be utterly shortsighted to assume that a bright researcher will not ultimately present an entirely revolutionary approach to information retrieval. Perhaps only when an extension of library-search technique is abandoned, and electronic operations assume a character of their own, will the problem yield. By the end of this decade more than $110 million will have been spent yearly on computerized information retrieval. The research and development efforts are largely funded by government, where the needs are vast and varied.

One of the greatest needs for information handling is within the CIA, the Central Intelligence Agency. IBM has developed for the CIA a file center system called WALNUT, which, it is claimed, is far more compact and faster than other existing microfilm storage systems. To give an idea of its capability, WALNUT can store the contents of 300,000 books in a space about the size of a radio console. The process reduces documents to 1/35th of their actual size. Instead of the usual library card index, WALNUT employs an automated index that is activated by the writing of key search words on a form. In response to these words, the system conducts an electronic search and prints out a list of all documents that have material pertaining to the key words. The user then selects which of these documents he wishes to see, and the system proceeds to reproduce those selected; the time of the exposing and developing process for each document is only one-half second.

The unique requirements for information retrieval of other groups, such as the Department of Defense, are noted in other sections of this book.

*Law.* Few professions are in greater need for the potential benefits of automatic information retrieval than is the legal group. Legal research is the study of statutes, decisions, rules, cases, or discussions which apply to an individual problem. The profession has long possessed an absolutely enormous system to digest and index, and these volumes are in constant use by attorneys. But the magnitude of this task is constantly increasing as does the general complexity of our society. Reed C. Lawlor, Chairman, Electronic Data Retrieval Committee of the American Bar Association, says of the attorney, "He needs new tools. Many of the tools are here. But scientists and engineers must help him learn to use these tools."[3]

Perhaps the first study made to test the comparative abilities of lawyers and computers to perform legal research was done under John F. Horty, Health Law Center, University of Pittsburgh. After all of the statutes of the State of Pennsylvania had been recorded on tape, the lawyers and the computers set to work searching for material pertinent to 24 questions. Three times as many statutes were reported by the computer as by the attorneys, and two-thirds of them were relevant.

When this tedious type of task can be automated, lawyers will be freed to apply their energies to considerations that truly utilize their intelligence. Of course, the first consideration must be how to create the system to take over the job effectively. Robert Wilson, at the Southwestern Legal Foundation, is working on a *root-word* analysis to search out the material. Another standard approach to information retrieval, the *association factor* between words, is being pursued by John Lyons t George Washington University. Working with that educaonal institution, also, is the Datatrol Corporation; their comned aim is to set up a network of legal reference centers.

## Medicine

A panel of the President's Science Advisory Committee reported early in 1963 that computers can open new horizons in medicine. The report pointed out that computers can lend to the life sciences the precision in observation and control that have been the hallmark of investigation in the physical sciences. The panel specified three ways in which computers could well be used: (1) to evaluate large numbers of medical records so that health officers might determine harmful side-effects of drugs, such as that of the infant-deforming thalidomide; (2) to assist in studies of behavior; (3) to assist in diagnosis.

In addition, the panel might well have noted that computers can assist in the operating room, can be used as tools for research and exhaustive patient examination, and can handle medical records. But of all these applications, perhaps that of diagnosis is most intriguing. It is an obvious application, once it is appreciated that modern diagnostic methods utilize a statistical approach—wherein the probability would be figured that the existence of a certain combination of symptoms, test results, and X rays indicates a certain disease. This kind of analysis introduces two elements that are the forte of the computer—figuring odds and drawing from vast stores of information.

Experience is a strong teacher. The doctor has, in addition to his medical education, the experience of treating patients. What if the past histories of all patients in the country, or even a good proportion of them, could be drawn upon? In such a vast effort, the data could be fed into a mammoth computer system, to be drawn upon by individual doctors via dataphone when they seek assistance in making a particularly difficult diagnosis.

This procedure gives the doctor a powerful new tool, and in no way takes him out of diagnosis. Contrarily, it is the doctor who must examine the patient and ultimately treat the patient.

In the treatment phase, computers are making contributions. Precise radiation doses for cancer treatment are calculated electronically. Space medicine research has achieved such miniaturization of sensors that they can be implanted upon a patient to send out signals that a computer can monitor; by this means, the patient who must be watched closely is guarded electronically, and deviations in signals are immediately noted so that treatment may come swiftly.

To cite an example of computer applications to medicine, spectacular utilization of advanced technologies was recently made when the brainwaves of a patient in England were relayed via communications satellite to Rochester, Minnesota. There a computer analyzed the signals and printed the wave forms. Within one minute, they had been interpreted, and were relayed back to the hospital in Britain.

The computer, with its ability to read hundreds of thousands of characters per second, is particularly valuable in emergency situations. Its speed is a vital factor in locating rare types of blood. In New York City, the Blood Council uses an IBM machine to manage the scattered inventory that amounts to 100,000 pints yearly; the Council also has stored in the equipment's agile memory the names, addresses, and telephone numbers of possible donors.

So extensive are the varied applications, and so intense the interest, that IBM annually holds a week-long Symposium on the Use of Computers in Medical and Biological Research. Here, indeed, is there exciting application, for even though computers are not built like men, they have the capability to simulate a man numerically. A mathematical *model* can be made of a man—as well as of a bridge, a highway, or a physics problem. And the important aspect of performing research with a computer-simulated man is that no harm is done if the experiment goes wrong and proves "fatal."

UCLA has the nation's largest computer installation for medical research. The Center's two primary functions are for basic medical research and for research in the use of the computer on medical and biological problems. It is truly a "laboratory within a laboratory." Dr. Wilfrid J. Dixon, Director of the Center, and Dr. Frank J. Massey, biostatistician in the School of Public Health, are heading a project to create general medical computer programs. They already have produced the most comprehensive collection of such programs that are available—one of these programs is now being used by 150 other research centers.

UCLA's Computing Center is being utilized by the University's Brain Research Institute. In such applications as the analysis of a 10-second brain wave record, the computer performed 225 million multiplications to produce in 15 minutes answers that would have required 700 man-years with a desk calculator. The installation is helping to provide significant new information on the organization of brain systems during sleep, fatigue, weightlessness, vibration, prolonged darkness, and other conditions to which astronauts will be subjected. Earth-bound patients will gain benefits from the endeavors in such projects as the analysis of great masses of data in a study to discover causes of heart disease.

Working in this field, Tulane University and IBM jointly have underway a study to analyze heart and brain waves, an endeavor to extract new information from X rays, a research program delving into the handling of huge numbers of medical records, and a comprehensive analysis of information gathered from a patient by means of various measuring devices.

The UCLA and the Tulane/IBM programs are examples of a powerful trend in medicine and biology. Advanced research techniques are employing the expertise of men of different scientific disciplines. Bionics is a new field that brings together the biologist and the engineer. The descriptive word was coined by Major Jack Steele of the Air Force; the aim is to imitate human functions in machines. NASA has given the project top priority, and over 100 organizations are working on bionics-related problems.

The possibility of adapting brain processes to computers was the dream of the great Dr. John von Neumann. As the electronic machine itself serves as a primary tool in the research, the research in medicine and biology may not only bring about better health for men but also superior concepts for computers.

## Automobiles

The automobile industry is not only the United States' largest, but has set for Americans a pattern of living not present anywhere else on earth. That automobiles have been placed within the economic reach of most people has been accomplished with assembly line operations. The cost of the custom-crafted Rolls Royce points up the contrast.

Detroit is truly a hot-bed of computer activity. There is real excitement within the automobile industry in connection with design automation; systems similar to Sketchpad (described on page 32) are being utilized. Although the competition factor has wrapped the details of individual manufacturer's utilization in a blanket of secrecy, there is evidence of the powerful impact of this new process in one meaningful way—the battles that are now raging at the level of top management between those who wish to maintain the design process in the accustomed manner, and those who are convinced that the widespread adoption of design automation is important to progress.

In other applications, computers are the master planners to control overall production, and they also have the capacity to cater to each individual order, with right color, body style, trim, power equipment, and other accessories. That not only quantity but quality is controlled is also to the credit of the computer. At the Plymouth assembly plant in Detroit, for example, all of the reports from the 150 inspectors are continuously analyzed and relayed to the superintendent of each section. Many mistakes can occur in assembling an automobile; the computer has a list of 3300 possible errors stored 'n its memory. This tight reign on the production is a most ffective means of assuring quality for the customer.

Beyond the production phase, the computer also keeps rack of customers' orders; regional preferences and general trends govern the following year's product manufacture and distribution.

To make an automobile requires, in addition to nuts and bolts, words. Each day, the Chrysler Corporation exchanges 1-million words between its headquarters, plants, sales offices, and warehouses. GE has recently installed a Data Net; it receives and retransmits messages automatically. As an indication of how fast the field of data transmission is changing, a comparison is made with the "torn-tape" system that was the latest one available in 1956—the Data Net can handle up to 3 times as many messages, and its use has cut down delays at peak periods of operation from 2 hours to only 4 minutes.

## Airlines and Airplanes

To achieve swift operation while handling great masses of data is most certainly a necessity for the airline industry. The elements that a commercial operation has to sell its passengers are speed, service, and safety. These are best accomplished through efficiency—and this spells a computerized system.

In recognition of this fact, most airlines have installed electronically controlled capabilities. The most extensive of these is PANAMAC created by IBM to serve Pan American World Airways. Located in the 59-story Home Office in New York City, it is the world's first commercial, global teleprocessing system, and has five basic functions: to control passenger reservation, to handle worldwide cargo reservations, to control the enormous flow of messages involved in the operation, to supply room reservation service for the hotels that are Pan Am subsidiaries, and to perform the conventional data processing operations—such as payroll, accounting, inventory control, purchasing, sales statistics, and forecasts.

Under each of these categories the equipment is programmed to do numerous functions without being told; for instance, it will automatically run through about ten steps in the matter of passenger reservations. The procedure in this operation is performed about 75,000 times daily in many offices on 6 continents.

This is typical of the way PANAMAC works: A passenger stops in Pan Am's Paris office on the Champs Elysees to purchase a ticket to New York. The reservation clerk inserts a card into the *air information device,* and depresses keys to indicate that a seat is desired on a flight of a given date. This is instantly transmitted to New York, where computers are set into activity finding which of their flights on that date has a seat open.

Before the passenger has time to sigh at the thought of leaving Paris, the availability status is returned from New York. As soon as the passenger nods his acceptance of the flight, the clerk presses the button marked "sell," thereby sending a confirmation message back to the computers in New York.

The equipment in Paris automatically prints out a record of the sale, and this information is, at the same time, stored in the 400-million-word electronic memory in New York. The clerk writes out the ticket with the passenger's name and telephone number, and includes any special requirement—such as rental car reservations, hotel reservations, or a special diet. By typing this on the reservations set keyboard, it is all transmitted automatically to New York. The clerk presses the "end transaction" button—but the computers will not close the transaction until they have checked it over. If any omissions have been made, they will notify Paris; if not, they will store away the entire record and respond, "O.K."

The follow-on steps, such as when reconfirmation is due, and how long to retain the record of each sale, is automatically programmed. The figuring of complicated international fares is done in seconds. These and other features make PANAMAC the real friend of the travel agent.

American Airlines, one of the first to computerize their reservation system, has added a small computer to do flight planning. The huge jet engines have such a voracious appetite for fuel that the computer is saving the company 30 times its monthly rental by figuring the most economical routes to fly.

Between New York and Los Angeles, 44 flight plans are usually computed before the most economical one is chosen. They take into consideration winds aloft forecasts supplied by the 90 U.S. Weather Stations, because fuel consumption is strongly affected by air temperature, wind direction, and velocity—as well as by altitude and number of miles flown. It is evident, even in these straightforward operations involving air lines, how computers today are feeding other computers. Three layers of such activity are perceptible in this instance—the Weather Bureau, the air lines, and the FAA.

Furthermore, it is not only the operation of the airline, but the operation of the aircraft that relies on computers. Jet airplanes are so complex that it would not be feasible to operate them without computer assistance.

Additional strata of computer application are the foundation upon which each airplane flies. It extends from the first glimmer of design concept. Lockheed Aircraft Corp. was perhaps the first company in the field to utilize accounting-type calculators to solve engineering problems; this was during the World War II years, 1943-4, when military requirements burdened engineers with an unprecedented work load. This company's success with the application of accounting-type equipment was probably one influence that prompted computer manufacturers to consider the scientific potential of their machines.

North American Aviation, Inc., has linked together the computer power of its five divisions. This has been accomplished by means of the Oat Mountain "bounce." Dish antennas on the top of this low mountain are within line-of-sight of each division; this allows microwave signals to be bounced from point-to-point. The company thereby can pool its seven IBM-7090's and three IBM-705's into a gigantic and versatile capability.

Surveying this broad aerospace picture, it becomes abundantly clear that the industry could never have "gotten off the ground" without some vital assist from electronic data processing systems.

The complexity of aircraft is indicated by the numbers of drawings required—9000 sufficed for a World War II pursuit plane, while 80,000 are needed for a modern bomber; many products will require 100,000 drawings.

First comes the process called numerical design, which replaces manual methods in defining the product: this consists of mathematical expressions of geometrical surfaces, which are then calculated by machine. From this master program, the computer takes over the drafting process by generating detail drawings—these may be tabular listings, punched cards, or displays on cathode-ray tubes; another form of output from numerically controlled drafting machines is the drawing, with 2/1000ths-inch precision, on glass cloth, which can be used as a pattern and transferred onto steel.

## Engineering Design

Spectacular results have been achieved by using computers in engineering design. A company that manufactures heat exchangers and flanges has reduced the number of man-hours of its design department by an incredible 98 percent. Designing a cam, that formerly required 25 man-hours, can now be

(MIT)

ɡ. 2-2. Sketchpad, a computer-aided design tool, is a magic stylus r the engineer.

done with 1 man-hour plus 2 minutes computer time. Whereas the designing of motors for mine hoists used to require 4 to 6 hours, a computer now does it in 30 seconds; more precisely, it does the designing in 1 second, and spends the other 29 seconds printing the answer.

Designing by computer gives a better product, in shorter time, and eliminates the numerous modifications that are generally required by the former engineering design methods. In truth, computer-assisted designing is so new, and yet has made such fantastic strides, that its ultimate potential is impossible to predict.

Massachusetts Institute of Technology has under development a remarkable tool for the engineer, Sketchpad (Fig. 2-2). Using this, the engineer draws with a light pen on a computer display scope. If he sketches a rough circle, it instantly becomes perfect. He may erase, or he may magnify and reduce at a ratio of 2000 to 1. Most incredible of all, he may sketch a part in perspective, then rotate the drawing and the computer display scope will show him all sides to the part!

## APT: Automatically Programmed Tools

MIT also has made other significant contributions to the application aspect of computers. Under Air Force sponsorship, MIT developed Numerically Controlled Tools, and the follow-on program, APT, Automatically Programmed Tools.

When it is revealed that APT can cut only straight lines, it might seem that the use would be restricted. But these straight lines may be as long as 1/1000th of an inch—therefore, any conceivable shape can be cut. But the machine has to be told, by the computer, to cut each of these tiny segments—which gives some idea of the tediousness of the programming of the operation of the tool. Once this is accomplished, there can be endless repetition of the procedure with no added instruction, or the tape can be stored for later use.

The great step forward that APT has made is to perform work better than can be done with a human operator. Also, it has made possible a production run of *one*—as opposed to thousands or millions of items.

## Telephones

No instrument ever devised by man has done more to shrink both distance and time than has the telephone. To most people today, it is quite inconceivable to live and conduct their affairs without access to telephones; they are the hand-held hallmark of the twentieth century.

The average subscriber is vaguely aware that there must be computers in the telephone operation when he spies the characteristic computer punched-card upon which his monthly bill is printed. As extensively as the telephone companies utilize electronic data processing to tally toll calls and service charges, this business application is routine.

The automation-computer conversion has occurred right at the heart of the entire giant system, and well it has—if automatic devices had not been developed, it has been estimated that every woman and girl in the nation would be required as telephone operators.

Just as people conveniently chat by telephone, so are computers now exchanging bits via Data Phone, an ingenious instrument created by the Bell System. The machines can talk at the rate of 1500 words per minute (which is slow by computer standards) by means of an ordinarily placed phone call, at the usual rates. The information the computers exchange may be in any form—punched cards, paper tape, or magnetic tape—and it will be automatically converted into tones for transmission. At the receiving end of the line it is converted back into computer language.

By use of the Data Phone, a large computer may service a number of locations—across the city or across the continent. AT&T estimates that soon half of their long distance calls will be this kind of pulse-coded transmission.

But this will not long suffice. With the constantly increasing demands for exchanging information, telephone facilities will have to be established that will handle larger volumes of data. One way of doing this is to use microwave transmission; it will carry 50 times as many words per minute as an ordinary telephone line. The system is already in limited use; it was noted previously that the divisions of North American Aviation, Inc. are linked by a microwave system. However, no great strides can be made until the Federal Communications Commission determines where the jurisdiction is to rest with such facilities.

The FCC is but one department of the government that is concerned with computers. Uncle Sam is the world's biggest user of computers.

## Government

Each year, the federal government produces about 25 billion pieces of paper—enough to reach to the moon 13 times! To aid in the obviously super-human task of handling the volume, computers have been drafted into heavy use. In 1963, the Government spent $705 million on equipment. Over 80 percent of this was centered in the Department of Defense, the National Aeronautics and Space Administration, and the Atomic Energy Commission. By the end of the decade it is expected that this amount will be tripled. Such a significant statistic forcefully conveys the role that these electronic devices have assumed in helping to run the biggest business in the world. Magnitudinous growth and limitless diversity characterize the government phase of the computer story.

A recent Bureau of the Budget report pays this tribute: "No single technological advance in recent years has contributed more to efficiency and economy in Government operations than the development of ADP, automatic data processing equipment."

***Bureau of the Census.*** The Bureau of the Census, now operating on the "third generation" of computers, was the first group to introduce the use of computers into business or statistical type data processing. This comment explains why: "Statistics are a very perishable commodity."

In 1790, when the first census was taken, time was no grave problem; the results could be published in a pamphlet-sized book, since the population numbered only 3,929,214. But our nation is now approaching a population of 200 million, and the results are published in volumes that fill several shelves.

Census Bureau surveys, moreover, have broadened far beyond the decennial counting of people. Business now reaps great benefits from the Bureau's statistics on housing, production, sales, employment, foreign trade, and other economic influences. Important advances have occurred on two counts—more information, made available more quickly.

The machine that revolutionized Census Bureau methods, UNIVAC I, was retired on October 3, 1963, after 73,000 hours of operational use. The computer was accorded all the ceremony and tributes due a faithful government servant. It is now leading a life of ease on exhibition at the Smithsonian Institution. The idea for this piece of equipment was born in the minds of Dr. John Mauchley and Dr. J. Presper Eckert during World War II while they were working on the ENIAC computer for the Army.

The Bureau of the Census gained much valuable experience from their first encounter with computers. A lesson that is still applicable is not to overestimate what a computer can do. It does exactly, and only, what people tell it to do. The pattern of sloppy thinking and half-formed thoughts that characterize the average human mind will not suffice for the electronic "brain."

The assistance, hence speed, lent by computerized operation is forcefully conveyed by this comparison—200,000 man-days were required to prepare punched cards to tabulate the 1950 census; 28,000 man-days were expended to put the information for the 1960 census onto magnetic tape for the computers. Much of this achievement must be credited to FOSDIC, Film ptical Sensing Device for Input to Computers. FOSDIC I eads" microfilm images of documents, and transfers the nformation to magnetic tape for processing on computers. It helps to answer the input problem that has faced personnel ever since they began using computers—how to get great quantities of data into machines in the easiest and fastest manner.

A census is now taken in this manner: A questionnaire is mailed to every household in the nation; the recipient is requested to fill it out and hold it. An enumerator calls at the house, transfers this information onto a FOSDIC questionnaire. (At every fourth household, a second questionnaire is left for more detailed information.)

The FOSDIC form does not need to be marked by any special pen or pencil; even erasures can be tolerated, since the device "reads" the darkest marking. Information is put onto the questionnaire by means of position marking—such as voters do when they mark X's on ballots. All completed questionnaires are first sent to Jeffersonville, Indiana, where they are run under control as records to insure that they are not lost, and to make sure they are handled once, and once only. Next comes the microfilming operation which prepares the information for FOSDIC's scanning.

FOSDIC puts the data onto magnetic tape, from which the computer makes its compilation. The machine is programmed to recognize obvious mistakes. For instance, if a questionnaire lists the age of the head of a household as 7, the computer knows that this is unreasonable. It would be far too time-consuming to go back to the respondent each time a human error is found, so certain tolerances are programmed into the computer. Accordingly, it makes minor type corrections and notifies the operators that it is making a correction. Should too many "corrections" be made, the operator would then check to see why—to see whether or not something had gone amiss in the automatic system. Ultimately, demographers, specialists in population statistics, check final results for reasonableness and consistency.

Considering the much-discussed population explosion, it seems clear that the Bureau of the Census will have an ever-increasing job, and will put to good use all advancements in computerized operation.

***Bureau of the Budget.*** The computer is many things to many people. To some it is a status symbol—the business equivalent of the mink stole or country club membership. When equipment is acquired on such a basis, results often do not justify the outlay.

Just when is the installation of a computer system justified? This is an involved question that must have careful evaluation. The Bureau of the Budget, BOB, has long been concerned with helping the agencies of the government in planning for conversion to ADP, automatic data processing, equipment.

In 1952, a joint study by BOB, the Treasury Department, and the General Accounting Office resulted in the installation of the check reconciliation operation. The problem is simple—take all the checks that the government disbursing offices issue and reconcile them to insure that the amount charged against the account is the same as the amount on the stub. The thing that makes the operation difficult is the volume—over a million government checks are issued each day.

Many feel that from an economic standpoint this is the most successful computer installation in government, for the new method saves taxpayers almost $2 million each year.

This typifies BOB's constant efforts to improve economy and efficiency in government operations. Members of this Bureau early recognized the computer as an effective weapon in this battle. The importance of ADP is emphasized on top level contacts between the Director of the Bureau of the Budget and directors of other agencies. Among the possibilities being investigated by the Committee is that of curtailing some of government's enormous amount of paper-work by putting reports on magnetic tape, paper tape, or punched cards. Some areas in which such a procedure is already being accepted or is in prospect are social security, income tax, and defense contracts.

***Weather Bureau.*** "Everybody talks about the weather, but nobody does anything about it," said Charles Dudley Warner in 1890. Early in this century, people started trying to do something about it. The Norwegian physicist and meteorologist, V. Bjerknes, conceived the idea of using laws of fluid motion for weather forecasting. Later, an English mathematician, Lewis Fry Richardson, outlined the actual manner of accomplishing this, but there was one slight drawback—such a means of weather forecasting would require 64,000 people to analyze observations.

Obviously, the only practical way to ever achieve Numerical Weather Prediction was through the use of computers. This became a reality in 1956; the entire new approach to forecasting had three notable benefits—the predictions were more accurate, they were available sooner, and they covered larger areas. Numerical Weather Prediction is so complex that about one hour is required for each of 2 daily runs.

The basic computer used in this phase of the forecasting is the IBM-7094. Dr. George Cressman, Director of the Weather Bureau's National Meteorological Center, says, "We would like them faster by a factor of 6."

The speed with which problems are solved depends not only upon the capacity of the machine, but, also, on the manner in which it is programmed. Cressman says, "We could not code in the programming language, FORTRAN, for instance, because it is not efficient enough for our kind of calculation. We write directly in the machine language, SAP, Symbolic Assembly Program. I am completely dissatisfied with the present type of systems that compile and sequence programs. They occupy as much as 35 percent of the computer memory, plus 2 or 3 tapes, and a good bit of the disc; it doesn't leave much of the computer to handle big problems."

The general method of Weather Bureau operation is for the incoming data from hundreds of sources to be translated from teletype to magnetic tape by a special piece of equipment, the AVCO Automatic Data Communicator. This can be fed into the computer. The process is reversed at the end of the run, with the forecast being translated into teletype messages.

Another item, the Curve Follower (built by Electronic Associates, Inc.), is used as an output device. This automatically draws weather maps and plots highs and lows by means of a computer-controlled writing pen.

In addition to the vast activity of the daily forecasting, the Weather Bureau has the General Circulation Research Laboratory. This effort was set up in 1955 in response to Dr. John von Neumann's urging that such theoretical studies be conducted. The aim is toward improving prediction techniques and basic knowledge through theoretically reproducing and explaining the atmosphere's response to the sun's energy.

The computers perform 10 billion operations each day to simulate weather on a global scale and allow the scientists to create a hypothetical atmosphere by means of a mathematical model. The complexity of the model is governed by the capacity of the computer, an IBM-7090. Forecasts are made as far as 100 days in advance, in 5-minute increments; scientists later study their predictions made from the mathematical models, and see how closely they paralleled the actual weather. These models could be used not only to study improved methods of forecasting but, also, to investigate the possibility of changing the weather and to study the effects of possible modification.

The Laboratory's calculations result in computer-printed maps, which are similar to the weather maps drawn by the Curve Followers; these are turned out by a line printer and give an analog reproduction of digital data. The "picture" is made up of the.placement of the characters.

Another giant weather research effort is underway at the National Center for Atmospheric Research at Boulder, Colorado; it is made possible by funds supplied by the National Science Foundation. One of the three main goals of the Center is the use of a computer in long-range forecasting. The large staff, made up of both visiting and permanently based scientists, will also use a computer system to safely "tamper" with the weather. By running elaborate experiments on the machine, for instance, they can see what would happen if they were to seed clouds over Alaska.

The National Hurricane Research Project computer center, operated by the Weather Bureau at Miami, Florida, processes ata gathered by reconnaissance aircraft that fly through live ırricanes. One day's data, equivalent in size to the New York lephone directory, is processed by a GE-225 computer to help in plotting the course of the storm, and is later used for long-range studies.

Another important Weather Bureau installation is the National Weather Records Center, at Asheville, North Carolina. More than one-half billion worldwide weather records, dating back to the 1870's, are stored on punched cards and microfilm. The stock is increasing at the rate of about 40 million weather observations yearly, so the reliance upon efficient electronic data processing is evident.

This information is being used in the area of applied climatology, to help plot sea lanes, lay out airport runways, estimate the amount of electricity required from power companies, and to help estimate seasonal trends in many commercial products.

The Center is using the full power of its Honeywell-800 computer in a vast project for the Navy—the preparation of a six-volume *Marine Meteorological Atlas of the World*, which will contain weather information for all the world's oceans.

Computers are closely linked to all Weather Bureau activity. As is said in a Congressional report, "In the Tiros meteorolgical satellite project, for instance, a computer is used to provide instructions, which are sent to the satellite by radio, regarding where in its orbit to take the next group of pictures. The computer is also used to determine the exact coordinates of the resulting pictures when they are sent to earth by radio."[4]

The highly successful Tiros satellites have brought about a revolution in meteorology. In doing so, they have nearly innundated the earth with their pictures and weather-related information. The 400-million bits of data that are collected on each satellite orbit are analyzed by electronic data processing at both NASA and Weather Bureau stations. Contained in the memories of this equipment are long-time records of climates, ocean temperatures, and storm patterns; by thus "remembering" the past, computers help forecast the future.

Based on the techniques of Tiros satellites, NASA and the Commerce Department are now establishing a national weather satellite system—a major advancement geared to both civilian and military use. This era's indispensable tool, the computer, is an integral part of the planning.

*Atomic Energy Commission.* For all practical purposes, the complex scientific problems relating to atomic energy simply could not be solved without computers. Before equipment was commercially available, the Argonne and Oak Ridge Laboratories fabricated their own computer, the ORACLE.

From this single machine, the tally has grown to about 140 computer systems, located at various AEC facilities. The AEC has customarily acquired the most advanced computers—such as LARC, STRETCH, and the giant CDC-6600. In selecting

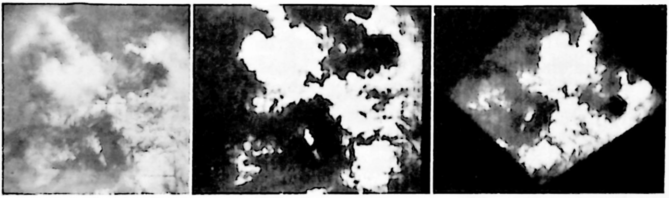


Fig. 2-3. Photographs sent back to earth from the orbiting Tiros satellite are processed by means of a digital computer.

new pieces of equipment, compatibility must be taken into consideration—can it "talk" to all the other pieces in the laboratory? If the new computer is fast enough and large enough, moderate incompatibility can be tolerated.

All of the programs of the AEC share the common requirement of highest scientific skill. The extensive computer systems are utilized about 80 percent of the time in scientific-type applications. In a recent report to a Congressional committee, this was stated:

"With computers, scientists are routinely able to discover and measure phenomena and to solve problems that were beyond exploration a few years ago. As a result, knowledge is expanding at a rate that is explosive even when compared with that of a decade ago. Moreover, future progress in fundamental knowledge and in applied science in the laboratories dependent upon significant expansion, both on advancement computer technology and expanded use of the machines in .periment."[5]

The programs of AEC are largely carried out under contract by industrial concerns and academic institutions. One of the facilities, the Lawrence Radiation Laboratory, has two major sites—one at Berkeley, on the campus of the University of California, and one at Livermore, California.

The latter laboratory is directing Plowshare, the project concerned with developing the peaceful uses of nuclear explosives. Computers were essential in first simulating the explosion that produced the cavity in Project Gnome, and also in the first nuclear excavation experiment in Sedan.

However, Plowshare is a small part of Livermore's activity. Most of the Laboratory's other work is classified because it is in the field of nuclear weapons research and development. Two examples of work that could not have been accomplished by Livermore without its $20 million computer facilities are: (1) a breakthrough in the design of small, tactical nuclear weapons, and (2) the development, ahead of schedule, of the warhead for the Polaris missile.

Mathematical models of nuclear warheads can be programmed into the computer and "exploded." Even were it not for the existence of nuclear test bans, the expense and great hazard of actual pre-testing of various designs would be prohibitive. Computers have made it possible for men to work with this force of gigantic proportions. Writes John N. Savage of the AEC: "The whole direction of research and development on weapons will always be heavily influenced by the kind of mathematical trial-and-error that is made possible by the existence of fast computers."[6]

The research at the Berkeley site of the Lawrence Radiation Laboratory is academic in nature and is not classified. Two-thirds of their computer time is devoted to analyzing nuclear events produced by accelerators, such as the Bevatron. Berkeley has contributed a large part to the veritable revolution in our knowledge of the particles of matter; digital computers have played a critical role in this basic advancement.

*Department of Defense.* The computer may yet emerge as the deadliest weapon of the military. It already has brought about major changes, and these but presage an impending revolution in operation.

NMCS, National Military Command System, will tie together more than forty Army, Navy, and Air Force systems. By means of this, our Commander in Chief and other leaders will have immediate and complete reports on our military status anywhere in the world. Further, this gigantic system will tie in all other agencies concerned with national security, such as the State Department, Civil Defense, and intelligence operations.

Even this massive network involving all U. S. military activities does not satisfy requirements in a world that is so intimately linked by modern technology. There is now urging from many sources that all the countries of the NATO alliance be tied together by standardized computer systems. Such a massive plan would infinitely strengthen the capability of the free world to react and wage defense in the event of an attack. The need for all possible capability is indicated, for if we detected a ballistic missile assault, we would have only minutes to issue the thousands of verified orders needed for our retaliation.

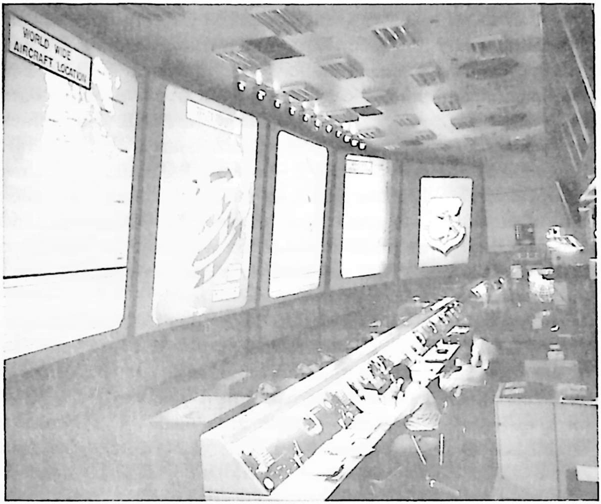
Means by which such ultimate systems could be achieved started about 1960 with the tying together of groups of computers into larger and larger systems. In this way, information could be transmitted more accurately, more thoroughly, and more quickly to higher echelons.

The obvious first problem that was encountered was one of standardization. Just as people of different nations have language barriers, so the computers of different manufacturers have a communications barrier. Even when this is partially surmounted, the technical interfaces to link various machines present difficulties no less stringent.

Despite such problems, hierarchial integration has been achieved. A strikingly successful example of this is NORAD, North America Air Defense Command, at Colorado Springs. Data regarding all aircraft over the United States and Canada fed into this huge computerized warning center from such systems as Pinetree, Mid-Canada Line, DEW Line, and SAGE. NORAD maintains not only this vigil in the air, but also to the reaches of space through SPADATS, Space Detection and Tracking System. The SPADATS central computer, a Philco-212 that can perform 1,680,670 additions per second, hungrily ingests data from sensors—including such systems as BMEWS, Ballistic Missile Early Warning System, Naval Space Surveillance, and Space Track. The bits are correlated into a comprehensive catalog of the positions of all orbiting objects, and, also, a prediction of where the objects will appear on future orbits; the latter is a particularly complex function, since there are constant perturbations that alter the orbit of a satellite or spacecraft.

The giant computer systems of SPADATS, NORAD, and others such as the Defense Communications Agency, have one pervading similarity—the ability to cope with staggering amounts of information. It has become evident that past procedures cannot cope with today's infinitely complex situation.

Yet, the changes that computers have keynoted are certainly not to the liking of all military men. Those officers who oppose the respect now accorded the computer contend that machines cannot measure the fighting capacity of a man or




(U.S. Air Force)

Fig. 2-4. The underground control center of the Strategic Air Command is linked to its global network of bases by means of computerized data.

the outcome of a battle—and that reliance on computers could lead to strategic miscalculations. The rebuttal offered by the operational analysts who are now influential in the Pentagon is that computers are lightning-fast tools to aid men, and are not in themselves decision-makers.

Immediate grasp of total information could spell survival. Located at an unspecified, hardened site is DODDAC, Department of Defense Damage Assessment Center. The purpose of the Center is to provide information in peace time on nuclear vulnerability of our military resources, and in event of attack to provide an immediate assessment of damage. As soon as the first-generation system went into operation, a new DODDAC facility was installed in the Pentagon as a development center for more advanced techniques.

Not all DOD facilities are restricted to wartime application. Operating under the U. S. Coast Guard is the system AMVER, Atlantic Merchant Vessel Report. By means of an IBM-305 RAMAC computer located in New York City, into which data from the crafts of 55 nations is poured, AMVER keeps track of ships and airplanes that cross the Atlantic. When a craft is in distress, the system swings into action. At Christmas-time, 1963, the dreaded SOS signal was picked up from the Greek ship, *Lakonia;* its location was fed into the computer, and almost instantly the machine indicated which of the 850 ships that were traversing the Atlantic were near enough to effect rescue operations.

Many of the computers of the Department of Defense are diverse and dramatic in their applications. But the majority the approximately one thousand machines (of which DOD ns about 40 percent and leases the remainder) are used keeping track of beans, bullets, and black oil. The newly tablished Defense Supply Agency is truly an organization that could not exist without a centralized computer control. The Agency already has catalogued 3½ million items, and ultimately expects to stock about 75 percent of the supplies and parts required by the Army, Navy, and Air Force.

The matter of getting what's needed to the right place at the right time involves many operations: requisition processing, stock record maintenance, materiel request and status history file, catalog records, procurement status, materiel management, stock fund, and billing and collecting. After this work at the Centers, there is the procedure at the Depots where the items are stored, requiring shipment processing, receipt processing, and adjustment processing. The prospect of trying to perform these operations without computer assistance is a nightmare fantasy.

The policy of the Defense Supply Agency is to centralize the requisitioning, accounting, and billing; the automatic data systems have been the means of accomplishing the goal. The second major accomplishment has been the standardization of inventory management data operations. Through the use of MILSTRIP, MILitary STandard Requisitioning and

Issue Procedures, standard-coded data can now flow from storage areas to Centers; results are evident in faster and more accurate reports. Eventually all buying agencies will be tied together in a single distribution system and a single information processing center. There is a giant effort underway toward efficiency and economy, with computer systems pulsing at the core of the activity. By standardizing items, duplication between the services will be eliminated; computer checks verify the inventories of all.

The Army Materiel Command has linked together all of the functions involved in supplying its forces. A major advancement in the handling of the Fleet's wholesale inventory system has been made with the Navy Tactical Data System. Air Force Logistics Command is termed "one of the world's biggest businesses."

From the 1950's this command began relying upon computers. A system that is a culmination of many individual steps is DATACOM, Data Communications. This global network, three years in the building, is both the largest and most advanced digital system now in operation—it transmits the equivalent of 12 million punched cards between 300 locations. Individual stockpiling of supplies by Air Force units has become outmoded, since any one of them can feed its requirement into DATACOM; the requisition is received immediately, the order is filled from a supply depot, and the shipment is sent via air on the same day.

The multitude of requirements within DOD operations has continually supported and accelerated the technological advances of the computer art. One instance of this is the associative memory, used in command-control computers in the Pentagon. Prior to the advancement to an associative-type memory, it had been necessary to specify the "address" of the place in the computer where each piece of information was stored—an operation that posed a giant "housekeeping" task.

Other major advancements in which DOD is deeply interested are on the horizon—such as techniques that will allow men and machines to interact in the "conversational mode," and means by which "time-sharing" of a computer may be accomplished. (These concepts are discussed in Chapter 8.) Whether scientists and engineers are performing research in these or other areas, they are faced with the common problem of requiring information that relates to their efforts.

An invaluable assist to research is DDC, the Defense Documentation Center (formerly called the Armed Services Technical Information Service). DDC, with a data systems approach, is employing a UNIVAC-1107 Thin-Film computer. The most comprehensive techniques are required, certainly, since DDC is increasing its store of material at the rate of about one hundred thousand documents per year; this includes all DOD scientific and technical output. DDC dispenses prompt and well-indexed announcements, disseminates requested documents quickly, and maintains a complete and current index of research and development programs.

*National Aeronautics and Space Administration.* "Operating in space would not be possible at all without computers." reports NASA to the Congress. Spaceflight, in all of a mission's phases—concept, design, development, test, preflight check-out, launch, injection into orbit, stabilization and control, guidance, navigation, re-entry, recovery, subsequent evaluation of data—is, for all practical purposes, entirely dependent upon the power of the computer to process data.

The functions are performed by two categories of computers —those that are ground-based, and those that fly in the vehicle. The latter has created a new family of computer systems that combine extensions of airborne technology with other unique features. Since about 1000 pounds of thrust is required to orbit one pound of payload, the first limitation on a computer system is that of weight.

The equipment should, therefore, fulfill the exact requirement of the mission. However, this cannot be spelled out in the early planning phases, because such requirements as trajectory and guidance are not known at that point; but if the computer is not created until after these are determined, the project might be delayed. Therefore, a general purpose digital computer, with a memory 3 to 5 times larger than the estimated requirement, must be supplied.

Further, the system must be rugged enough to withstand the torturous environment of space—radiation, meteorite impact, vacuum, and zero gravity—and the rigors of preflight sterilization, launch vibration, and re-entry build-up of g forces. Towering above all other requirements is that of reliability—reliability to ensure success because of the great cost of each mission, the prestige factor, and most of all, the human life that is involved in manned spaceflights.

To achieve computer reliability upward of 99 percent, the present approach is one of "brute force"—triple redundancy. Obviously, this imposes a weight penalty on the system, which brings the considerations full circle to the first restriction—weight.

Despite the impossible-seeming demands, computer science has undergone such tremendous progress in integrated electronic solid-state devices that the requirements can be met with special systems. Soon, perhaps, it will be accomplished with off-the-shelf items.

The role of the computer is placed in this perspective by Dr. Joseph F. Shea, Deputy Director of Manned Space Flight (for Systems), NASA: ". . . the key to reliable execution of a wide range of complex, long-duration missions is the computational capacity provided aboard the spacecraft."[7]

Telstar, the communications satellite, has demonstrated the feasibility of creating a worldwide computer-to-computer network. Successful tests, with a Honeywell-800, have proved that the two technologies—computer sciences and astronautics—can revolutionize international data transmission.

Orbiting Astronomical Observatory (OAO) is another of the unmanned satellites that makes unusual use of computers. As it orbits 500 miles above the earth, a data processor directs on-board telescopes to look at the stars, and the information they observe is stored in an IBM ferrite-core memory with a 200,000-bit capacity. The read-out on all the information that OAO has gathered during each 100-minute orbit can be read-out in just 7½ seconds as the satellite passes over the ground stations in the eastern United States and South America. The stations can then send out further instructions for experiments to be performed in orbit by OAO; this information is stored in the command memory of the on-board equipment.

Several basic characteristics distinguish the parameters of computer equipment for manned spaceflight. First of these is the possibility of on-board maintenance by the astronaut. The computer can be programmed to monitor its own performance, and thereby diagnose a failure so that the astronaut could replace the ailing module. This technique, and other advances in computer technology, will extend reliability periods from months to years—to such a point that they will be able to fulfill the requirements of prolonged flights to the planets.

Generally, the manned missions require flexible, large-capacity machines because the flights perform several functions. The basic policy is that manned flight be capable of operation that is independent of ground command. Guidance and navigation computations are performed on-board. Also, there are changes in trajectory and velocity, maneuvering for rendezvous and docking, and other controlled operations, all of which draw heavily upon computer assistance.

Project Mercury, our pioneering man-in-space effort, dictated "real-time" control (as contrasted with some unmanned missions for which data computations can be made weeks or even months later), because many decisions hinged on data being received. For example, the decision as to whether a launch was "go" or "no-go" into orbit had to be based on only 25 seconds of critical data. The nerve center of the Mercury operation was Goddard Space Flight Center, near Washington, D. C. There data from the launch site, Cape Kennedy, and all of the worldwide tracking stations were fed into an IBM-7094 computer. The enormous amounts of raw data were at that point transformed into understandable bits of information—information upon which vital decisions could be made at Mercury Control Center at Cape Kennedy.

Continuously during orbital flight, readings on the astronaut's physical condition and the performance of the spacecraft were telemetered from space to the nearest Manned Space Flight Tracking Station, then relayed to Goddard Space

Flight Center, where they were fed into computers; in the memory of the equipment was stored data as to what the performance should be at that given instant, so immediate comparison could be made. At every point in orbit, computers determined the capsule's position to within 300 yards. Their precision made it possible for Astronaut Gordon L. Cooper to land within 4 miles of the recovery ship.

These missions were "old hat" to the Mercury team, for they had flown them many times before, by means of computer simulation. These simulated-flight tests were called CADFISS, Computation and Data Flow Integrated Subsystems; the "rehearsals" even simulated malfunctions, so that the mission controllers at Cape Kennedy might gain experience in coping with emergencies. The CADFISS exercising of the network, via computers, is given major credit for the success of the Mercury missions.

Project Gemini, the 2-man-in-space effort, uses a computer as the heart of its complex inertial guidance system. This equipment will accomplish the remarkable feat of rendezvousing the Gemini spacecraft with an Agena D—while both are racing through space at better than 17,000 miles per hour. The computer then aids the astronauts in the delicate docking maneuver, in which the two craft are linked together. As the missions are becoming more sophisticated, it is imperative that computers absorb the complexity and take the heavy load off the astronauts.

The Gemini computer will provide visual displays from which the men can navigate; they will have complete attitude and abort control during the entire mission. A manual data insertion unit enables the astronauts to enter new information into the IBM system during flight. The computer, which performs more than 7000 calculations per second, is connected with such devices as horizon sensors, radar, star tracker, and control electronics.

IMCC, Integrated Mission Control Center, at NASA's Manned Spacecraft Center, Houston, Texas, is the new focal point for manned flights. The vast computer complex was installed by IBM at a cost of $36 million.

Saturn V, the gigantic booster rocket that will develop 7½-million pounds of thrust and will stand as tall as the Washington Monument, will "fly" the moon mission many times on computers before it finally thunders off from Cape Kennedy. The job of checking out the massive vehicle is a superhuman task. More than 200,000 components comprise the Saturn. Each is tested again and again and again, with the data being read directly into the computer.

Project Apollo will perform its lunar mission by means of the Saturn V booster. Apollo guidance will be performed by means of a digital computer being developed by the Massachusetts Institute of Technology Instrumentation Laboratory. Microcircuitry will be used throughout the equipment.

As soon as the Apollo spacecraft is in earth orbit, the crew will calculate their position by taking star fixes with a space sextant. The data will be fed into the computer, and an orbital calculation will be received before the rockets are again fired for the lunar trajectory. The computer will determine the exact instant for the firing of braking rockets in order to put the vehicle into lunar orbit.

The lunar "bug" will separate from the orbiting mother craft and descend to the moon's surface. After a period of exploration, the astronauts will prepare to return to the mother craft; the checkout and countdown will be performed by on-board computer equipment. Every intricate phase of the return journey to earth will be calculated on the most advanced automatic equipment. With these flights, the computer will assume the nearly ultimate role of being the central data reference.

# 3

# History

The computer business has at last gotten old enough to boast "old-timers." At a gathering of this select group, recollections caused chuckles about such things as: ". . . the 602A that stacked its cards carefully out of the window . . . the CPC iceboxes that were used, in fact, to store ice cream . . . the girl who was commissioned to watch when the counters of the 602 rolled negative (and *did* watch) . . ."[8]

Today's computer is a young invention, but it is the direct descendant of a device that made its appearance about 2000 B.C., the abacus. Variations and refinements of counting contraptions crop up throughout the unfolding cavalcade of civilization.

Modern computer systems have drawn most heavily from the contributions of ten people; Pascal, Leibnitz, Jacquard, Babbage, Lovelace, Hollerith, Aiken, Mauchley, Eckert, and von Neumann. If justification is needed for inclusion of the fifth name, let it be that the individual was a brilliant, prescient woman and offers charming relief from the male assembly.

## The Calculating Machine

The strong emphasis on youth that is apparent in our space effort has had its counterpart throughout the annals of science. The first major step toward the computer was taken by a 19-year-old Frenchman. Blaise Pascal was recognized as a mathematical genius in an age that boasted such figures as Descartes, Fermat, and Huygens. Being a man of great intellect, Pascal, therefore, was understandably provoked at the tedium of adding long columns of numbers—a task that fell to him when Cardinal Richelieu gave Pascal's father the post of administrator of Rouen, France. Blaise Pascal solved his dilemma and made a notable contribution to technology by inventing, in 1642, a device with ten numbered wheels and an assortment of gears—similar in principal and function to modern adding machines.

Gottfried Wilhelm Leibnitz, who promulgated some of Pascal's work, repeated the characteristics of youth and genius. In 1671, Leibnitz announced impressive discoveries and plans in such diverse areas as natural philosophy, nautical science, optics, hydrostatics, mechanics, and mathematics. Figuring importantly in this array was a machine that expanded upon Pascal's invention. Leibnitz's calculating machine, which was exhibited to the Academy of Paris and the Royal Society of London, could subtract, multiply, divide, and xtract roots.

The link from one genius to another continued. Charles ıbbage (Fig. 3-1), a century-and-a-half later, tried to upgrade he standard of mathematics in England by urging the adoption of Leibnitzian notation in the infinitesimal calculus. Further, Babbage shared his predecessor's trait of having wide-

*(Burndy Corp.)*

Fig. 3-1. Charles Babbage was a century ahead of his time when he struggled to build an automatic computer.

ranging interests. The English genius wrote of his "contributions to human knowledge" citing such instances as research on glaciers, establishing a uniform postage rate, parcel post, submarine navigation, Greenwich Time Signals, and the cause of magnetic and electric rotations. Further, he invented the speedometer, the cowcatcher, and the analysis now termed "operations research" (which he performed on the pin-making and publishing industries). Babbage urged the development of machine tools, mass production, and generally advocated the application of science.

Of all this effort, he is best remembered for his invention of two machines. The first of these was the Difference Engine, for which he may have gained some inspiration from a similar engine devised in 1786 by H. H. Müller of Germany. Müller's machine was never built, nor was Babbage's ever completed, because the technology of the time could not produce such devices.

The second machine that Babbage invented, the Analytical Engine, proved his true greatness. Had the means existed for transforming his dream into a reality, a computer would have been built in 1822. In thousands of detailed drawings, Babbage projected the very fundamentals upon which the machines of today operate, but his ideas were not generally understood.

Shortsightedness has not been limited to Babbage's contemporaries. Within our twentieth century a supposedly astute individual wrote that it was clear Babbage's invention was never completed because the need for it was imaginary. We have the counterpart of such thinking today reflected by the tiresome question, "Why should we go to the moon?" Those who spearhead progress need infinite tolerance and patience—and Babbage had neither.

He was plagued over the years by many aggravations—among them were street musicians, whose serenading encroached upon his concentration; their reply to his protests was to gather beneath his windows and play louder. More meaningful was Babbage's conflict with many of his colleagues, such as the influential Astronomer Royal. The number of errors in the astronomical tables, as well as other mathematical tables, were of great concern to Babbage; a primary purpose for his proposed Difference and Analytical Engines was to have been the recomputing of basic tables.

Beyond that, he displayed remarkable vision as to other uses for computers, for he wrote: "The whole of chemistry, and with it crystallography, would become a branch of mathematical analysis, which, like astronomy, taking its constants from observation, would enable us to predict the character of any new compound, and possibly indicate the source from which its formation might be anticipated."[9] About 115 years later, the SWAC computer was used to determine the crystal structure of Vitamin B-12.

The person who most clearly understood Babbage's inventions was Lady Lovelace, the daughter of the poet Lord Byron. Even as a young girl, her mathematical brilliance allowed her to grasp the operation and significance of the machines. She certainly was the world's first programmer, for she planned problems for the proposed machine. When L. F. Menabrea wrote a paper about the Analytical Engine in French, Lady Lovelace translated it and added many notes of her own that enhanced the clarity. She even found an error in Babbage's calculations, for which he paid tribute to her.

Babbage's Engine was capable of *branching*—selecting from alternatives. He also planned a serial operation—the performing of all operations on a piece of work in sequence. Another feature that he planned for his engines that is common for today's computers was the punched card to feed information into the equipment. Babbage gained his inspiration for this method from the operation of the Jacquard loom. Combining the inventions of many men before him, Joseph Marie Jacquard produced in 1804 the first completely automatic loom. It functioned by means of punched cards.

## The Punched Card and Early Computers

The use of punched cards to compile data was "rediscovered" in 1885 by Dr. Herman Hollerith. This time it was not an instance of a scientist working for the general betterment; instead it was the matter of Hollerith needing a specific tool for a specific job—that of compiling the nation's census.

It had taken 7 years to complete the 1880 census. As the 1890 event approached, and the population had increased by an estimated 25 percent, it became clear that old methods could not complete the one counting before the next census would begin.

So statistician Hollerith prepared cards, snipped off one corner in order for there to be a means of determining when they were right side up, and used the method of the street car conductor to punch information onto the card. The first cards had 45 columns and were punched with round holes. The shape of the hole was later changed to oblong to permit additional columns. The IBM card now has 80 columns; horizontally, there are 10 rows for numbers, and 2 rows that combine to designate letters.

By means of EAM, Electric Accounting Machines, the 1890 census was completed in one-third the time of the previous one.

When Hollerith devised the method, he did not consider other applications for his machines. But the successful operation expanded his aims, and the company he had formed began manufacturing machines for railroad accounting. This tabulating equipment formed the bridge to calculating machines. Following a merger in 1911, the company was known as Computing-Tabulating-Recording Company; in 1924, it became IBM.

The highly respected scientist, Dr. Vannevar Bush, contributed to the computer evolution by building a large-scale computer (also called differential analyzer) on the MIT campus in 1925. Bush encountered the same problem that Babbage had faced—the mechanical problem that a long train of gears requires considerable power; Bush solved this problem by means of mechanical torque-amplifiers between the stages of his machine—a principle that may be compared with that used in cargo hoists.

Both the Babbage and Bush machines were mechanical, but they were two different kinds of computers. The Englishman had planned a *digital* machine, which is the type primarily in use today. Bush's machine was *analog*. However, it must be conceded that Babbage also invented an analog computer—in the form of a speedometer. This, and the slide rule, are the oft cited examples of analog computing.

## The Computer and Astronomy

The first man ever to use commercial accounting equipment for scientific computation was the brilliant and ingenious Dr. L. J. Comrie. In 1926, he was head of the Greenwich Observatory and Deputy Superintendent of England's Nautical Almanac Office; he was disturbed, as had been Babbage, at the numbers of human errors contained in astronomical calculations. Comrie used a Burrough's Posting Machine in the application Babbage had intended for his Difference Engine. With 500,000 punched cards, Comrie computed the position of the moon at every noon and midnight until the year 2000 A.D.—an invaluable aid to navigation.

This remarkable feat was the beginning of *scientific* application of automatic equipment, as opposed to the tabulating-type utilization that represents *business* application.

Comrie then established another first—a technical computing bureau, the Scientific Computing Services, Ltd., in London, England. This bureau is still in operation, although the brilliant New Zealand-born astronomer is now deceased.

Dr. W. J. Eckert, then Professor of Astronomy at Columbia University, was so stimulated by news of Comrie's feat that he secured equipment from IBM with which he could perform similar work in this country.

Eckert requested that the company build into the equipment the first sequence control—a rotating shaft with 10 positions that allowed the electro-mechanical equipment to perform a series of operations without having to change the plug board. With this, Eckert integrated the orbits of asteroids.

In 1944, IBM extended the first of their generous gestures to universities by establishing the Thomas J. Watson Astronomical Computing Bureau at Columbia University; Eckert is now Director. (It is an interesting sidelight to note that while this work that foreshadowed computer development was being conducted in the physics building on the top floor at Columbia, momentous work was also underway in the basement—one of the early cyclotrons was pioneering research on atomic energy.)

Eckert's outstanding work at Columbia led to an invitation to join the United States Naval Observatory and set up a small, mechanical computing laboratory to produce the *Nautical Almanac* for sea navigation and, also, the *Air Almanac* for aerial navigation.

Thus did two astronomers, Comrie and Eckert, working on different sides of the Atlantic Ocean, pioneer scientific computation on business data handling equipment—an important advancement even though the machines were electric, not electronic, and the code was decimal, instead of binary.

## A Boost for Computer Development

Curiously, several events during the depression years of the 1930's accelerated the development of computing equipment. The initiation of Social Security created immediate and extensive demand for tabulating equipment. Fortunately, IBM had the capability to produce this (even though their primary output at that time consisted of scales and punched card equipment).

Under the WPA, two copies of Dr. Vannevar Bush's machine were produced—one for the Army's Aberdeen Proving Ground, to be used in conjunction with ballistics research, and one for the Moore School of Electrical Engineering at the University of Pennsylvania.

Another root was being implanted in the 1930's that would eventually grow into the modern computer—this one was at Bell Telephone Laboratories. Dr. George R. Stibitz, a research mathematician, displayed inventive talents by putting together two observations: (1) Many important circuits that were then a part of operations, including the valuable flip-flop, were ones that could become computer concepts; (2) Bell Laboratories required a staff of girls using hand-operated calculating machines to solve their many design problems—problems involving addition, subtraction, multiplication, and division of complex numbers.

In that recognition of related facts, Stibitz included two obvious elements—the possibility, and the need. He designed a relay-type, semi-automatic machine that was named Complex Computer. Samuel B. Williams added such features as push-button keys for the input, and standard teletypewriter equipment for the output. The machine went into successful operation early in 1940 at the New York City location of Bell Laboratories, and demonstrations of remote operation over teletypewriter circuits foreshadowed present data transmission services.

## The Automatic Computer

Mark I was the world's first fully automatic computer. This electro-mechanical machine was the brainchild of Dr. Howard Aiken (then Professor of Mathematics at Harvard University, now a consultant). Mark I was built by IBM, and four of that company's engineers assisted in the design—J. W. Bryce, C. D. Lake, B. M. Durfee, and F. E. Hamilton. Work was financed by the Navy.

When Mark I, also called Automatic Sequence Controlled Calculator, made its debut in 1944, it established a milestone in computer history. It was the first machine to transform the dream of Babbage into reality—though Aiken had worked on the design for 3 years before he came across the Englishman's plans. Mark I followed the general principles of the Analytical Engine; the major exception to this was that the original Mark I did not have the capability to branch in its operations, though this feature was incorporated later.

The machine, operated almost entirely by mechanical switches, was a giant piece of equipment with a panel 51 feet long and 8 feet high. It had a storage unit for numerical data, and instructions were fed into it by means of a 24-hole punched paper tape, similar in appearance to a player piano roll, which advanced at the rate of about 200 steps per minute. This gave Mark I a speed equivalent to the output of about 20 men working with desk calculators. Mark III used vacuum tubes, and Mark IV relied heavily on solid-state techniques.

However, machines, like members of the animal kingdom, must lie along the right evolutionary lines in order to survive. The Mark series of computers were externally programmed, as were the early plug board machines. This basic design made it difficult, if not impossible, to incorporate a stored program within the machine. So even though Mark computers were remarkable in their time and made vital contributions to the war effort in service to the Navy, that type machine did not survive. What truly did flourish was the influence of Aiken, both as an individual scientist and as a teacher.

## The Electronic Computer

The era of the electronic computer came into being with ENIAC, Electronic Numerical Integrator and Computer, designed and built by Dr. John Mauchley and Dr. J. Presper Eckert.

Prior to ENIAC's "going on the air" (as computer men term the initial operation) in 1945, there were periods of dreaming, planning, hoping, being discouraged, and ultimately realizing success—steps that appear to accompany the emergence of most scientific products.

Mauchley, as a teacher, and Eckert, as a graduate student, met at the Moore School of Electrical Engineering of the University of Pennsylvania during World War II; each was involved in the activities of the Army's Aberdeen Proving Ground and felt deep concern about the inadequacy of the methods that then existed to supply urgently needed mathematical data for ballistic trajectories.

The 2 machines that were copies of Dr. Vannevar Bush's analog computer were being urgently employed in work for Aberdeen as were other pieces of equipment; there were many girls seated in cubicles throughout the University operating desk calculators—and still the output was totally inadequate. A real "breakthrough" type advance was needed.

Mauchley had prepared a proposal for an electronic computer and submitted it to the University. It became lost. At the urging of Dr. Herman Goldstein (then an Army liaison officer, now with IBM) Mauchley was able to reconstruct the proposal from shorthand notes, and Eckert added a considerable technical section; valuable help in the detailed planning was given by Dr. Arthur Burks. The proposal was submitted to Col. Leslie E. Simon, at Aberdeen Proving Ground, and a contract was immediately forthcoming. Dr. Leland Cunningham (then at Aberdeen now at the University of California) wrote the specifications for the machine.

The plan was for a very specialized computer for ballistics calculation. It was not designed as a general purpose computer. To prove the design theory, Mauchley and Eckert first constructed and successfully tested 5 percent of the machine. Then came the giant task of putting together the entire computer—with its 500,000 soldered joints, 18,000 tubes, 6000 switches, and 5000 terminals. Mauchley and Eckert, plus a team of 10 engineers, labored 2½ years on this meticulous task, and during the construction they tripled the machine's function.

Whereas Mark I could add two numbers in ⅓ of a second, ENIAC could add numbers at the rate of 5000 per second. Gears were eliminated—the counting was performed by electronic pulses. This machine operated on the decimal system of numbers; the input was electro-mechanical, the output on punch cards. ENIAC had a master programmer, making it an automatically sequenced computer.

The project was classified as a wartime secret and all work was done behind locked and guarded doors. Those who did have clearance to enter the marvel under construction were amazed. Among the visitors was Dr. John von Neumann. This mathematical genius, as a consultant to Aberdeen, was able to suggest expanded use of the ENIAC. Von Neumann was also a consultant to Los Alamos on the Manhattan Project.

The initial test problem programmed into ENIAC that served as the machine's "shakedown" was one formulated by Dr. Nicholas Metropolis and Dr. Stanley Frankel; it related to the Manhattan Project. Though the machine performed as expected, Mauchley and Eckert kept expanding their thoughts, just as Babbage kept changing his Difference Engine during construction. Thus ENIAC, like a great proportion of machines ever constructed, was virtually obsolete even before it was completed. In a new and growing field, especially, the concepts expand at such a pace that it is almost impossible to keep abreast of technology.

ENIAC had gotten rid of the roll of paper tape that Mark I required and stored its instructions internally. However, the instructions had to be wired into the machines by means of hooking up appropriate circuits—a job that might involve hundreds of connections and require several days to perform. The means of short-cutting this tedious process was the invention of the stored program. Although there is still dispute as to who originated the stored program idea, it is conclusive that the initial important paper on this and other modern computer concepts was the one written by Burks, Goldstein, and von Neumann on June 28, 1946, entitled *Preliminary Discussion of the Logical Design of an Electronic Computing Instrument.*

The first stored program computer, EDSAC, went into operation at the University of Cambridge in 1949. EDVAC, a machine similar to EDSAC, begun by Mauchley and Eckert, was completed after they left the University of Pennsylvania and put into use at Aberdeen. The two men formed their own company, which was bought by Remington-Rand Corporation (later, Sperry Rand). Eckert has remained with UNIVAC; Mauchley left and formed Mauchley Associates, Inc.

Many of the design features proposed in the Burks, Goldstein, von Neumann paper were radical departures at that time; the soundness of them is indicated by the fact that not a dozen important differences exist between that machine and ones in use today. After World War II, von Neumann was relieved of some of his time-consuming consulting duties and was able to return to his post at the Institute for Advanced Study at Princeton. One of his first undertakings was the building of the computer described in the paper. Although the Army Ordnance Department financed the building of the machine, they requested in return only information in the form of reports and allowed the Institute to retain the machine. This computer is known variously as the von Neumann Machine, the Princeton Machine, or the IAS Machine.

This computer may be well appraised by the fact that it was copied, in principle if not in detail, in these and other machines: AVIDAC at Argonne National Laboratory, ORACLE at Oak Ridge, ILLIAC at the University of Illinois, ORDVAC at Aberdeen, MANIAC I at Los Alamos, SILLIAC at the University of Sydney, Australia, and JOHNNIAC at RAND. Also, the IBM-701 machine was patterned very much after the von Neumann Machine.

Comments Dr. Willis Ware, The RAND Corporation, "One commonly hears machines referred to as von Neumann-type machines. All the machines that we have today are essentially organized in a similar way. This has to do with the internal, logical structure, rather than the details of the individual electronic circuits."

The individual machines that sprung from the common ancestor had noteworthy characteristics of their own. MANIAC, for example, had a 1024-word memory, which seemed practically infinite at a time when an 80-word memory was run-of-the-mill. This machine, in the opinion of scientists, was the means by which the United States was able to develop and test thermonuclear reaction (the principle of the H-bomb) prior to any other nation.

Computers have enabled scientists to play games—for very serious reasons. The fact that the machines can treat any number of samples in a statistical way enabled Dr. John von Neumann and Dr. Stanley Ulam to develop the Monte Carlo method which was used to solve an important problem in atomic energy—the distribution of neutrons radiating from an atomic pile outside the shielding. This information was vital to the safety of personnel working near an atomic pile.

England achieved two important computer "firsts"—the first workable electrostatic storage device, and the first commercially available electronic digital computer. But despite these early advances, the United States attained a leadership that has not been challenged.

Prior to 1947, the Army and the Manhattan District were powerful influences toward advancement of computer technology. Then the Office of Naval Research, ONR, formed a Computer Section with its Mathematics Branch under Dr. Mina Rees. Relates Dr. Joe Weyl, ONR, "It became clear to some of us that something new was happening. What the United States government was going to do in that area was something that would determine very profoundly and very essentially how the country was going to look across the board in its technology a decade hence. ONR was the first government agency that had a clear recognition as to what the development of the computer was going to mean for science and technology—and acted on it."

ONR called together a steering committee, chaired by Dr. Rees and made up of representatives of various government agencies, that did two principle things—surveyed on-going programs to identify the gaps that existed in the overall effort, and then served as a collection point for funds from government agencies to support further activity.

This led the Bureau of Standards into the computer-building business. The agency began a pilot project to construct at the Washington, D.C. location a computer named SEAC, Standards Eastern Automatic Computer. SEAC was the first U.S.-built stored-program computer. Then a second machine was begun for the Bureau's Institute of Numerical Analysis, located at the University of California, Los Angeles. This was called SWAC, Standards Western Automatic Computer. (SWAC later was taken out from under the Bureau of Standards and made a research project of UCLA because those in government who protect small business felt that it was competitive.)

Both SEAC and SWAC were under Air Force financial sponsorship; the aim in undertaking them was to build "state of the art" computers—ones based on the level of technological development that then existed—and to put them into operation within 2 years. In that way, it was hoped to gain experience in the operation of installations before the really big and fast machines were ready. However, computer-building was new, strange, and complicated. As it turned out, SEAC and SWAC were not ready long before such elaborate machines as UNIVAC I. (This inability to accurately estimate a completion date is expressed in what has been termed the "von Neumann constant"—at any given time, the completion seems about one year away.)

The steering committee spearheaded by ONR reached another salient conclusion—that in all the concentration on *machines, people* were being forgotten. No group was giving thought to the establishment of a systematic plan to train computer personnel, though it was already clear that increasing numbers of complex machines would make sizable manpower demands.

ONR pioneered the development of training programs that were particularly oriented toward supplying the needs of the Department of Defense; these programs started the pattern that is now followed by computer manufacturers. ONR further succeeded in establishing computer mathematics as an important new field and in gaining the interest and participation of leading mathematicians.

A complicated mathematical model—which involved the simulation of high performance trainer aircraft—led to the concept of a very fast machine, Whirlwind II (Fig. 3-2). This ranks as one of ONR's most important early projects; it was developed by the Digital Computer Laboratory of MIT. The name described its primary characteristics—a target speed of 50,000 operations per second. Whereas the von Neumann machine operated at a 1-megacycle rate, Whirlwind ran at 4. However, in order to do this it sacrificed accuracy, having a register size of only 16 bits as compared with the 40 bits of the von Neumann machine.

As the design developed, great controversy arose and it was said that Whirlwind would never work. The pessimists

Fig. 3-2. Whirlwind served as one of the milestones in computer history.

were almost right. During the first period of Whirlwind's operation, it chalked up a calamitous record of failure—whereas the slower-but-surer Mark I machine, with its relay operation, kept plugging away.

It is to the very great credit of those responsible that Whirlwind eventually achieved a reliability record of 85 percent. This was to large measure achieved by the joint MIT-Sylvania development of the 7AK7 tube, the first one made especially for use in computers. These tubes attained an average life of 500,000 hours.

As an added form of insurance when something did go amiss with one particularly weak point, Whirlwind was programmed to instruct the operator how to make repairs! This imaginative maintenance program typed out a list of instructions. The final step in the repair was to go down the hall, around the corridor, down a flight of stairs, and make a critical voltage check. The machine timed the operator's activities; if the signal to start came too soon, Whirlwind would query, "Are you sure you checked the voltage?" The operator had to reply, "Yes," before the machine would start.

## Magnetic Core Memory

A giant technological stride was taken with the magnetic core memory, which was the second type installed in Whirlwind. (The original one was an electrostatic memory.) The magnetic core memory was the great contribution by Dr. Jay W. Forrester, and its significance is noted by Dr. Frederick Frick, "Insofar as any one development or invention has made the modern computer possible, it has been the memory core."

The ideal utilization for Whirlwind presented itself in the summer of 1951 when it became apparent we needed to guard our nation against surprise air attack. The information that came off a major air surveilliance radar was fed into the Whirlwind by means of a data link, and it was found that he computer could very effectively sort out that data, and elate the radar returns to the right target tracks! As Dr. oe Weyl so eloquently phrases it, "Though the development of Whirlwind was a checkered one, it stepped on the stage of world history during a very important period and vindicated all the cost and trouble of the entire project."

The final achievement of this MIT computer lent special meaning to a statement that Dr. Jay W. Forrester had made in an address years earlier: ". . . I believe that if a high-speed computer . . . were sitting here today, it would be nearly two years before the machine were in effective and efficient operation. One would be caught totally unprepared for feeding to this equipment problems at its high acceptance rate. On the other hand, this represents but one half of a vicious circle in which an adequate national interest in computer training cannot be developed until the equipment is actually available."[10]

## The "Real-Time" Computer

To make available a system for the next requirements of air defense was one of the most challenging problems that has ever faced computer scientists. In 1952, Lincoln Laboratory of MIT was established under Air Force support with the mission to develop SAGE, Semi-Automatic Ground Environment. The parameters were beyond experience, beyond the technology—seemingly beyond reason. Specifications called for speeds that were almost instantaneous, sizes that were almost infinite. Our defense demanded the development of such equipment. To preserve freedom, it was essential that our nation be ringed with radar's searching eyes, that forces stand ready to intercept, and that instantaneous detection and reaction become our way of life. Admittedly beyond the capability of men alone, such aims could be realized only with the augmentation of machines.

By means of appropriately placed computer systems, SAGE has to perform "real-time" (as it happens) interpretation of information gathered by radar. Sequentially, it has to identify as friendly or unknown every aircraft in the skies above our nation and Canada, and to furnish information on its location, speed, specifications. If the aircraft remains unknown, the computer must next determine and designate which of our ADC aircraft are to "scramble" and intercept and, immediately, it computes the trajectory for missiles that are standing

Fig. 3-3. SAGE, Semi-Automatic Ground Equipment, computers must interpret incoming data "real time"—as it happens.

ready. Though we now have been so surfeited with technological achievements that such functions as these seem little more than "routine," SAGE must be considered in the context of its planning phase a decade ago. These were giant goals.

In addition to the innovation of a real-time operation, there was another—the use of computers for processing information. The functions of the SAGE operation are only in small part mathematical—largely they are a super-colossal bookkeeping system. Computers have to store data, retrieve data, file data, check data, up-date data, rearrange data. This kind of function is now an accepted application of the equipment, but it was a revolutionary use in that day (Fig. 3-3).

For the handling of such masses of information, machines far larger than any then known were required. An entire new elephantine breed of equipment came into being, and has nce thrived on a diversity of applications. Lincoln Laboraries brought in IBM as contractor, and much of the equipent development was a joint effort. This became something r a turning point for that company; it put them in the large-scale computer business.

In all ways, SAGE evolvement gave explosive acceleration to the technological state of the art and was a milestone for military applications. It is the closed loop, the total system. Yet, equipment, *hardware,* is but half the requirement. It cannot perform without its partner, the programming, or *software.* Some of the first programming was done at Lincoln Laboratories, but the task became too vast, and was assigned to The RAND Corporation.

This organization, known as a "think factory," was established in 1946 largely to give guidance to the Air Force on long-range research and development programs. Dr. Cecil Hastings, Jr., the man at RAND who pioneered computing at an early date, rented IBM accounting equipment. (He selected an 016 Key punch, feeling a larger machine was ruled out because of its high rental—$30.00 per month!). Later, when RAND got news of the machine that von Neumann had under construction, they set out to build a copy of it; they named it, in tribute to its designer, JOHNNIAC.

But even this machine was not capable of solving one giant problem that faced the scientists at RAND, so on one of von Neumann's visits to that organization, they solicited his help in designing a new super-computer. He asked just what the problem was that had them stumped. The array of scientists began describing it. For the next two hours with the use of formulas, diagrams, and tables, they conveyed the extent of it. Then the group waited for the genius to describe the kind of computer that would solve the problem. He stared blankly into space, scribbled for a moment, then said, "Here is your answer. You won't need a new computer."

The problem assigned to RAND in programming SAGE was almost as complex, and far more time-consuming. So immense did the undertaking grow that the section of RAND devoted to it became like the tail wagging the dog. A change was clearly indicated. This section "spun off" and became a new organization, SDC, Systems Development Corporation. Several hundred people at SDC worked several years on two aspects of SAGE—writing the program for the computers, and training people to operate the system.

But modifications alone could not keep pace with the war-making potential of this era. Whereas nuclear bombs delivered by long-range bombers had been the concern of SAGE, a new threat arose—bombs delivered by intercontinental ballistic missiles that travel many times the speed of aircraft. BMEWS, Ballistic Missile Early Warning System, a billion dollar plus installation, was begun in 1959. The first site went into operation at Thule, Greenland, 2 years later.

BMEWS is the largest integrated electronics system ever developed, and consists of three basic elements—extremely powerful radar, extremely efficient computers to sort out and reduce the data from the radar, and extremely reliable communications equipment to transmit the data to NORAD, North American Air Defense Headquarters, at Colorado Springs. The reliability requirements on the entire system were incredibly high—99.99 percent.

BMEWS was to warn of any mass missile attack over the northern hemisphere. Soon after it went into operation, the radars spotted a mass of targets over the horizon, the computers reduced the data, and headquarters went on red alert. But, fortunately, there is always the top-level judgment of men to interpret what equipment tells them. Instead of immediately launching a retaliatory attack, the commanders took a second look at what was happening—and found that the mass appearing over the horizon was only the rising moon!

From the development of ballistic missiles came orbital capability. The military must monitor space as closely as it does air, and computers aid men in the vigil. To fulfill the needs presented by these and hundreds of other requirements, there is an array of equipment that is wondrous in its capability and versatility. Today's production output becomes the more remarkable when it is remembered that the first years of the computer effort manifested one-of-a-kind, made-by-hand machines. They were indeed the progeny of their designers, with individual names and distinct personalities. Sometimes they performed in ways that delighted, and other times they were recalcitrant children, balking in such a frustrating manner that even a usually well-controlled lady programmer, Mrs. Ruth Horgan, once kicked a computer!

This equipment became very personal because it had to be "raised." Computers know only what they are told—and told in absolutely painful detail. Then, with the introduction of compilers, some of the programming burden could be placed upon the machine. With the maturing of the computer, not only was the individuality of each machine submerged, but, also, the era of the single inventor vanished. Complexity demanded teams, not individual men, to do the design work.

In those years of eager interest and consecration to the cause of computing, the scattered but keenly sympathetic group of pioneers spread word of their activities by means of what was one of the first publications in the computing field, *Computing News*. This was edited by Fred Gruenberger when he was an instructor at the University of Wisconsin. The means of subscribing was most novel—at the first of the year, each subscriber simply mailed to Gruenberger 12 stamped, self-addressed envelopes.

Even at this time it is difficult to draw a line of demarcation where commercial production tipped the balance over pioneering creativity. Some will say that computers "came of age" with the CPC, Card Programmed Calculator; it was the first to be widely used by engineers. The credit for development is shared by IBM and Northrop Corporation. A true pioneer, Northrop farsightedly formed a digital computer group in 1946, and ordered the BINAC machine from Eckert and Mauchley the following year. Other aircraft companies were also *avant-garde* in the stampede toward data processing.

The beginning of the electronic computer industry dates from UNIVAC. The first machine was delivered to the Bureau of the Census early in 1951, the second to the Air Force later that year, and the third in 1952 to the Army Map Service. (The government got these first machines at a bargain price—about $250,000. Later models sold for about $1.5 million.) General Electric Company initiated the business use of UNIVAC machines, followed by Metropolitan Life Insurance Company. Despite these major sales, there was no widespread conviction that a real market for computers existed.

A few smaller groups, with more faith than financing, endeavored to get a foothold in the future. Though they fell by the wayside, perhaps it was their rustlings that prompted IBM to investigate further. Still playing it safe, the company approached the defense contractors and proposed a machine called the Defense Calculator—subsequently designated IBM-701. IBM decided that if they could secure 13 firm contracts, they would produce the machine. They exceeded their goal, for they got contracts to build 19 machines. With that, a great leap was taken in the industrial use of computers. Further, it generated momentum within IBM. The first IBM-701 was delivered in the spring of 1953. A year later, they brought out a computer suitable for either scientific or business use that became the "workhorse" of industry, the IBM-650; nearly 2000 of these machines were eventually produced.

As technological advances were made, the need for interchange of information became more imperative. As an outgrowth of a meeting at the Harvard Computation Laboratory in 1947, the Association for Computing Machinery was formed.

But of all these gatherings, none had more far-reaching implications than a meeting late in 1954 of a group of Southern California users of IBM-701's. The meeting came about largely through the efforts of R. Blair Smith, IBM; he perceived, as did others, that the amount of redundant effort expended on systems and programs for the IBM-701 had been horrendous—usually in excess of a year's rental for the machine. Jack Strong and Frank Wagner, both with North American Aviation, Inc., at that time, suggested a cooperative effort be undertaken toward devising a better coding system for the IBM-701's.

PACT, the coding system they subsequently devised, was little used, because at just about that same time IBM brought out a computer language known as SPEEDCODE. But the spirit of this joint effort of the IBM-701 users ripened into one of the most unusual features of the entire computer picture, *cooperative user groups.*

George Bynum, Corporate Director of Data Processing, North American Aviation, Inc., vividly recalls the early struggles. He says the inspiration for user groups can be summed up in one word: "Desperation. At that time, everyone had a high degree of ignorance about use of computers. We wanted company in our misery."

SHARE, the first of the groups, was made up of those who acquired IBM-704's. The aim of the organization, quite simply, was to try to eliminate redundant effort among its members with regard to use of the computers.

The user groups have been a remarkable effort, for seldom, if ever, has there been demonstrated such cooperation between different organizations. The mutual effort for the mutual good proved so effective that each major computer system now has its own user group. They are known by intriguing names such as POOL, GUIDE, USE, DUE, and TUG.

Another major invention ushered in the present era of computers. In 1952, Bell Laboratories announced that three of their scientists had created the transistor, a device with boundless applications. Its benefits to computer design were immediately obvious: The transistor eliminates the vacuum tube, reduces size by an order of magnitude, adds greatly to reliability, and slashes cost. Hardly could more be asked of one tiny device.

The face of history is ever changing. The first business machines had used notched wheels for counting. Wheels gave way to vacuum tubes. Tubes were replaced by transistors. And next, transistors are giving way to . . . . But that is another chapter.

We have reached the point where the present is a bridge across the growing edge of progress leading us from the past to the future.

# 4

## Anatomy of a Computer

A man reads a problem. To solve it, he uses a scratch pad to jot down some figures, and he draws upon his memory for knowledge that applies to the problem. When he has the answer, he writes it out.

A computer does the same thing. Its basic operation may be described in this oversimplified manner, even though in full detail its functioning is a maze of complexity.

Computers come in two different types. The *analog computer* records changes in physical quantities in the machine itself—changes in electrical impulses or changes in temperature, for example. These physical changes are expressed in the form of a graph, which is mathematically analyzed. Thus the analog computer is built as an analogy (physical likeness) of the type of problem that it is designed to solve. A thermometer is a simple analog computer. The liquid in the tube rises or falls in response to a physical change, which is read on a scale. The *digital computer* directly solves a problem, and its solutions are read out in numbers. Human hands are simple digital computers; problems can be solved by counting fingers. More complicated digital computers operate by means of switching circuits, which can remain either *on* or *off* indefinitely. A circuit that is on might represent the digit "one"; a circuit that is off might represent a "zero." Any problem or symbol (numbers, letters) that is to be handled by the computer can be translated into various combinations of the two.

Analog computers, because they are designed to handle one type of problem (a thermometer can measure only temperature), are limited in their use. Digital computers are more adaptable and economical, and constitute the majority of computers now in use.

## Input:
## The Eyes and Ears of Digital Computers

*Punched cards* were one of the first means of getting information into a computer, and this method is still one of the most popular. Information may be put onto the cards by means of binary code or Hollerith Code (illustrated on page 78). The card is divided into 12 horizontal and 80 vertical rows. The number 7, for instance, is indicated by a hole in the horizontal row of 7's. But a hole in this row combined with a hole in the top row indicates the 7th letter of the alphabet.

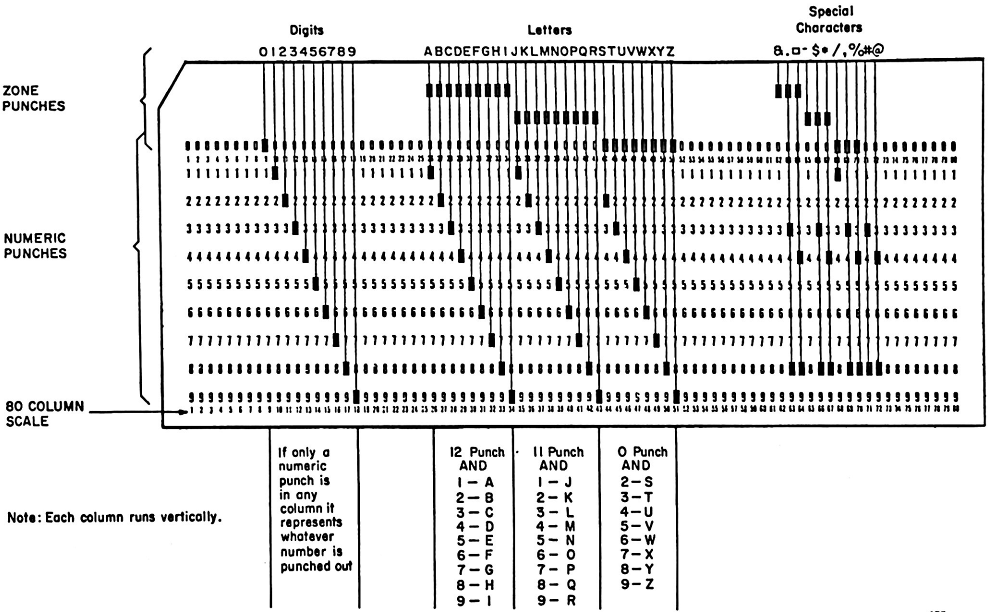
Cards are prepared on a key punch machine, similar to a typewriter, into which cards are automatically fed. Since it is important that there be no mistakes in this first step, the cards prepared by the key punch operators are usually checked by a second operator using a verifier. This machine looks like a key punch, except that it does not punch. Instead it reads; if what is read does not agree with the key that is depressed, a red light indicates an error.

*Mark-sensing* is another type of operation that has advantages. In reading public utility meters, for instance, a card may be marked with a pencil, then later the cards can be fed into special equipment where they will be punched in accordance with the marking.

Once the decks of cards are punched and verified, they are moved to the computer. As they are automatically fed in at rates up to 2000 cards per minute, the computer "reads" the information by passing the cards under a set of metal brushes; electrical contact is made at each place a hole appears on the card.

Punched cards have several advantages: The stock is cheap, and cards can be sorted and handled easily. They can be used as bills, and records thereby can be kept easily. Punched cards can be read with the human eye, whereas magnetic marking on tape is invisible.

But there are, also, disadvantages to punched cards: The input is relatively slow. The cards are sensitive to environmental conditions, for they warp easily. They can be mutilated




*(Honeywell)*

Fig. 4-1. The Hollerith card.

easily; a capricious or disgruntled bill-payer used to have it in his power to upset the most efficient operation of a big company by the dexterous cutting of a few additional holes in his card. But the designers of input equipment have outwitted such shenanigans by inventing the Honeywell *Orthoscanner*. This device, using the orthocorrection process, can regenerate and read material, even though as much as 25 percent of it is destroyed.

Perforated *paper tape* was another early input method that is still being used. As with punched cards, the holes are the means of conveying information to the computer. Paper tapes may be created directly or they may be created as a by-product during the preparation of material by means of a special attachment to a typewritter and thereby eliminate a second operation. Paper tapes provide a simple means of communication for data transmission via telephone, telegraph, or mail. They provide a good basic means of very low cost input to scientific-type computers. But the use of tapes makes for a slower method than do cards, because there is a maximum input of 500 characters per second. There are other drawbacks to using paper tape; it is difficult to correct mistakes or to insert additional items, and paper tape is very vulnerable to destruction (Fig. 4-2).

*Magnetic tape* has become practically a household item through the widespread use of portable tape recorders. It is the most extensively used input to computers because of several striking advantages: It is the fastest of all methods, with speeds as high as 40,800,000 characters per minute in IBM's hypertape machine. It requires a minimum of storage space—one reel may equal the information contained on one or two million punched cards.

The *electric typewriter keyboard* provides a means of direct input into the computer.

*Magnetic character reading* is one of a new class of input methods. This process is used almost exclusively in the handling of banking and financial data. The odd-shaped MICR characters that appear at the bottom of checks are magnetized prior to reading by the machine. An obvious advantage is

Fig. 4-2. Paper tape, an input method still being used, is being hreaded through a reader punch unit.

.hat these characters can be read either by men or machines (Fig. 4-3).

*Optical character readers* were developed concurrently with the MICR equipment. Scanning equipment of this type reads data as does the human eye, except at far greater speeds. The first equipment to appear for this special purpose interpreted printed numerals and a few special symbols; the development then advanced to encompass recognition of the entire alphabet.

The optical scanner reads a printed line and converts each character into an electronic signal that identifies it. The reading is performed by means of a mobile scanning mirror. Speeds attained are about 400 characters per second.

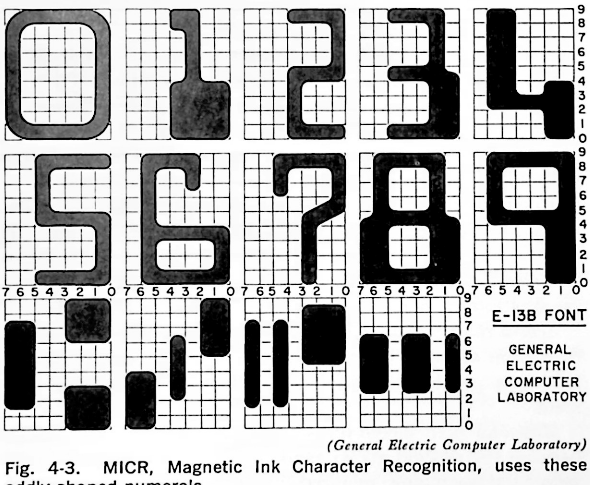
This is a most advantageous method of input, since it uses ordinary paper, can be read by the human eye, and the format is more concise than the coding of punched cards. The real scope of optical scanning is just beginning to unfold, as noted in Chapter 8.

*Audio readers* constitute the next big hope of computer designers. The machines truly will have gained "ears" when they can receive their data by means of the spoken word. IBM has developed a tiny unit, Shoebox, that has limited recognition; if any number from 0 through 9 is spoken into its microphone, the unit responds by lighting up that number. Shoebox proves the theory of voice recognition, but this is a small beginning toward full comprehension of spoken instructions. To develop the system to the point that it will be able to recognize the many different speech characteristics, dialects, and slurred pronunciation will be a truly magnitudinous task.

## Central Processing Unit: The Brains of the Digital Computer

All that the computer sees or hears (the *input*) first goes into the *storage* portion of the *Central Processing Unit.*

But just as a man would not know what to do with information if his mind were a blank, the computer has to have prior education in order to know what to do with the data. It is




*(General Electric Computer Laboratory)*

Fig. 4-3. MICR, Magnetic Ink Character Recognition, uses these oddly shaped numerals.

given two kinds of information: (1) a *program*, which consists of specific instructions regarding the disposition of particular data; and (2) data to tell what the instructions are going to do it with.

A computer is part genius, part idiot. The program has to tell it in greatest detail exactly what it is to do. It cannot "think," except to choose between several alternatives. For instance, it can make "less than" comparisons, whereby it will not credit an employee with any overtime if he has worked *less than* 40 hours.

In addition to the stored program that each user puts into storage, the computer contains (through its control circuitry) the ability to program each of its basic instructions.

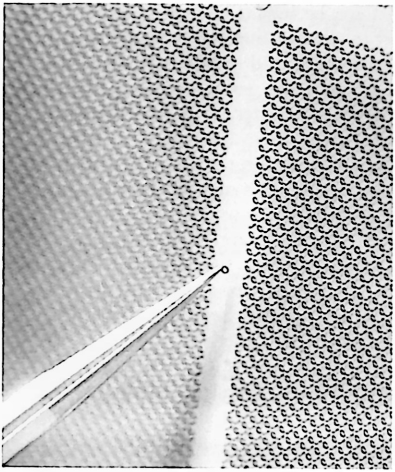
Each of the operations is identified by a number, known as an *address*, so that the program may call for one of these functions from the stored program merely by specifying the address where it is located in the memory. Every piece of data in the memory is stored at a certain address, and the address must be specified in order to get that piece of data out of storage.

The storage capacity is the feature that most distinguishes a computer from other data processing machines. There is *primary storage* which is fast, but expensive and limited; this is, in almost all machines, magnetic core type. There is, also, *secondary storage,* which is slower, cheaper, and more extensive; this is usually one of three types—drum, disc, or tape.

*Magnetic tape* is a low-cost means of storing large quantities of information. It has the disadvantage that a tape-reading device must scan the encoded electronic signals, character by character, over a reel 2400 feet long in order to find a desired piece of information.

*Access time* is the length of time that is required to obtain data from storage. The speed with which the computer can process a problem is largely dependent upon this time element.

*Magnetic core* memories were an important development because the method allows random access, as opposed to the sequential searching required by magnetic tape memories,



*(International Business Machines Corp.)*

Fig. 4-4. A single memory core is being assembled into a form ready to be wired. The computer senses binary digits (a "0" or "1") by the direction of the magnetic orientation in each core.

and thereby reduces the access time. The individual magnetic cores, some of which are as small as the head of a pin, are doughnut shaped, and made of ferro-magnetic materials (Fig. 4-4). The cores are strung like beads on 4 wires into frames, which are called planes; the planes are arrayed into stacks (Figs. 4-5 and 4-6).

Each core can be magnetized in either a clockwise or counterclockwise direction, signifying a "bit" or "no bit" condition. An example of the speed of access that can be gained with magnetic core memories is the RCA-3301 REALCOM which operates at 250-billionths of a second. One disadvantage to this type of memory system is that the reading of the information changes the condition of the core, and it must be restored by regeneration after reading; the process of reading and restoring is called the "memory cycle."

*Magnetic drums* make up a storage method that is cheap, compared with magnetic cores, but has the disadvantage of having comparatively slow access time. The drums rotate at speeds of over one thousand revolutions per minute, and information is taken from them by means of read heads (Fig. 4-7). Similar heads also write—that is, implant the information onto the drums as magnetic spots placed in bands or channels.

*Magnetic discs* operate on the same general method. As an example of performance, the computer for the advanced Minuteman missile uses magnetic discs that rotate in excess of 8000 revolutions per minute. Both the discs and drums are relatively expensive when compared with magnetic tape.

*Magnetic cards* are not as fast as drums or discs, but provide greatly increased capacity at about 1/10th the cost of drums and 1/30th the cost of discs.

*Woven screen memories* are another example of the ferromagnetic principle; they have recently been developed by The Bunker-Ramo Corporation. In this method, a two-dimensional array of wire is woven on looms controlled by the flexible warp selection developed by Jacquard—a name found in early computer history. After weaving, the screen is plated with a magnetic material. The aim in this development has

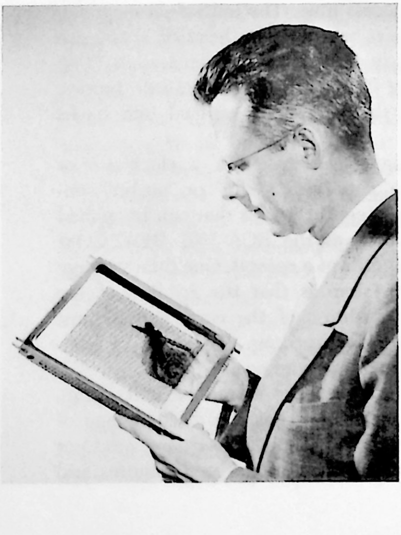


Fig. 4-5. Dr. Jay W. Forrester examines his invention, the magnetic core memory.

been to turn out a rugged, inexpensive, and easy-to-produce memory.

The *control unit* is the part of the computer that executes the instructions given in the program (explained in the following chapter). The execution cycle begins with the transfer of data from storage to the control unit. This unit, in turn, sends the data to the *processing unit,* also called the *arithmetic unit,* where there are performed the arithmetic functions of addition, subtraction, multiplication, division, and comparison of numbers; complex calculations are only combinations of these basic functions. When the processing has been completed, the data is returned via the control unit to storage or is sent directly to *output* where it is written out.

Output constitutes the finished results, and may be given in any of several forms, such as the already discussed *punched cards, punched paper tape,* or *magnetic tape.* There are other forms that are exclusive to the output function, such as plotters, cathode ray tube display, and the *high-speed printer.* The latter might be regarded as the capability that has become a curse, in many instances. Some users who have been inclined to make maximum use of its voluminous capacity have

*(International Business Machines Corp.)*

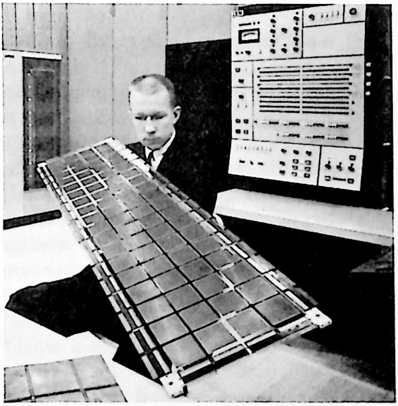


Fig. 4-6. The single large memory plane shown here can store 32,768 characters.

Fig. 4-7. Magnetic drum memory—capable of holding 100,000 bits of information on its surface.

found themselves veritably deluged with data. Some nontechnical people, on first being exposed to the performance of the high-speed printer, have actually believed that the machine was running wild!

*Peripheral equipment* is the term used to describe both the input and output equipment—it is peripheral to the central processor, which includes storage, the control unit, the arithmetic unit, and the *console.* Though the console is outside the central processor, it is considered to be a part of it. The console is a device, operated by means of a keyboard, by which the operator can communicate with the central processor; it allows him to monitor the processing by means of indicator lights and to maintain manual control over the operation of the system during processing.

As a kind of "topper" to the situation of the man monitoring the machine, there is now a machine to watch the man who watches the machine. The device, called an *Alertor,* is certainly not in general use but is intriguing; it consists of a small box attached to a large floor pad laced with wires. Any slight movement on the pad keeps the box content; but should there be no motion from the operator during a suspicious interval of time, the Alertor concludes he is either inattentive or napping and sounds an alarm.

*Turn-around time* is the elapsed period from the time that the machine run is given to the computer center until the completion of the output. Two factors influence the length of the turn-around time—the efficiency with which the program was prepared, and the operating speed of the machine.

# 5

## Manufacturers

Anyone can manufacture computers. It is a game that can be played by complying with four simple rules:

(1) Have a million dollars with which to begin the company, and have more millions ready to sustain the company until the pay-off begins. (2) Have a "star cast." Computer buyers resemble moviegoers—they want "names" in top positions. (3) Have "know-how" so that you can start building today what customers are going to want about three years from now. The lead time that is necessary to produce a machine requires a long and accurate look into the future. (4) Have the next machine on the horizon. No one wants to buy an "orphan." Unless a customer is assured that the company is planning a future machine, he won't consider buying the current model. (An analogy to this has been clearly seen in the automobile business. When the Ford Company announced they were stopping manufacture of the Edsel, the value of that car drastically dropped—despite assurances that parts and services would be available.)

The computer companies that have failed—and there have been many—have tried to shortcut one or another of these rules. Currently, there is a strong trend toward consolidation. The 26 companies of today will likely be 5 giant corporations in the years ahead. One aspect of the present scene is unlikely to change, however, and that is the strong competition that exists between companies. They divide roughly into two groups: (1) Those that were manufacturers of scientific equipment, such as GE, RCA, and Honeywell, and (2) those that evolved from the manufacturing of old-line business machines into computers, such as Remington-Rand, Burroughs, and IBM.

No attempt will be made to tell the story of each important computer manufacturer. The stories that are told are of representative companies that produce machines for varying applications.

## International Business Machines

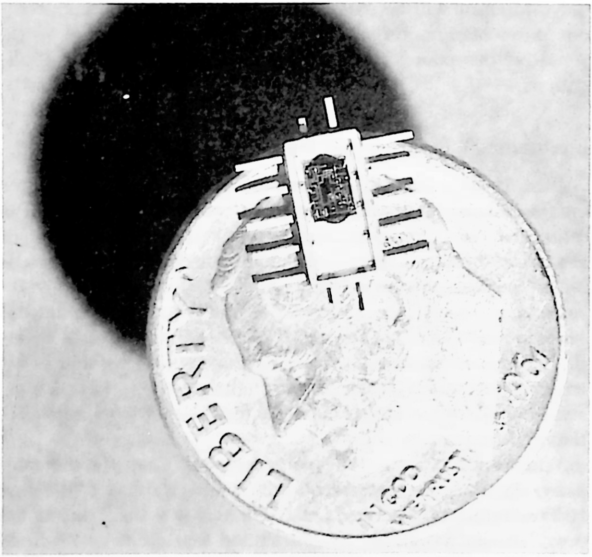
IBM is the giant that dominates the field. Actual figures on the number of installations are a company secret, but it is estimated that this organization has cornered 80 percent of the market. IBM's annual revenue is about $2.8 billion, according to *Business Week* magazine.

Perhaps one of the strongest elements in the phenomenal growth has been a policy established by the first IBM President, Thomas Watson, Sr. He took the engineering staff of his company to sales conventions so that they would have understanding of the problems and requirements of the machines they were creating.

Watson was true to the motto he established for the company, "Think." In the early 1930's, he established the first IBM school in Endicott, N. Y. Now this is a vast educational program that is offered in 159 United States cities, and in 43 foreign countries. People with varied interests attended these classes: salesmen gained basic knowledge about the equipment, customer engineers learned how to service the machines, and customers were instructed in the use of computers. Thomas Watson, Jr., who now heads the company, emulates his father's view. He says, "There is no saturation point in education."

One of the most productive segments of IBM is its Federal Systems Division at Rockville, Maryland. The activities are directed toward problem-solving for space and defense needs, with special emphasis on systems management and development, communication systems, space guidance, and command control. This organization has a total systems capability for all phases of the information-decision cycle.

It is by no means in this elaborate application of the largest equipment that IBM has specialized. Great attention also has



(Autonetics)

Fig. 5-1. Integrated circuits, such as this one, go into computers produced by Autonetics. The tiny black spot is the working component of the circuit.

been given to low-cost computers for wholesale and retail companies, secondary schools, and manufacturers. The 5 or 6 families of computers that previously have fulfilled the variety of needs have ranged from the small-scale IBM-1440 ($1500 per month rental and up), and the IBM-1401, the most popular computer ever built ($2475 per month rental and up), to the powerful IBM-7094 II ($76,000 per month rental).

But a startling announcement was made by IBM in April, 1964. The company has taken a "billion dollar gamble" and brought out IBM-System/360. During the 3-year developmental period, the industry buzzed with rumors that IBM was planning to bring out some new equipment. But the industry was stunned when IBM introduced machines that will replace their entire previous computer line.

System/360 presents more than 300 separate catalog items, and the equipment can be arranged in widest variety—from a "card whalloper" ($2700 per month rental), all the way to a system several times as powerful as any prior IBM machine ($115,000 per month rental). The large configurations have a primary storage capacity of 8 million characters; the capacity can be expanded to hundreds of millions of characters. Moreover, a system can start small and grow big as needs increase, since these computers can use interchangeable sets of programs. Another notable feature is that System/360 is adaptable to business, scientific, or process control work.

System/360 is the first commercially available line of equipment with a design based on microelectronic hybrid integrated circuits. These advanced devices previously have been used in equipment for the government, as described in the section on Autonetics, a division of North American Aviation, Inc. (Fig. 5-1).

The impact of IBM's new line upon the industry, obviously, has been great and will no doubt serve as a strong impetus to competitors. Furthermore, IBM is not resting upon any plateau of advancement. With typical resourcefulness and courage, they are continuing important research. For instance, the company already has been successful in transmitting audio information signals over a light beam generated by an injection *laser;* this method achieves operating speeds in excess of those attainable by sending signals over wires.

## UNIVAC Division of Sperry Rand Corporation

The biggest order ever written for computers was signed by the Air Force for more than one hundred miniaturized solid-state UNIVAC 1050-II machines! The sizable order came as a result of DOD's efforts to standardize computer systems and to bring increased efficiency to the base supply system.

UNIVAC has traveled a long and frequently bumpy road since Dr. John Mauchley and Dr. J. Presper Eckert completed the first UNIVAC for the Bureau of the Census in 1950. The fame of the UNIVAC machine spread nationwide when it predicted the outcome of the presidential elections of 1952.

UNIVAC computers also became television "stars" by tackling such posers as the selection of proper mates for participants on the Art Linkletter show, and by the simple but effective sorting of cards on several quiz shows. At that time UNIVAC had the undisputed lead in commercial computer activity. Then IBM started a powerful climb that took the company to the top position.

UNIVAC produces a varied line of equipment. The LARC, a large-scale solid-state machine built in the late 1950's for the Lawrence Radiation Laboratory in Livermore California, provided the design for the powerful UNIVAC III—a machine possessing a magnetic tape transfer rate of 200,000 digits per second.

In 1960, the UNIVAC-490 appeared—the first business-oriented real-time computer; Bethlehem Steel uses this machine for order entry, production control, inventories, order status, and related order procedures. The same year produced the UNIVAC-1107, the first scientific computer to use a thin-film memory.

The UNIVAC-1004 desk size, high-speed card tabulator has been a particularly popular machine for use by small businesses. *Datamation* magazine termed the 1004 "their hottest number since the cordless razor."

Dr. J. Presper Eckert, now Vice-President of Sperry Rand, comments, "The first computer that John Mauchley and I built, the ENIAC, weighed 30 tons and could perform 5000 additions per second. The UNIVAC-1824 weighs 17 pounds and can perform 125,000 additions per second. In the laboratory, we are now working on circuitry that will allow about fifty million additions per second."

UNIVAC has long experience, and has an investment in equipment amounting to hundreds of millions of dollars. Its move to a new building symbolizes to the Division's President, Dr. Louis T. Rader, a spirit of renewal and growth that permeates all levels: "The one-time benefit of surprise by invention has given way to planning and timing."

## General Electric

"Progress is our most important product," says GE. This is well demonstrated by the computers that number among the 200,000 products this mammoth company manufactures for the home, industry, and defense.

GE's greatest asset toward the successful building of computers is experience—10 million man-hours not only in building but in using the machines. GE, the first commercial company to use computers, presently has an array of 185 machines. Obviously, this gives them tremendous familiarity with the application aspect; greatest concentration has been made upon industrial-type utilization.

Although GE manufactured a dc calculating board in 1920, and produced differential analyzers and control for firing systems during World War II, its first real entry into the field of computer manufacture occurred in 1956 with the formation of the Industrial Computer Department in Phoenix, Arizona. ERMA, the banking system, was GE's first project. This required 3 years to develop and produce. About 45 ERMA systems and 65 modified GE-210 computers have been sold to banks and financial institutions.

Two of the company's lines, the GE-200's and the GE-400's, are known as "The Compatibles," since the machines can interchange programs and peripheral equipment. Another major line is the DATANET. One model of this can be used for production control, another is a data collection system for transmitting data from a remote station to a central point, and another permits an operator to dial and send perforated-tape data over a phone line.

For the user who does not have his own equipment, GE has established 6 Information Processing Centers across the country—in Phoenix, Dallas, Schenectady, Chicago, Washington, and New York City.

Computer companies are always eager to find more effective utilization of their equipment to justify the sizable expenditure. GE's Manager of Special System Sales, Clint DeGabrielle, projects the trend toward 24-hour use of equipment. A single computer may handle process control functions during the day at a manufacturing plant, then do business data processing at night.

Despite the strides that GE has made since 1956, the Computer Department still is not operating at a profit. Comments the Company's Chairman, Ralph J. Cordiner, "We have not encouraged our associates to set an early target date that they have to maintain on making an annual profit."[11] Nearly 90 percent of the GE machines are on a rental basis—a factor that delays reaching the profit-point.

GE has ambitiously set its sights on the worldwide market. A substantial overseas sales operation has been launched and there exists the basic corporate strength and resources to follow the pattern of their domestic success.

## Radio Corporation of America

Brigidier General David Sarnoff is a determined man. He decided to bring about widespread acceptance of color television. With 13 years of work and an investment of $130 million, he did it. In 1958, he determined that RCA should become the Number 2 company in computer manufacturing. In efforts to accomplish this goal, the company expended a staggering $150 million. Profits started accruing 6 months ahead of the target date, as announced at the annual stockholders' meeting in May 1964.

The company was lured into the field when, in conducting business matters with the Department of Defense, RCA representatives noted great activity either centering around or depending on the work of a computer. So, in a "let's not fight them, but join them" attitude, RCA decided the best way to maintain their yearly increase in volume of business was to begin building major computers. It even made for a lyrical slogan when added to their traditional output: "The

(General Electric Computer Laboratory)

Fig. 5-2. Wire wrapping of computer modules at General Electric.

three C's, computers, controls and communication—the triumverate of automation."

The entire corporate philosophy of RCA was appropriately geared to this step, for it has been heavily oriented toward electronics. RCA produces more than 90 percent of the electronic components that are incorporated into their own computers (a record not equaled by any other computer manufacturer). Furthermore, RCA actually had been dabbling in computer activity for years, having developed flight and fire controls for fighters and bombers during World War II, manufactured such components as magnetic core memories for IBM, and built the gigantic vacuum tube computer, BIZMAC I, for the Army in 1955. But such efforts were no more than teasers to the big show of designing, engineering, manufacturing, and selling complete commercial computer systems.

The initial product of this concentrated effort was the medium sized computer, the RCA-501, which met with great success. This machine was the field's first fully transistorized business computer, and after a sale to New York Life Insurance Co., June, 1959, RCA garnered 91 other contracts for rental of the màchine; the only comparable business computer that tops the record is the IBM-7070. Riding high on this success, the smaller RCA-301 made its debut.

At this point, the company believed they had sufficient grounding and preparation for a real leap, so the complex RCA-601 was announced. This ultra-fast machine would handle both data processing and scientific problems, it was planned. But engineering problems arose. Delays on the new machine aroused skepticism within the industry, but RCA quelled it by finally delivering the first RCA-601 to the New Jersey Bell Telephone Company in October, 1962, a year behind schedule.

The corporation phased out its industrial control machine, the RCA-110, in awareness that troubles with the 601 had sprung from making a frontal assault on the entire market. With a change in strategy, General Sarnoff is now aiming at selective markets with the precision of rifle fire, instead of the broadside blast of a shotgun. RCA's biggest contract to date, consisting of 34 RCA-301 installations, has been with the Air Force Logistics Command.

In August, 1963, the announcement was made of the RCA-3301 REALCOM—so named because it operates at real-time. This computer has the capability to keep up with incoming data from such operations as rocket firings, since it operates at speeds measured in cycles of 250 *nanoseconds* (a nanosecond is one-billionth of a second). The computer can provide data communications and scientific computation.

RCA manages to combine diverse achievements in impressive ways; one such was the demonstration of computer capability made by means of Relay, the communications satellite built for NASA. The experiment, performed for the American Newspapers Association, started with the punching of a teletype tape of a news story in Chicago; it was transmitted over standard teletype lines to Camden, New Jersey, where the copy was fed into the RCA-301 computer. The machine justified and hyphenated the copy into lines of proper width for newspaper columns. From the computer, the signal went to Nutley, New Jersey, where a transmitter beamed it to the orbiting Relay satellite. After amplifying the message, Relay aimed it back to earth at Goonhilly Downs, England. Via standard teletype lines, the story was transmitted to three newspapers—*Manchester Guardian, Edinburgh Scotsman,* and *London Times.* At each office, the signal produced a tape, the tape was placed on an automatic linecasting machine, and the story was set in hot type ready for the newspaper forms. The elapsed time for this involved procedure was less than two minutes! RCA is indeed making a strong pitch for the spot as Number 2 computer manufacturer.

### Honeywell

Eight years of determined effort and $95 million have been funneled into Honeywell's pitch for a top position in the field of electronic data processing. This company pioneered the use of automatic heating in American homes with its thermostat-regulators; it has been a powerful factor in bringing automation into offices by featuring a medium-sized line of equipment. These units have the common feature of electronics, as have half of Honeywell's other 1300 products that range from burglar- and fire-alarm systems to space vehicle controls.

Honeywell's EDP (Electronic Data Processing) Division had its inception in 1955. It was originally founded jointly with the Raytheon Corporation; then Honeywell bought out its partner. The EDP Division retained from Raytheon a nucleus of top-flight scientists who had contributed to such early important machines as Harvard's series of Mark computers.

The first model produced was the Datamatic-1000, a vacuum tube computer. The first solid-state machine produced by the company appeared in 1959—the Honeywell-800; it combined great power and parallel processing ability, yet it had many economy features. This computer has gone into diverse applications for such organizations as the Metropolitan Life Insurance Company, Southern California Edison Co., U.S. Navy Polaris Training Center, and Chrysler Corp.

The next Honeywell machine was the 400, which was so moderately priced that it could fit into the needs of two-thirds of the top companies in the U.S. Another, termed "the welter-weight champion of the computing world," is the 1400, which has an internal speed of 14,000 additions per second, and which can read, compute, and print simultaneously.

The Honeywell-300 system, announced in May, 1964, is low in monthly rental—$2200—yet has speeds and capabilities that match all but the largest systems: 1.75-microsecond memory cycle and, also, a memory expandable to 131,072 characters. Honeywell recently rounded out its line with the large-scale 1800 series of computers, appropriate for either business or scientific applications; these machines rent for monthly fees ranging from $8000 to $60,000.

The policy of the company maintains that the job isn't finished until its equipment is in intelligent use. Toward that end, there has been established a vigorous educational program that provides customer training, in-service training, and field service training. For the latter category, Honeywell actively recruits personnel from technical schools, then provides them with concentrated courses on the servicing of the company's equipment.

Hard-hitting Walter W. Finke, President of the EDP Division, realizes that these are still formative years for electronic data processing, and that it is imperative for companies to give keen attention to research and development. This attitude has made Honeywell a leader in the field of high-speed thin-film memory devices, as well as in advanced methods of optical scanning.

## Control Data Corporation

Americans, inherently, are success-lovers. The spunk and courage of the immigrant boy who became a tycoon is a tale deeply rooted in our lore.

Control Data Corporation, CDC, is the computer industry's most exciting success story. It came into being in 1957. As a

"David" standing up against the giant company, it did not lunge into business data processing competition, but aimed its slingshot in the oblique direction of scientific and engineering applications. CDC, IBM, and recently RCA, are reported to be the only *major* manufacturers of electronic computers operating at a profit.

CDC's President, William C. Norris, and the founding group had worked together in the Navy during World War II; their projects were among this nation's most important computer developments. At the Navy's urging, they remained as a team post-War and formed Engineering Research Associates. Lacking capital to expand from making special-purpose equipment into commercial production, they sold out to Remington-Rand, Inc. in 1952.

But the group dreamed of again having their own company. This manifested as Control Data Corporation, formed in Minneapolis and financed through the sale of a public stock issue. Since the proposed company had virtually no assets and was entering a field of fierce competition, the Securities Exchange Commission requested a pre-subscription list of people who wanted to buy the stock. The Commission's worry was quite unfounded. CDC's total initial capitalization of $600,000 was supplied by 300 shareholders, and the stock later increased in value 250 times! Says the *New York Times*, "No other issue listed on the New York Stock Exchange can match this phenomenal rise during the same period. It marks one of the most fabulous six-year runs in recent history for any Big Board Stock."[12] In 1963, CDC acquired the computer division of Bendix Corporation for $10 million.

The true strength of CDC, it is said, rests with its personnel—a young group averaging in age from 30 to 35. Engineer Seymour R. Cray assured the company's destiny by designing one of the industry's first solid-state transistorized computers, the CDC-1604. This is a good, compact, and versatile computer; it has the feature of being operable from remote stations. The CDC-1604 is built from 7000 complex printed circuit cards, or "printed building blocks," instead of miles of intricate wiring. Notable, also, is its price: The basic

CDC-1604 computer is priced at $990,000; with peripheral equipment the total cost is about $1.5 million. The IBM-7090, said to be somewhat comparable to and competitive with the CDC-1604, sells for nearly twice that amount. CDC has recently announced a replacement for the 1604—the scientifically-oriented 3400.

When CDC introduced the 3600, a machine with 5 times the performance of the 1604, *Business Week* noted it to be the largest commercially available computer in the world at that time. But the next product of CDC's laboratory, at Chippewa Falls, Wisconsin (which has such touches of nature as a salt lick for deer), is *several times* faster and more powerful than any computer ever built. It is unlike any previous machine, for it is made of 10 independent computers that are connected to a super-fast central computer. Because of this feature, the system can perform 11 sets of instructions synchronously. The speeds are incomprehensible—some of the circuits in the CDC-6600 must switch back and forth 30 million times a second.

The machine was invented by Cray and James E. Thornton—each of whom gives the other most of the credit. The first 6600 is being installed at the AEC's Lawrence Radiation Laboratory in Livermore, California at a cost of $7 million. Believing that machines of this caliber are custom pieces, Cray and his 34-man staff at Chippewa Falls will not turn loose the reins of production until they have personally built the next dozen CDC-6600's.

Mathematicians and physicists can investigate an entire new universe of scientific calculations through the gigantic computational power of the CDC-6600.

## Hughes Aircraft Company

Hughes Aircraft Company is one of the companies that specializes in the sale of computers to the military, as opposed to the commercial market. Hughes has probably built more airborne computers than any other company, because of the six or seven hundred MA-1 fire-control system units that were installed in the F-106 aircraft; this was the first airborne digital computer.

A current project is VATE, Versatile Automatic Test Equipment, that presents a new concept for computer-controlled checkout of complex systems. The overall system consists of equipment, test programs, and trained people.

In the past it was necessary to have PTE, Peculiar Test Equipment, for each requirement; this could not be adapted to the next generation of equipment to be tested. But with VATE, the same equipment can be used simply by redesigning and by adapting the interface that links the computer to the system to be tested.

VATE is designed to test Air Force inertial guidance systems, including those on the F-4C aircraft and the Titan and Minuteman missiles. The latter system is put on a platform, and flying conditions are simulated during test. The operator at the VATE console receives instructions on each step in the testing procedure by means of a 35-millimeter slide viewer.

This concept enables relatively untrained technicians to draw from the computer knowledge and experience of the Ph.D. scientists who designated the system and, thereby, to conduct the test procedure skillfully. The computer-controlled random-access slide viewer forms the upper portion of the operator's console and displays a succession of instructions to the operator. When a fault is detected, an illustration of the malfunction is displayed; as VATE then isolates the fault, the exact location of it is shown.

This is, in many respects, an application of a "teaching machine" approach. Hughes has given it the trade name of Video-Sonics, and first developed it for use within their own factory to instruct unskilled assembly workers to perform very involved tasks; it proved so successful that they marketed the system for use in other factories.

The trend at Hughes, as with several other companies, is toward microminiaturization—the step from discrete (distinct or separate) circuitry into integrated circuitry. In any discrete system, it is possible to see single components; they cannot be distinguished in the integrated circuit systems.

This is an advancement of major proportions in computer technology, for it will accommodate the low-weight and small-size requirements of future space systems, and will further permit the redundancy so essential to guarantee reliability in the deep space voyages.

## Autonetics: A Division of North American Aviation

*Microelectronics!* This is today's magic word in the advancement of computer technology. The technique, also called microminiaturization, has brought about a change of even greater significance than the one that occurred when transistors replaced bulky vacuum tubes.

Several manufacturers—including IBM, Hughes Aircraft Company, Litton Industries, Inc., Sperry Rand Corporation, RCA, Raytheon, Inc., Westinghouse Electric Corporation, Texas Instruments, Inc., and Fairchild Semiconductor Division of Fairchild Camera and Instrument Corporation—have invested over one hundred million dollars in research and development to bring microelectronics to its present status. Autonetics has been a leader in this activity, with efforts dating from the late 1950's.

However vital is the advantage of *reduced size* in these microminiaturized computers, this is not the primary benefit. It is, rather, the tremendous increase in *reliability* that marks microelectronics as such a great achievement. Further advantages are *increased operating speed* due to size reduction, major *reduction in cost*, and *decrease in the power requirements.*

Various techniques are being used in microelectronics—the two-dimensional approach, which is a ceramic printed circuit; the hybrid approach, which combines integrated circuits, thin films, ceramic printed circuits, and discrete components; and the integrated circuit approach. In the latter method, each circuit is a chip of silicon or other semiconductor material; it measures about $\frac{5}{1000}$ths of an inch thick and $\frac{1}{16}$th of an inch long. The transistors, resistors, diodes, and other devices are diffused into this chip. Usually, about eighty of these circuits are formed on one silicon wafer, and the individual chips are later cut apart. It is estimated that integrated circuits are hundreds of times more reliable than the same number of components arranged separately in a circuit board.

About ninety percent of the cost of integrated circuits is expended on (1) encasing the tiny chip in a package, and (2) connecting the integrated circuit (by working under a stereo-microscope) with other elements in the computer. The real breakthrough will come when improved techniques for interconnections are developed—perhaps through use of LASER diodes, fiber optics, or photo-transistors. Says Gordon Smith, Autonetics, "We are just on the brink of a major revolution in electronics."

Autonetics has pioneered the use of integrated circuits on a major scale in the shoebox-size D37B computer built for the Minuteman missile. Prior to flight, the computer accepts instructions from ground equipment, makes checks, controls the countdown, and transmits the signal to launch.

While Minuteman is in flight, the computer accepts information from the inertial guidance platform, and determines almost instantaneously the missile's position along its planned trajectory; commands are transmitted to the flight control units to keep the missile on the proper path.

VERDAN, one of the early military computers, is the brain of the guidance and control system of the Hound Dog, one of SAC's major retaliatory weapons. Over 2000 VERDANS have been produced—more than any other model computer.

MONICA is another of Autonetics' microminiaturized computers; one version measures only 0.15 cubic foot in size. It is designed for use in inertial guidance and flight control for intercontinental ballistic missiles, underseas navigation, and automatic checkout for missiles and space vehicles. MONICA operates from an internally stored program, and has an instruction list of 75 commands; it performs addition in 6 to 12 microseconds. This computer is expected to operate with such reliability that it will average 2 years between failures. This reliability record would be comparable with 500 television sets operating full-time for 2 years without the picture even so much as rolling.

Though present achievements in microminiaturization are astounding, Autonetics researchers are continuing the effort. They are endeavoring to best the skill of the engraver who etched the Lord's Prayer on the head of a pin—they are working toward writing complete circuits into blocks of material smaller than the point of a pin!

## Problems and Bottlenecks

"People constitute the biggest problem. This is because they are faced with a situation that is new to our society—a technology that progresses at a pace that is quite fast when compared with the life span of man. A man used to be able to accumulate years of experience, rise in position in his company, and do a very good job of management based on that experience. But, now, the individual who ceases to educate himself in important advances—including the application of computers—soon becomes inadequate to the job," says Paul Armer, The RAND Corporation.

Dr. Robert Rector, Aerospace Corporation, echoes the same general thought. "The equipment has progressed faster than the people."

Another variation of the "people" theme comes from Robert Albrecht, Control Data Corporation, "Our biggest problem is education—showing the general public what computers really are, what they really can and can't do. If we can correct the weird misconception about the computer being a 'giant brain,' we can remove a lot of the superstition and fear that some day the world will be run by automation."

In another vein, Dr. J. C. R. Licklider, Advanced Research Projects Agency, says, "There are many people who feel that the limiting factor in most uses of computers is not the hardware, not even the software, but it is formulating clearly what one is trying to do. However, I feel this can be overcome providing one has a sufficiently powerful facility, and can talk to that machine in something like ordinary language—not a highly constrained, problem-oriented language, but ordinary English language."

One of the most vital areas of current research is concerned with this problem.

## Technical Trends

In the future, manufacturers will not supply computers, but entire *data processing systems;* the computer may be the least expensive element in the complex. Lockheed Aircraft Corporation is a forerunner in this type of operation, having about five hundred RCA data collection units. Here is one example of the manner in which a unit operates: when a man at a given station has finished his particular work on a wing section, he drops his badge into a slot; a punch card identifies the work he performed and the time spent on it. The information is automatically relayed by telephone lines to the Sunnyvale plant where an RCA-301 computer records it; at the end of the day, a report is produced indicating the wing's status.

*Modularity,* the ability to buy separate modules piecemeal and fit them together, is the systems approach suited to the smaller business. As the need dictates, pieces of equipment can be added or replaced until a complete system evolves.

*Cryogenics* is a relatively recent technology that may have a potential in computer switching units and memories. It is based on a physical phenomenon discovered many years ago that certain metals lose their resistance completely at extremely low temperatures—temperatures ranging down to near absolute zero, which is minus 459 degrees Fahrenheit.

Dr. John S. Davis, The Bunker-Ramo Corporation, says, "Using cryogenic techniques, one could, essentially, build what is commonly referred to as a 'perpetual' machine of some type. At room temperature, materials have electrical resistance; if current is applied to a wire, for example, this energy is dissipated in terms of heat because the wire has resistance. However, a wire at very low temperature essentially has no resistance; therefore, if a pulse of current is put into this wire, the current would circulate indefinitely."

LASERS, the invention with seemingly endless applications, will enter the world of computers in an estimated five years. LASER action will take place using optical fibers as the active transmission lines. This optical transmission technique could raise the speed of operation to rates measured in gigacycles—billions of cycles—per second.

A signal cannot be sent farther than one foot in one-billionth of a second. Since the speed that electrical impulses travel cannot be increased beyond that, the only way to achieve faster operation is to reduce the size of the computer, hence reduce the distance that the signals must travel. But solutions only beget other problems, as Howard Campaigne, Department of Defense, points out: "If we picture a machine with a 35-nanosecond memory, logical units of comparable speeds, and as complex as most computers are today, then it will be able to do a man-year of work each second. How will we plan such work?"[13]

*Memories*, faster, larger, and cheaper ones, have been the object of consistent and concerted efforts by manufacturers. Laminated ferrite memories, which will easily adapt to integrated semiconductor circuits, are among the promising developments. Efforts in this field also include such esoteric research as that of Dr. Marcel Vogel, IBM, to find a chemical memory. He is experimenting with the action that occurs when cholesterol acetate cools and forms crystals; since cholesterol is found in the brain, he speculates that this may be the storage material of memory in the human mind.

But improvement of present concepts will not suffice. For military utilization, particularly, current needs demand complete reorientation of computer design, programming, and operation. How can there be designed a computer that can perform any task which may be proposed? Dr. Burton R. Wolin, System Development Corporation, points out, "There are problems that people are good at solving that computers can't handle, such as the problem of hierarchy, on which Dr. Sydney C. Rome and I have been working for 13 years. This is the problem of putting together detailed items, and emerging with an aggregate form that is different from the parts, for it includes interaction factors. For instance, an enumeration of all the colors in a painting doesn't describe the painting, for it is an entity.

"So we must learn how people solve problems and make decisions (there's basically little known about it), and from that ask if it is possible to construct a better model for a computer than the one we now have. There are many logics available, yet the only one that has ever been used in computers is Boolean logic."

The worlds of exploration that exist within the research laboratory are truly endless.

## Tomorrow's Computers

There is a theory propounded by Dr. Warren Weaver that an increase in an ability by factors of 10 to 100 constitute a *new kind* of ability. Where are computers with this new kind of ability needed?

Dr. James A. Ward, Office of Electronics in the Department of Defense, specifies, "They are needed in jobs where the state of the art in software is lagging, such as numerical analysis and higher order compiler languages. . . . there is a large variety of very important classes of problems for which there is no foreseeable solution except for faster hardware."[14]

The ultimate in speed of computer operation, in accordance with Einstein's Theory of Relativity, is limited to the speed of light—186,000 miles per second. The way in which inventive designers are circumventing this barrier of speed is to create smaller (microminiaturized) computers—hence, the shorter distances over which the signal must travel allows faster operation.

Even this cannot be regarded as the final point in development. What route will designers explore in order to expand the concepts? The computer has not altered basically since Babbage's concept; the addition of electronics did not change the logical structure, but merely made the operation more efficient. When the upper limits are reached in electronic capability, is the next move toward a radically new approach?

While some people contend the analogy is a forced one, the comparison continues to be drawn between the computer and the human brain—a concept first expressed by Dr. John von Neumann. He pointed out, ". . . the natural componentry favors automata with more, but slower, organs, while the artificial one favors the reverse arrangement of fewer, but faster, organs."[15]

A remarkable device, the Perceptron, has been developed by Dr. F. Rosenblatt at Cornell University. As opposed to the ordinary computer, that never "learns" but must be reprogrammed for each new problem, the Perceptron is an electronic invention that demonstrates learning capability. It has been "taught" to recognize the letter A, written in many different forms.

This suggests that it may be possible to combine the striking advantages of the human brain with the peculiar features of the computer, to create a super-machine quite beyond present imagining. If men have become too restrictive in their channels of thought to create such a device, then they have the computer as a tool to assist. Computers have already designed other computers. In the research laboratories of National Cash Register Co., an NCR-304 designed an entirely new control system for the latest model machine.

While men of theory are thus engaged in visions of the wonders they must produce, their counterparts sitting behind impressive desks in the executive offices are concerned with yet another aspect to the machines of tomorrow: What will be their price tag? To date, Grosch's law, formulated by Dr. H. R. J. Grosch, generally has prevailed for commercial machines: "Economy is as the square root of the speed." (A machine that is four times as fast should cost twice as much.)

Dr. Richard Hamming, Bell Telephone Laboratories, Inc., has pointed out that since the inception of this young computer age, the speed has increased by one million, while the cost per computation has gone down by a factor of at least one thousand. If this similar ratio had prevailed in the automobile manufacturing industry, now we would not pay parking fees, but would merely throw our cars away!

# 6

## Software

The art and science of transforming a computer from an expensive piece of junk into a marvel of productivity is the process called *programming*—a twentieth century witchcraft-like manipulation of symbols and numbers. Within the industry, programming falls into the category of *software*, as opposed to the equipment itself, which is *hardware*.

Several steps are involved in preparing a problem for input to the computer: (1) *Analysis*—The user prepares a report of the problem, comparable to writing equations to define a scientific problem. (2) *Programming*—A systems analyst (or methods analyst) writes a *flow chart*, a graphic representation of the logical flow of processes required to solve the problem. The flow chart tells *what* to do. In the next step, a programmer prepares a block diagram that tells in detail *how* to do it. A coder then transforms the block diagram into a program made up of individual instructions. There are two portions to the program—the *operation*, which instructs what to do with the data, and the *operand*, which tells the machine where to find the data. The following example, from the publication *Business Machines*, shows how a program is set up:

| *Operation* | *Operand* |
|---|---|
| Select | Tape Unit 200 |
| Read | Four records into storage locations 1000-1050 |
| Clear and add | Quantity in storage location 1001 to arithmetic unit |
| Store | Result in storage location 1011 |
| Branch | To instruction in storage location 5000, etc. |


(UNIVAC)

Fig. 6-1. A sample flow chart for robbing banks for fun and profit (follow the arrows).

When a completed program is ready for the machine, it may be put into any form of input. That form frequently is punched cards, prepared by key punch operators. (This description has specified a different person to perform each of the steps; one person can, and often does, prepare the entire program.)

When the program is fed into the computer, a process ensues in some systems that is quite remarkable—the machine scans the program for any simple mistakes, such as ones in punctuation. If any are found, the computer prints out the mistakes in what seems a reprimand to the operator for careless work, and goes on to the next job.

The computer does not speak the language in which the program is written, but converts the instructions into its own machine language. The large and fast digital computers operate in the *binary system:*

| *Decimal* | *Binary* |
|---|---|
| 0 | 0000 |
| 1 | 0001 |
| 2 | 0010 |
| 3 | 0011 |
| 4 | 0100 |
| 5 | 0101 |
| 6 | 0110 |
| 7 | 0111 |
| 8 | 1000 |
| 9 | 1001 |

Since all values are expressed by combinations of either "zero" or "one," the binary system is ideal for the computer, which recognizes the presence (a binary "one") or absence (a binary "zero") of a current. Whereas the written figures in the binary system look complicated (the year ENIAC made its appearance, 1945, would be written 11110011001), it actually can express numbers quite easily.

The binary system is thus suited to computers, but it is cumbersome for people. The Herculean task of programming in machine language became apparent with the earliest machines, which were programmed by the men who built them. Computers had been created to alleviate mental drudgery; the difficulty in using them resulted in creating another form of drudgery.

Dr. Howard Aiken suggested in the manual for his Mark I machine that a library of routines be prepared; for the Mark III computer, he designed a coding machine that had a keyboard with mathematical symbols. Dr. John Mauchly, while working with Dr. J. Presper Eckert in the construction of ENIAC, set forth the basic principles of a "short-order code." Dr. M. V. Wilkes, working on the EDVAC at the University of Cambridge, wrote a book on the problem.

Dr. Grace Murray Hopper, UNIVAC, summarized the ideas of these individuals in a paper that was published in 1952, *The Education of a Computer,* and presented a concept of automatic programming, wherein the computer does the actual work of writing its own complete instructions after it has been given key instructions.

*(Ohio Oil Co.)*

Fig. 6-2. These punched cards can process data by any of 373 individual procedures.

So just as it was one woman, Lady Lovelace, who had originated the concept of programs for computing machines, it was another gifted woman mathematician, Dr. Hopper, who created the idea of compiling. The first compiler language, Flow-matic, written for the UNIVAC machines, introduced the use of English words and phrases to express computer instructions.

The field was ripe for such an innovation. Three major forms of automatic coders evolved—assemblers, interpreters, and compilers. The latter has been the most widely used, and is appraised by Howard Bromberg, CEIR, Inc., in these words: "The automatic compiler is the most useful and versatile tool provided today for computer operation." The present widespread utilization of computers has been attained only through the "breakthrough" of programming in artificial languages.

There are several advantages to compiling systems—they lend standardization so that all programs prepared in a given compiler language look alike. Further, it has made it possible to compile a program for a certain machine, then recompile it for a different machine without having to completely rewrite the program.

Compiler programs are not as efficient as those that can be prepared by a good programmer; but this superior human preparation requires a tremendous amount of time expended by a highly skilled person. So, all aspects considered, the compiler has been a boon to computer utilization.

A great proliferation of compiler languages have come into use—there are now about 200. IBM spent 2½ years in developing FORTRAN, FORmula TRANslator, and began the aggressive marketing of it in 1956 for use with the IBM-704. It has been implemented for successive IBM machines, and has now gone through 4 revisions. FORTRAN so closely resembles the language of mathematics that it allows people untrained in programming to prepare their scientific or engineering problems for the computer. It effects an 85 percent reduction in the number of instructions that would have to be written if coding were done directly in machine language.

The FORTRAN program is supplied on magnetic tape and consists of about twenty-five thousand lines of machine language; but even with this amount, it is considered a limited language, and the translation is not particularly efficient.

To develop a language that is a step beyond FORTRAN, a joint project was organized by the American Association for Computing Machinery and the German Association for Applied Mathematics and Mechanics. Participation of 7 countries (Denmark, England, France, Germany, Holland, Switzerland, and the United States) by representatives of manufacturers and leading computer specialists resulted in the publication in May 1960 of ALGOL, ALGOrithmic Language. It is a more powerful and more flexible language than is FORTRAN, but to date has not been widely accepted in the U.S. Popularity is the foe to progress—FORTRAN is so xtensively used, and organizations have such a heavy investlent in FORTRAN programs, that there is resistance toward ıdopting the improved scientific language, ALGOL.

In addition to the basic ALGOL, many dialects have been created to fit specific needs. Among them is NELIAC, a dialect written by the Naval Electronics Laboratory; JOVIAL, Jules' Own Version of an International Algorithmic Language, developed by Jules Schwartz of Systems Development Corporation to add extensive data processing commands to the basic scientific language; and MAD, a version of ALGOL which is very fast in compilation, created by the University of Michigan.

FORTRAN and ALGOL accommodate scientific needs. Business applications of computers during the mid-1950's were using assembly programs. It was obvious that a business-oriented compiler language was needed. Many manufacturers started to work and the prospect arose of several business languages appearing—a circumstance perhaps worse than having none at all.

A meeting of educators, computer users, and manufacturers at the Moore School of Engineering in 1958 considered the problem; they suggested that an effort to develop a single business language be spearheaded by the Department of Defense—an agency that was spending $80 million annually on programming. Charles Phillips, then Director of Data Systems for the Department of Defense (now with the Business Manufacturers Equipment Association), called a Conference on Data Systems Languages in May, 1959; by the following year, the group of manufacturers, and government and industry users had hammered out COBOL, Common Business Oriented Language; the original version has since undergone 2 revisions.

The leading computer manufacturers agreed to make COBOL compilers available; this move was strongly motivated by the fact that DOD adopted the policy to buy or lease those machines that could use the new language. The government believed that this utilization of a single business language could result in great savings in time and money and, also, increase efficiency.

COBOL uses English words and terms that make it a familiar to those concerned with data processing as the mathe matical FORTRAN or ALGOL are to the scientist or engineer. COBOL uses very powerful commands; one command often represents a lengthy sequence of machine instructions.

A major disadvantage of COBOL is that it requires a tremendous amount of computer time to translate the compiler language into the machine language. This and other considerations have prompted many leaders in the field to severely question its merits.

It is doubtful that the "ideal" computer language ever will be created, for its requirements are too stringent—it should be a precise yet concise statement of the problem, be unambiguous yet flexible, should not be governed by the characteristics of any specific computers yet adaptable to all, should be easily read by people, and be optimum for all types of programs.

To fulfill all of these requirements seems remote. Yet there is much urging that one standard programming language be created. It is now being considered by a committee of ASA, the American Standards Association, the group that establishes standards. This is not a government group, but instead it is voluntarily established by U.S. manufacturers and industry. For instance, it was recognized that standards should be established so that the television sets manufactured by all companies could receive the same signal; to accomplish this, a committee, formed under ASA, expended one million engineering man-hours.

The situation with regard to applying standards to computer hardware and software is not as clear-cut at this time. Howard Gammon, of the National Bureau of Standards, wisely says, "It is better to avoid making bad standards, even if it means making fewer good ones." (The National Bureau of Standards is a part of the U.S. Government and establishes standards of weights and measures, as opposed to the function of the American Standards Association of establishing standards of practice.)

The group that has the most to gain from standardization of both hardware and software is, perhaps, the government. There is an attempt to accord equal opportunity to all 26 computer manufacturers; the result is that the governmental agencies possess a conglomeration of equipment. A recent Congressional report contains this statement: ". . . since the lack of industry standards is costing the Government millions each year in programming and translation expense, the Federal Government should move firmly and positively to expedite the formulation and adoption of standards."[6]

Leading experts in the field have a variety of comments. Dr. A. O. Oettinger, Harvard University, says, "It would be essentially like standardizing on the Model T Ford. Yet, it would make sense to establish standards on various approaches to the information gathering problems." Dr. Richard Hamming, Bell Telephone Laboratories, Inc., summarizes the crux of the dilemma when he asks, "How do you get as much as you can of the gain and minimize the disadvantages?"

This perplexing consideration of establishing standards has been faced at some point in the evolution of all major movements or systems. If there ever can be stated a formula that will evaluate the countless ramifications, calculate the degree of stultification, and appraise the potential benefits of a proposed standardization structure at a given point in time, the equation will doubtless be far too complicated for men to handle—only a computer can give the answer.

Meanwhile, one of the points that must be noted in the 2 facets of computer development is that the enormous sums of money currently being invested in hardware will, in a few years, be equalled by the sums invested in software.

A release from CEIR, Inc., an international company devoted to problem-solving for business, industry, and government, states, "Software: multi-million dollar migrane. If this price tag seems exaggerated, consider what was once meant by a 'complete programming package' five or six years ago. Then contrast it with the increasing responsibility of today's manufacturer to provide COBOL, ALGOL, FORTRAN, assemblers, interpreters, compilers, report program generators, simulators, utility and checkout packages."

Computer Sciences Corporation is another firm engaged exclusively in computer-oriented services. It has undergone spectacular growth and now employs several hundred specialists. An interesting activity of the company was the recent production by computer of 40,000 income tax returns.

The stakes are high, and the competition is keen between these computer service bureaus as with other companies involved in the computer cavalcade. It is more than a new industry. The computer has brought a new way of life to a vast segment of the world. That it will continue to be a powerful force in bringing order and advancement is to the credit of those who manufacture the hardware, and also those who specialize in the challenging specialty of software.

# 7

## Employment and Education

The computer industry's manpower needs are so vast that it could employ all those graduating from college during the next decade! Such is the opinion of Hugh P. Donaghue, president of Datatrol Corporation. PREPARE, the first full-scale computer training program to be launched under the U.S. Manpower Development and Training Act, is being conducted by Datatrol and the U.S. Employment Service of the District of Columbia. It will serve as a pilot project, and evaluation by government and industry will determine if similar programs should be conducted on a nationwide scale. PREPARE courses run for 8 months, and require only a few hours daily; the student receives subsistence pay during training.

It is truly amazing that this great demand on today's labor market is for a type of professional worker who was nonexistent 10 years ago. The majority of those now working as *computer programmers* simply stumbled into it, since there was no clearly-defined preparation for it a few years ago.

Because computers are tremendously complex electronic devices, it has been assumed by many people that training for all computer jobs is extremely difficult. The truth is, however, that one can operate a computer without fully understanding its function, just as one can drive an automobile without grasping the principles of the combustion engine.

The range of computer jobs is broad. Coding can be learned with no more effort than is required to master typing. From there, the requirements scale up to a Ph.D. level for such positions as those relating to theory and design of computers.

Although, as is generally the case, the greatest demand is for people with higher education, there is no lack of opportunity at any level. On the contrary, new positions in the computer sciences are opened by the tens of thousands each year, and the on-coming supply of training people to fill the jobs is very small.

The test that most employers use in the selection of prospective programmers is PAT, Programmer Aptitude Test. But neither this test alone, nor it in combination with other tests, has proved of any great value.

Perhaps the reason that guidelines cannot be drawn firmly is that there are so many kinds of programmers. The computer is a tool, which is used in innumerable applications. So, whereas a test can measure qualities that are important to one type of programming effort, they may be meaningless in another instance.

It has not always been easy to predict just who will be a good programmer. A few years ago, an organization with a huge military project had such desperate need for people that a girl who had been a music major at Wellesley College was accepted as a trainee. The teacher of the programming class was horrified when the girl stared blankly at the blackboard upon which he had written "SIN and COS"—symbols she should have recognized from high school trigonometry. But the girl's gaps in knowledge did not deter her from becoming one of the best programmers of the organization.

It is now clear that a certain kind of general intelligence, not knowledge of mathematics in particular, is prerequisite to programming. Says Dr. Frederick Frick, Lincoln Laboratory, MIT, "Certainly the notion that a person has to be a mathematician in order to be a good programmer has been proved invalid. It appears that people who are good at mathematics tend to be people who like to program, but it is not really clear that their mathematical training is directly applicable; so much of the mathematics being used on computers is a different sort of mathematics from that which ordinarily is taught. Such forms as series approximations are used on the machines, and these are not taught in the average mathematics courses in schools."

Then, what is necessary? Mary C. Richey, IBM, gives this answer: "It's not what you *study* that's important in this work.

It's how you *think* that counts." *Logical, analytical reasoning ability* is the vital requirement, most experts agree. The second most important qualification is a regard for detail; computers will do only what, and exactly what, they are instructed to do.

## Ideal Work for Women

Says Mrs. Ida Rhodes, Bureau of Standards, "I employ only women because I believe that women are particularly suited for this type of work. It requires patience, and a great attention to detail—the kind of activity that generally men do not like."

The work is ideal for women for one major reason that Mrs. Rhodes explains, "It is possible for me to employ women who do not come to work on the premises. They stay at home, take care of their husbands and babies, and still can make a very wonderful living. This is possible because a person can be anywhere and perform computer coding. I travel a great deal, and many times I have worked on the train, in the hotel room, or wherever I found myself. The results were in no way hurt by the fact that I did not do the work at my desk in the Bureau of Standards.

"This is highly remunerative work, and in addition there are absolutely no expenses. I'd rather be a programmer than a lawyer or a doctor, because there is no need for an office, a secretary, a license, or any other outside expense. All that's needed is a pencil, paper, and the ability to perform intelligent work." Mrs. Rhodes' words are to be heeded, for her outstanding work in government has brought her the great honor of having received in 1959 the Department of Commerce Gold Medal Exceptional Service Award.

IBM has long urged women into the field, and sets an example by employing a greater number of women in technical and professional jobs than, perhaps, any other company in the nation. Young women who go into IBM directly on graduation from college soon may have positions of importance and responsibility—as an example, a 23-year-old blonde conducts computer seminars for brain surgeons.

The opportunity for women in computer-related occupations is by no means limited to the two examples just mentioned—that is, of employment by the Bureau of Standards, or by IBM. A woman may work in business, industry, education—or, she may work for herself as an "independent consultant." For example, Mrs. Ruth Horgan has been in this field for several years. At first she worked full time at UCLA; now she works independently, as many hours as she can spare from rearing her family. She says, "Once a woman has worked in the field for a while, she can retire from full-time effort and do consulting. The word gets around within the close-knit circle that she is doing this work, and she will be contacted by those who have jobs to be done."

The final encouraging consensus is that there is less prejudice against women in this field than in many others.

## Jobs for Special People

The success that Mrs. Ida Rhodes has had in teaching computer work to blind people is indeed noteworthy. She says, "How delighted I am that most of the individuals I have taught are so good that they got way ahead of the teacher—most are earning twice the salary I am. Also, I taught a group from the Gallaudet College for the Deaf. I stressed to them that they were to use their training to continue the effort and teach others; they did, and established a very fine computer school for deaf people. That is, all of the group did this, except one; he was so exceptional that we at the Bureau of Standards went against our own suggestion and kept him to work with us."

## Job Displacement

There is only one sure way to have no job displacement—that is to have no change. Of course, the point in time at which such an edict was decided upon would determine the point where progress ended and stagnation set in. If this plan had been followed 100 years ago, we would today have no electricity, no telephones, no automobiles, no airplanes, no modern medical methods, no modern science and engineering concepts. But, the people who held jobs as candlemakers and stagecoach drivers would still have their jobs. Or, really, would they?

Life is the essence of change. To fight against transition is both futile and stupid. To embrace advancing concepts and make any adjustments that might be required is only good sense.

The job displacements that have occurred as a result of automation have been the topic of long and serious discussions—as well they should be. But it must be considered, also, that the computer industry has created over one million new jobs and will create over one million more in the next few years. Computers, which control much automation, figure in the broad spectrum of technological change. Upheaval of this era, furthermore, is not diminishing but is showing every sign of increased momentum. A vast segment of our greatest minds are concentrating on how to change and improve things.

This can only mean that job displacement in the future will not be a remote consideration in some isolated occupations, but will sweep across the broad employment picture to touch virtually all people. Says Paul Armer, The RAND Corporation, "This means that most of today's labor force (managers included) will have to be retrained or retreaded at least once. And children in school today will probably face retraining for new jobs two or three times throughout their careers."

Whether it be training or retraining, or the growing problem of training for the leisure time created by shorter workweeks, the answer to the problem is to be found in one word—education.

Presently, the preponderance of computer programming training is being done by industry, government, and the computer manufacturers. They are assuming this responsibility not through choice, but through absolute necessity. The time is long overdue when the educational institutions must assume a major part of this burden by making computer courses a standard part of the curricula.

## High School Training

There appears to be no more fertile learning ground than that of the young and receptive mind. It thirsts (whether knowingly or not) for knowledge, and is uncluttered by the mass of mis- and pre-conceptions. The slogan, "Get 'em' while they're young" has great basis in truth. No less of an expert than Stanford's Dr. George E. Forsythe believes that high school students learn computer programming more quickly than do graduate students.

Dr. Gloria M. Silvern, who is responsible for Computer Programmer Training at a division of North American Aviation, Inc., would begin training even earlier: "In my opinion, computer concepts should be taught to youngsters in elementary school—it's never too early."[16] Today's children regard television as one of the real necessities of life. The oncoming generation will regard computers in this same manner.

George C. Heller, IBM, has spent his spare time in educational activities with some highly gratifying results. Mr. Heller now serves as National Education Chairman of the Association for Computing Machinery. In 1960, working with the Washington, D.C. Chapter of this organization, he initiated a large-scale educational experiment conducted with students from four high school districts. There were 316 students who participated; 96 percent of these pupils completed introductory courses, and another 164 students completed a full semester's work. To further the experiment, an advanced course was then added for students who excelled in the subject. The purpose of this last instruction was to see how quickly the students who had learned programming on an IBM-709 could learn to use a conceptually different machine, the IBM-1620. The transition was accomplished in the remarkably short time of 8 hours. A "5 percent" law was evidenced; that is, after a person has learned to operate one machine, only 5 percent additional effort was required to learn to program another machine.

Individual accomplishments of the group included (1) the design of a small computer (by a 17-year-old young lady);

(2) the simulation of a minus 2 base computer on the IBM-1620; and (3) neural network simulation. The latter work was of sufficient importance that the student presented a paper on the subject at the 1961 Eastern Joint Computer Conference.

So interested did the teachers become in this program that the 12th grade curriculum of the Montgomery County, Maryland schools now includes a computer-oriented mathematics unit. The entire ACM program is being considered as the basis for a complete 4-year course of study in computer technology.

This tremendously favorable experience is no isolated example. The spirit of it was duplicated by students from the George Washington High School in Denver, Colorado. Control Data Corporation sponsored a summer course of study, for which enthusiastic young Robert L. Albrecht was instructor. Of the original class of 35 students, 25 completed the course (Fig. 7-1).

Albrecht recalls, "The summer course was merely an appetizer for many of the students. They clamored for more training. During the fall semester we set up an advanced course for 12 students. (The rest had graduated.) A bleary-eyed mathematics teacher (Hoffman), a bleary-eyed Control Data instructor (me), and 12 bright-eyed young scholars met every Thursday morning from 7:30-8:30 A.M. before regular school hours. . . . The students did the required mathematical analysis, developed problem-solving procedures, programmed their solutions in FORTRAN and ran their problems on the 160A."[17]

The machine was kept in constant use by the students in the computer program. In fact, they almost came to blows over it, and finally persuaded the mathematics teacher to come and open up the school at 6:30 every morning; they then proceeded to keep the computer busy until the custodian pushed them out of the door at 6 in the evening. "Medicine Show" type demonstrations to other students in the school have so heightened interest that the classes are constantly enlarging.

These two examples of adventures in teaching computer programming in high schools highlight the eagerness and capability of young students, and project a serious problem of vast dimensions—a large number of teachers will be needed in the rather immediate future at the high school level, as well as university level, for computer subjects instruction.

Fred Gruenberger, The RAND Corporation, has long had a keen interest in teaching students of both junior and senior high school level. At the end of just one all-day training session, some students have progressed to the point of writing simple programs.

Regarding the educational aspect, Gruenberger says, "A computer is a superb teacher, all by itself. If I had to start from scratch, I'd rather have a computer and no teacher than the best teacher and no computer."[18]

But the combination of both is quite necessary for the schoolroom. To secure the supply of equipment that will be required within the nation's high schools is indeed a formidable problem. Gruenberger makes the suggestion that schools

Fig. 7-1. Students from a class taught by Robert L. Albrecht, Control Data Corporation.

purchase obsolete computers. For example, about one thousand drum-storage vacuum-tube machines will become available as they are replaced by faster equipment. These are quite adequate for teaching purposes.

To aid in the training of large numbers of teachers, Gruenberger suggests a "packaged course in computing," which consists of a series of 40 half-hour films.

The day of mass computer education is foreseeable. It is not so difficult to imagine that the courses in computer programming will be as familiar an elective as shorthand or typing.

This impending upheaval places stringent demands upon educators. Among the major groups actively working on the problem is The National Council of Teachers of Mathematics. Members have held conferences to discuss the topic and have produced a substantial book entitled *Computer Oriented Mathematics.* Says the President of the group, Frank B. Allen, "What do we tell our hard-working teachers? May I remind you that many of these teachers are still engaged in mid-career struggles to adjust themselves to the requirements of new mathematics programs for which, through no fault of their own, they were totally unprepared by their previous training. They can, if they must, make the additional effort to learn computer-oriented mathematics and computer techniques. However, they must have the opportunity to learn, and they need the motivation that springs from the conviction that the results are worth the effort."[19]

The motivation for learning computer technology could well come from the thought of G. Truman Hunter, Educational Programs, IBM: "Every high school and college graduate has from 30 to 40 years of working life ahead of him. During this time, the accumulation of knowledge will be doubling every ten years (or less). This will have a tremendous effect on the working and living environment of most of these people. They should learn as early as possible as much as they can about the information processing technology so that they will be enlightened instead of frightened by the changes which will take place."[19]

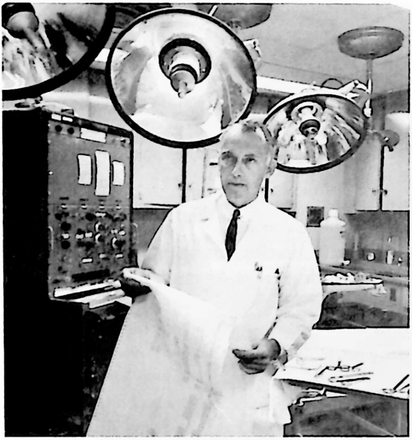
## University Training

The Committee on the Uses of Computers recently completed a study on the future of computer activities in universities; the Committee was established by the National Academy of Sciences National Research Council, with Dr. Barkley Rosser as Chairman, and Dr. Thomas Keenan as Executive Director. The two foremost findings of this study were (1) that there is a desperate need for trained people, and (2) that it is urgent for universities to help meet this need.

About three hundred colleges have on campus approximately five hundred computers—not including equipment in laboratories administered by universities but directed toward specific federal projects. The value of these computers when new was about $160 million, but much of it has been rented, not purchased, by the universities. Of these schools, perhaps twenty of them offer enough applicable subjects to make up a program that leads to a degree. It is to be expected that, in time, all of the nation's accredited 1200 universities, and many of the junior colleges as well, will want to offer computer training as a course of study.

The report of NSF anticipates that the first schools to make computer training compulsory for all graduates will be the engineering schools. Also, it is expected that in a few years, computer training will be required for all science majors. Dartmouth is installing a system costing $800,000 consisting of a central computer and 16 remote-control stations into which students can type out mathematical problems.

But application in science and engineering represents only the beginning of the computer's benefit to the university curricula. The machines can help English professors to teach good grammar. Computers will be a valid adjunct in the study of literature; the machines have prepared concordances of the Bible, and the writings of Shakespeare and Saint Thomas Aquinas. Much in-depth knowledge about our language is being acquired through research on the computer translation of foreign languages. This aids the English teacher and, also, the teacher of foreign languages.



(Leigh Wiener)

Fig. 7-2. Dr. James V. Maloney examines print-out from the University of California, Los Angeles Health Sciences Computer Facility; data is concerned with complex problems of blood chemistry encountered in surgery.

The schools of law and medicine will find that their enormous burdens in research are lightened by computers. Students who acquire the habit of availing themselves of the process will step into professional practice with an advantage over their noncomputer-oriented colleagues.

The school of agriculture will gain help through the computer functions in weather forecasting, and in the compilation of statistical calculations relating to increased yields, crop rotations, and economic crop planning.

The ability of computers to make mathematical models aids those in the psychology department to better understand human behavior, and those in the business school to better grasp economic situations. Business-game playing is a simulation that teaches how to control various business situations. The management control systems, PERT, Program Evaluation and Review Techniques, and CPM, Critical Path Method, are concepts that students can adapt to the planning of almost all types of businesses or projects.

The school of education has several interests in computers—for training in use of the machines; as a teaching aid; as a machine for record-keeping, guidance, and finance. The responsibility will rest heavily upon tomorrow's teacher to integrate the computer properly into the educational spectrum. The rapidity with which this tool is shaping countless aspects does not allow for either disinterest or the hesitancy of ultra-conservatism.

The dynamic movement of computers onto the university scene presents two mighty problems—providing an adequate teaching staff and, in addition, a gigantic budget for acquisition of the equipment. The needs appear beyond the grasp of universities, unless they receive additional support—most logically, from the government.

As mentioned earlier, one agency of the government that is a major influence in the field and has been since 1958 is the National Science Foundation. The NSF Computer Science Program offers to academic institutions two kinds of grants—*research grants* for computer-oriented investigations in the computer sciences, and *facility grants* that assist institutions in establishing (or modernizing) a computer center.

One of the more unusual of NSF's grants was one issued to the Social Science Research Council and The RAND Corporation in 1963 for a Research Training Institute in Techniques for the Computer Simulation of Cognitive Processes. All of the lectures, seminars, and projects of the Institute were of psychological interest. The purpose was to introduce behavioral and social scientists to the use of computers to construct models of complex human behavior. Of the 24 participants, 20 held Ph.D. degrees, and over half were professors at universities.

Such highly aimed meetings as these are vital to the progress of the computer field. Says Dr. Donald Laird, National Science Foundation, "One of the most important problems is one with greatest requirements—to develop scholars in the field. We must stimulate activity at the very highest level in education, so that benefits can filter to all levels."

Such stimulation will surely come from the universities that have taken the lead in the computer-conversion. For their role in the early developmental period, four schools are noteworthy—Harvard University, the University of Pennsylvania, the Institute for Advanced Study at Princeton, and MIT. A few examples of individual institutions indicate the kind of activity that is shaping the educational future.

*Stanford University.* This school is one of the pioneers in presenting computer education. The Computer Science Division, headed by Dr. George E. Forsythe, boasts the second most popular course on the campus, Use of Automatic Digital Computers. This is one of 43 courses that are either concerned with or involved in the use of computers. Forsythe is convinced that every technical student should receive the introductory computer course, and nontechnical students should receive a course in computer appreciation—designed to acquaint them with the meaning of computers in the world today.

Classroom work is supplemented with the facilities of the Computation Center. During a 9-week quarter, the Center will process an average of 22,000 jobs. Students outnumber faculty in utilization of the facilities on a 3-to-1 basis.

Forsythe regards computer science not as a segment of mathematics, but as a combination of humanities, science, and engineering. He feels that continuing development will enhance our understanding of the phenomenon of human thinking, simply because computers can simulate many aspects of thought and even creativity. He foresees that the early impact of computers upon technology will be overshadowed eventually by their effects upon men—how they think, and how they regard one another.

Once the Stanford Center was heavily oriented toward numerical analysis, but now it has been guided into other research areas. Work is being conducted on such problems as those involved in time-sharing and artificial intelligence. Those at the Center find stimulating recreation in a popular program that might be described as "the ideal gift for the computer man who has everything." This program—the modern equivalent of *Cowboys and Indians*—is called *Space War* (a game evolved by a group in the Boston area). It is played by means of armed spacecraft displayed on the console scope. Each player has a limited supply of "fuel" and "bullets"; when one craft is destroyed with a hit, a new image appears. To erase the craft from the scope to avoid being hit by an opponent's shot is not considered cricket. Though the game teaches some fundamentals of computer usage, conservative judgment has restricted playing the game to non-business hours.

When the new quarters of the Stanford Computation Center were dedicated recently, Dr. Richard W. Hamming, Bell Telephone Laboratories, Inc., said, "The library and the digital computer are jointly the heart of the university. . . . But let me make it clear that I am not thinking of the computer as an information retrieval device to be used by the library staff; I am thinking of it as an information processing machine, a tool for research, for combining ideas and information to produce new ideas and new information."[20]

The entire Computer Sciences Division, including the Center, has a personnel of about 70 people. Of this number 6 are members of the Stanford faculty and 4 are visiting professors. Forsythe has found it astonishingly difficult to find capable professors; this fact contributes to his strong advocacy of higher computer education in order to help meet the increasing needs.

The division has begun work on a program that will offer master's degrees and Ph.D.'s in computer sciences. Such efforts are indeed urgently required if Forsythe's broad aim is to reach fulfillment—to enable almost anyone with a problem to solve to have as ready access to a computer as they now do to a telephone.

*Massachusetts Institute of Technology.* The MIT Computation Center, directed by Dr. Philip M. Morse is one of the largest such facilities devoted to education and research. IBM installed a 704 computer at this Center in 1957 in a cooperative program similar to the one at the Western Data Processing Center at UCLA. The equipment has continually been updated, and now consists of an IBM-7094 machine. Over 40 New England colleges are able to make use of the facilities; some are connected by data link.

IBM not only contributes to the maintenance and operation costs of the Center, but also provides funds to students from

MIT and the other participating colleges to work at the Center as research assistants.

Work at this facility has embraced many areas, including those of economics, aerodynamics, meteorology, plasma research, nuclear theory, operations research, artificial intelligence, language translation, and time-sharing. The latter problem has been the basis of Project MAC, which is described in Chapter 8.

The Cooperative Computing Laboratory is a separate facility that contains some interesting equipment, including an IBM-709 with facilities for on-line Flexowriter input, visual display, and real-time processing of analog data. The Laboratory staff maintains a program of research in the areas of mathematical physics and non-numeric use of computers. The facility is used for research, teaching, and administrative work.

The Servomechanisms Laboratory of MIT made history early in 1950 by demonstrating the MIT Milling Machine, which was the first numerical control of equipment; this automatic operation of machine tools by means of computers evolved into APT, Automatically Programmed Tool. The activity inspired industry to plunge into the development of numerical techniques, and has brought about a major advancement in manufacturing processes. The Servomechanisms Laboratory next endeavored to bring the assistance of automation to the design process in the Computer-Aided Design Project. The product of this has been Sketchpad. (Both APT and Sketchpad are referred to in Chapter 2.)

Another major benefit has been realized as a "fall-out" from the computer-aided design system: "A significant theoretical development of the MIT project is an algorithmic theory of language that is designed to provide a common foundation for verbal and picture languages. . . . The theory has already been used in translation of human languages. . . . The result of continuing research promises to be a system in which mathematics, logic, and linguistics will be inextricably intertwined in such a way that almost any communication—statements from a human via the typewriter or light pen, manipulations of picture elements, or the status of mathematical or logical computations—will have meaning and will automatically cause the appropriate behavior throughout the system being investigated."[21]

In April, 1964, MIT was awarded a settlement of a long-standing patent suit involving the invention of the ferrite memory core by one of the university's professors, Dr. Jay W. Forrester. IBM paid MIT $13 million, and RCA agreed to a royalty arrangement.

The LINC, Laboratory INstrument Computer, is a small stored-program computer developed at MIT's Lincoln Laboratory, now under development at Washington University. The machine is noteworthy because it is designed for biomedical research.

MIT's Department of Civil Engineering has replaced a blackboard with a black box; in Room 1-150, the fundamental principles of engineering disciplines and the methodology of civil engineering practice are taught with the aid of a computer. Students have quickly adapted to the use of the equipment to solve problems. When classes are not in session, the equipment is used for laboratory purposes.

The application of computers for engineering problems has been made both cheaper and easier through the development of a new kind of language, which is problem-oriented instead of being machine-oriented. Instructions may be given to the machine in the same words that might be used to describe the problem to a colleague. Among these languages is STRESS, Structural Engineering System Solver, SEPOL, Soil Engineering Problem-Oriented Language, and COGO, COordinated GeOmetry. One inconsistent word has crept into the vocabulary for COGO—the word DUMP means "write everything out so we can see what's wrong" to the machine, but has quite a different meaning to a city engineer!

*California Institute of Technology.* One of the newest and possibly the most advanced of all university facilities is the Willis H. Booth Computing Center at the California Institute of Technology. The 3-story building and its facilities were financed by gifts from the Booth Ferris Foundation and the National Science Foundation.

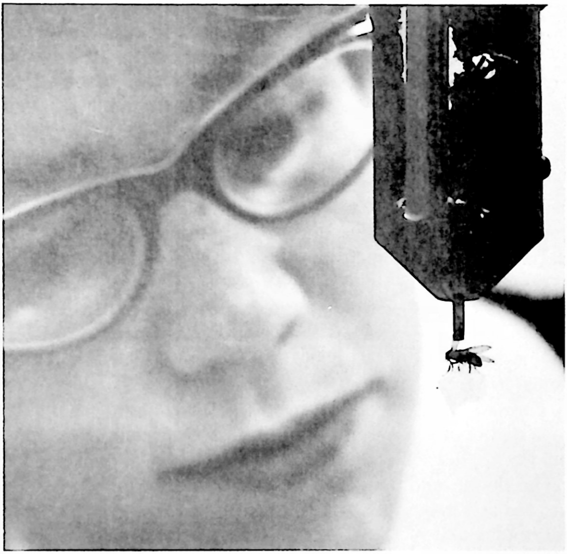
Two large machines, an IBM-7090 and an IBM-7040, are the heart of the system. Ingeniously, engineers have tied them together in such a way that the 7040 performs the routine operations called "housekeeping chores," such as monitoring input and output, and the 7090 is thereby freed to perform high-speed calculating. An IBM Multiplexor controls the flow of data to the 7040 from other components, such as a Burroughs-220.

The system has great flexibility in its applications, and can handle input from remote consoles that involve many different research projects at the same time; the interplexing system assigns each problem to the equipment best suited to give the solution.

One of the programs underway at Caltech is described by Dr. Gilbert B. McCann, Jr., Director of the Computing Center: "It is rather unique research on the nervous system, and is an interdisciplinary effort between biologists, psycho-biologists, engineers, computer people, communication theory people, and systems engineers. They are all working together to attack the problem of studying the nervous system, trying to understand how intelligence is created in the nervous system, and how it might be related to the design of computers. We are striving for a new concept."

Dr. McCann previously has made a major contribution to the computer design field with the development of direct analog computers in the post-World War II era. These machines are still being used by the aircraft industry in design work.

On the Caltech campus the major areas of research that involve the computing facilities are seismology, nuclear physics, and biological systems. Dr. McCann feels the latter has the biggest potential for intensive use of computers: "One application involves the efficient reduction of vast amounts of data from experiments. A second and very important application to biology is 'conceptual modeling.' This is a method of making a model to fit the results of an experiment, then conducting another experiment to find out whether the model is right or wrong. The models are continually created, tested,



(Leigh Wiener)

Fig. 7-3. At the California Institute of Technology, computers are helping in the study of a housefly's brain and its topflight navigation system.

and changed in a cyclic manner. Physics and chemistry have developed through the years by this method, but there has been little use of the approach in biology, principally because the kind of mathematics that developed is not well suited to biology. But, now, computers can get around this problem, and the important technique of conceptual modeling is beginning to be used in biology."

The Computer Center has made it possible for Caltech to undertake big and challenging research programs. It can perform tasks as varied as taking data directly from the atom-smashing synchrotron, or nerve impulses from the optic nerve of a crab's eye. There are plans to link the system to Caltech's off-campus facilities—Mount Wilson and Palomar Observatories, and to the Caltech Radio Observatory in Owens Valley.

*University of Chicago.* There are several computer groups on the University of Chicago's campus. The principal ones are The Institute for Computer Research, The Computation Center, The Biological Sciences Computation Center, and The Operations Analysis Laboratory. Among the special project groups that perform work that is heavily computer-oriented are The Laboratory of Molecular Structure and Spectra, The Center for Mathematical Studies in Business and Economics, and The Enrico Fermi Institute for Nuclear Studies.

The first mentioned, The Institute for Computer Research, has been established to provide the means of research that cannot be clearly confined to a single department. The Institute is largely supported by a grant from the Division of Research of the Atomic Energy Commission. Its purpose is to embrace three general aspects of computer activity—the logic and organization of computers, programming languages, and the application of computers.

The design and construction of a computer, MANIAC III, was the first major task of the Institute staff; the effort allowed full application of the three divisions of the Institute's stated purpose.

MANIAC III is a transistorized machine which uses a magnetic core memory, and it has basic input-output of a photoelectric paper-tape reader, a paper-tape punch, a console typewriter, and a line printer. This computer has served as an effective vehicle for investigations of programming languages.

Research has been conducted at the Institute regarding the matter of processing data by computer during the course of an experiment. This is of particular interest in the biological and physical sciences, since the volume of output data is so vast. The first demonstration of this effort was to couple the computer directly to the output of a spark chamber for recording nuclear events. The information was thereby directly digitalized, and thus was eliminated the customary steps of photographing and subsequent scanning for relevant spark information.

*University of California, Los Angeles.* A unique and diversified collection of computers is to be found at the University of California, Los Angeles. SWAC, which is located in the Engineering Building, has been previously discussed from the historical aspect. Also in this building is located the UCLA Computing Facility, directed by Dr. C. B. Tompkins; it has an IBM-7094 machine. A third installation at UCLA is the Health Sciences Computing Facility, the nation's largest medical research computing complex, directed by Dr. Wilfrid J. Dixon; the funding for this $3.3 million center came from the National Institutes of Health.

The fourth major facility at UCLA is the WDPC, Western Data Processing Center, directed by Dr. George Brown. It was established in November, 1956 as the first and the largest university computing center specifically oriented to business applications. WDPC had its inception under a most remarkable arrangement. IBM felt that progress in the area of data processing rested upon a foundation of education and research. So the company shared with the Regents of the University the cost of the building. Then IBM supplied all original computer equipment to WDPC, and have continued to keep it up-to-date through the years with the latest models; IBM and the university share the operating costs. This is similar to the arrangement IBM made at the Massachusetts Institute of Technology; the major difference in the two centers is that the UCLA facility is business oriented, while the MIT facility is essentially science oriented.

The $8 million facilities of the Western Data Processing Center are available *free of charge* to UCLA faculty, and also to students who have faculty sponsorship. In addition, these facilities are available to faculty and students of any other accredited 4-year college or university in the 13 western states, including Hawaii and Alaska, plus the National University of Mexico, and the University of British Columbia. There is no criterion except that the users be conducting legitimate university education and research projects. There is no screening of requests, and, so far, powerful equipment (an IBM-7094) plus efficient operation have enabled WDPC to accommodate all requests.

In the first years of the operation, WDPC handled the problems from other campuses only on a "mail order" basis. But, now, in addition to the approximately eighty schools that participate by mail, 11 schools are linked to the UCLA installation by means of the IBM Teleprocessing network. The schools merely dial a telephone number in order to transmit data to the WDPC. After being processed by the computer, the information is transmitted back to the individual campuses. As examples of utilization, 10,500 separate jobs were handled from 11 schools during the period from February, 1963 to February, 1964.

The problems that the various schools submit are the essence of diversity: Project on the Selection of Real Estate Salesmen, Simulation of Traffic Systems, Analysis of Retail Credit Application Information, Surveying Routines, Family Characteristics of Student Leaders and Nonleaders, and Parole Prediction.

IBM has just installed a switchboard-like communications center at WDPC to handle the incoming data from about fifty sources concurrently; in a sense, all of the users are sharing time on the one computer. This process makes the operation more completely automatic, and greatly increases the workload that WDPC can process.

The next step in servicing is proposed by Dr. Clay Sprowls, Acting Director: "Instead of having just one Teleprocessing unit at each school that is linked to WDPC, I would like to see terminals in the individual offices of the faculty members, or in classrooms. This, essentially, would make available to all of these people a very large and powerful computing center that could be used more conveniently and as easily as could a desk calculator."

The Computer Club on the UCLA campus, with a membership of about 200, has the aim of providing the means for students to learn about computing. This is accomplished by holding classes and by giving students the opportunity for actual experience on machines.

Steve Crocker, President of the Computer Club, tells of one project in which there is keen interest: "The members of the

Club thought it would be a good idea to teach high school students a little about computing and to make some machinery available to them. At most schools, there is no staff available to them at their level. Yet, there's no reason why it should be a closed-off field, because, essentially, programming is a skill that can be taught in a high school vocational arts department.

"We knew we couldn't make any great dent in the problem, but at least we wanted to put in our 'two cents' by opening up the opportunity to a few students. A group of us went to the Beverly Hills and the Hamilton High Schools and talked to a few students after school. The response was tremendous. Even more students showed up for the classes on the UCLA campus than we had talked with.

"Several of us in the Computer Club taught the classes that met Friday evenings and Saturday mornings. The rate at which the high school students learned to operate the machine and to do simple programming surprised some people—but it didn't surprise me. I knew they could learn it if they wanted to. One of the students was so good that he now has a permanent job here on the UCLA campus, and he is not yet a senior in high school. Overall, it was a successful project."

## Home Study

The trickle of courses that is seeping into the high school and university curricula is augmented in a few other ways. For instance, there is now available a correspondence course in programming. It is the result of a joint effort of IBM and Pennsylvania State University. A 12-part textbook and home-study guidebook are the tools with which the student may learn the programming principles—principles that are applicable to all machines. This course covers the basic elements of data processing, program coding, introduces symbolic programming, address modification, branching, and other operations. The cost for the course and books is about $30; it can be secured by contacting the Correspondence Department, Pennsylvania State University, University Park, Pennsylvania.

## Government Training

Civil Service workers have courses in computer programming made available to them.

Those who do not work for the government can receive help and guidance from the National Bureau of Standards. This is provided in several ways: An Information Service is maintained to answer inquiries from people. Classes in programming are offered free of charge; there are prerequisites if the course is to be taken for credit, but anyone is welcome to audit—providing the class is not overcrowded. Summer employment is available—a marvelous opportunity for college students to get paid while learning computer programming.

## Teaching Machines

Education is destined to reap rich reward from widespread computerized operation. Although early teaching machines were invented by such pioneering spirits as Arthur L. Runyan in 1918, and by Sidney L. Pressey in the 1920's, serious attention was not given to the advance until 1954 when Dr. B. F. Skinner persuasively presented the possibilities in his article, *The Science of Learning and the Art of Teaching.*

Skinner, a professor of psychology at Harvard, has well stated the present dilemma: "There are more people in the world than ever before, and a far greater part of them want an education. The demand cannot be met simply by building more schools and training more teachers. Education must become more efficient."[22]

The actual equipment involved in the teaching machine is relatively simple; the delays have not been due to technical problems. Rather, it was the manner in which material should be presented that was the critical factor, and this is where Skinner made his contribution. The general format that he designed is still being followed. A segment of information is broken down into its basic concepts; these are then arranged in logical sequence of perhaps 20 or 30 items; each item consists of 1 or 2 sentences of information, followed by a question. By thus proceeding in such small steps, a student of any aptitude can, theoretically, understand the subject matter. In fact, the machine will not proceed to the next item until the student demonstrates that he does understand by supplying the right answer. Since the student sets his own pace and works independently of fellow classmates, he develops a keen sense of responsibility.

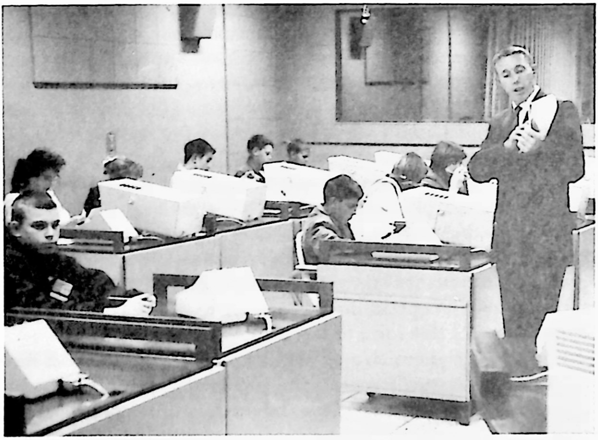
Although over the past decade educators and psychologists have been deeply interested in programmed instruction—both from the technical and human aspect—there has been remarkably limited acceptance or adoption. Two factors have prompted resistance—the considerable cost of such systems, and the misconception on the part of teachers as to the real implications of this form of teaching.

Fortunately, these two obstacles are yielding. The cost factor will be drastically cut in the foreseeable future, and educators are realizing that these methods will supplement, not supplant, their efforts. Indeed, when teachers gain real understanding of the concepts, they are apt to go overboard and regard them as the panacea for all shortcomings. To help place the entire field of programmed learning in proper perspective, there has been formed the Association for Educational Data Systems; the current president is Don D. Bushnell of Systems Development Corporation (SDC).

Bushnell makes this interesting point: "The usual approach to programmed learning is of more value to the normal and below average learner. The bright child seems to learn no matter how you present the material."

SDC conducted other educational studies that indicated that the manner in which a student learns greatly influences results. About one-third of all individuals are symbolic reasoners—they possess high mechanical aptitude, can work well with objects, and understand spatial relationships. Another one-third of the people are verbal reasoners and grasp examples laid out in verbal form. The remainder of the people are a combination of the two abilities.

Says Bushnell, "We suspect that in teaching we discriminate against the symbolic reasoner—the person who would make



(SDC)

Fig. 7-4. Don Bushnell is Coordinating Director of a laboratory classroom at Systems Development Corporation; students do their lessons by means of automated tutoring machines.

a good engineer—because most of the professorial staff are of a verbal nature. We have found that the majority of the senior high school drop-outs are ones who are interested in cars and have high mechanical aptitude. Essentially, they have the same mental ability and potential as verbal reasoners, but because of the way we present the materials, their experiences are unhappy ones. Programmed learning can present organized material in ways appropriate to these different aptitudes."

## School Data Processing

The computer is utilized in association with education in three general categories: (1) for business applications, (2) as a tool for research projects, and (3) as a teaching aid.

Insofar as the business application is concerned, each school system or educational institution must carefully decide how deeply to plunge into the use of electronic data processing equipment.

As with operating any other organization, there are inescapable routine functions attendant to running a school. So it was in the business application that computers were first utilized in the field of education; for such things as keeping employee records, keeping inventories, and figuring payrolls. In addition, however, the machines were used to relieve teachers of many of their nonteaching duties. For example, in maintaining attendance and other records, scheduling classes, scoring tests, and reporting grades.

The major advantage to automating is the factor of time saving. There are many levels of mechanical assistance to which the school can progress, each one being capable of faster handling of larger amounts of data: manual card systems, bookkeeping machines, punch card installations, and, finally, computers.

Only a very small percentage of the schools have taken that final step of installing computers. Partially, this may be due to the correct decision that it is too elaborate for their needs; but much of the hesitancy, also, is probably due to the educator attitude described by Dr. Murray Tondow, Director, Pupil Personnel Services, Palo Alto Unified School District, "One of the more formidable phenomena that any new endeavor in education faces is that of inertia. This is not in and of itself bad. A profession should not adopt every fad that occurs: the new concept should prove its worth first, preferably through controlled experimentation."[23]

Pilot projects to study the practicability of data processing networks have been undertaken by the state education departments of California, New York, and Massachusetts. A report by The California State Advisory Committee on Integrated Data Processing warns of too rapid and total acceptance:

"Experience indicates that the developments in technology and design, as well as possible applications, are under continuous change. Consequently, the data processing system should be viewed as a service which is operating through continuous evaluation and development."[24]

# 8

# Research

Research, the growing edge of computer advancement, is being carried out in vital projects nationwide. The diversified activity—which is taking place largely within industry but also in laboratories, universities, and government agencies—divides into several major efforts.

## Conversational Mode

*Conversational mode* is the term given to the man-machine communicating technique that is the great dream of the future. This will permit a user to "talk" to the machine as though it were a research assistant, instead of operating with the present confinement of having to tell the machine precisely what it is to do. For instance, if a user wants a list of the lieutenants stationed at Offutt Air Force Base, present programming methods would necessitate a long and elaborate program consisting of detailed instructions. The computer would have to be told to get the data from one register, put it in another, shift it to the right one place, subtract this, shift it back, etc. With the conversational mode, the instruction simply would be given, "Search the file for lieutenants."

This by no means implies that the job of programming is to be eliminated. Most of the present, as well as the new applications probably can be best handled by conventional means. But for the specialized areas, such as those of scientific research, this unique new means of interchange between man and machine not only will offer a different approach to problem-solving, but will greatly expand the use of the computer.

This concept also offers excellent interchange in instances where the problem is not clear-cut. At such a time the conversational mode would involve what R. W. Worthy, Librascope, very elegantly terms, "A Socratic discourse—like Socrates used in his dialogues with Plato, where he would ask certain questions to make clear exactly what the speaker was saying." Another major advantage is that of immediate feedback.

## Time-Sharing

*Time-sharing* is a means of making maximum use of a computer, for it gives a large number of users simultaneous access to a machine; there may be anywhere from 10 to 100 consoles connected to one central computer. Dr. Willis Ware, The RAND Corporation, explains, "Present day machines are so fast that they can be arranged to sequentially service on a round-robin basis a large number of users. When one user is not giving the computer anything by means of his typewriter console, the machine is taking care of another user's problem." In addition, the machine will have a backlog program to run in the time between users' problems.

Dr. Ware continues, "In a sense, we are moving toward an organization like the telephone system, in which central equipment is used on a time-shared basis by a great number of subscribers." Steve Jamison, IBM, adds, "By the year 2000—maybe sooner—every household will have a computer terminal, just as they now have utilities such as water, gas, and electricity."

With its many terminals in many locations, time-sharing has been termed "cottage computing," for it resembles the procedure followed by the textile trade in the 17th century when piecework was done by workers in their cottages.

In Project JOSS, scientists at RAND have connected 8 typewriter-consoles to its JOHNNIAC computer.

Bolt, Beranek and Newman, under a contract to the National Institutes of Health, has established a system at the Massachusetts General Hospital to develop the use of time-shared on-line computing in hospital transactions.

In 1963, MIT initiated Project MAC—the acronym stands for a Multi-Access Computer that has the goal of Machine-

Aided Cognition. MAC, funded by ONR, the Office of Naval Research, on behalf of ARPA, Advanced Research Project Agency, is described in this manner: "From 40 desks now, MIT's professors, students and researchers can dial an IBM-7094 for help, and get it quickly. They can put all sorts of data into the machine, retrieve it later when they need it, and order the machine to perform tedious tasks for them at any hour of the day or night. Different users can converse with the machine in different languages, and utilize its help in different ways. A first step has been taken, in other words, toward making the use of a big modern computer almost as convenient as telephoning to consult a friend."[25]

Systems Development Corporation, in a program also sponsored by ARPA, has combined ideas of its own with concepts proved by MIT and Bolt, Beranek and Newman, and has created a large-scale time-sharing system involving an AN/FSQ-32 computer built by IBM. In a dramatic demonstration that linked Massachusetts and California, MIT was connected by long distance telephone lines to SDC and time-shared the machine.

## Language Translation

*Mechanical language translation,* also, has defied timetables. It is one of the great problems in the computer field today, and years of effort, plus tens of millions of dollars, have yielded results that are far from spectacular. There is an apocryphal story to the effect that this familiar quotation was programmed into a computer: "The spirit is willing, but the flesh is weak." The computer is said to have translated the saying as, "The liquor is still good, but the meat has gone bad." This well illustrates one of the grave difficulties—the machines translate literally, not idiomatically. In purely scientific fields where meanings are more precise, mechanical translations are improved but still inadequate.

An example of this is the following: *Machine translation*—"Product of reaction is mixture of maximum and unsaturated/unbound aliphatic hydrocarbons chiefly normal structure how/as with even, so also with odd numbers of atoms of carbon in molecule."[26] *Man translation* of the same sentence by Joseph L. Zygielbaum, Electro-Optical Systems, Inc., "The product of the reaction is the mixture of saturated and unsaturated aliphatic carbons of mainly normal construction with an even, as well as an odd, number of carbon atoms in the molecule."[26]

Mrs. Ida Rhodes has long been working on the mechanical translation problem at the Bureau of Standards. She says, with candor, "The computer of today is completely unsuitable for mechanical translation. The machine is good for systematic kinds of work, like mathematics. But language did not develop like mathematics on certain axioms and rules; instead, it grew like Topsy and became completely chaotic. It is full of contradictory and unbelievably exasperating rules that are made to be broken; there are more exceptions than rules."

But along the path of attempting to solve this perplexing problem of language translation, which is closely involved with information retrieval, some interesting by-products have resulted. Dr. Anthony O. Oettinger, Harvard University, states, "The most positive thing that has resulted from the translation effort is that it has spurred fundamental and linguistic research. We use the same tools and techniques for studying the structure of natural languages, like English and Russian, as we do for studying artificial languages, like computer languages. It is in the broad area that progress has been made. Translation is one of the most insignificant of the applications of the work."

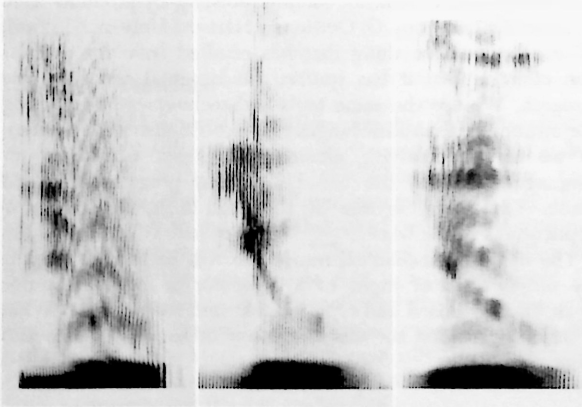
The cost for mechanical translation will be high as long as the only means of input to a computer is for an operator to sit at a keyboard and type the text into the machine. What is urgently needed for this and many other applications is a page reader.

## Character Recognition

*Character and pattern recognition* is a dynamic research area. Says Ernest G. Andrews, Sanders Associates, Inc., "The application field of the future computer will be greatly increased when computers can cope with ideas in addition to mere numbers. A step in this direction is underway in the form of automatic character recognition."

Dr. Oliver G. Selfridge and Dr. G. P. Dinneen have been among the most important pioneers in this intriguing area; their work dates back to the early 1950's. Determined efforts continue, both nationwide and worldwide, to crack the complexity of this problem, for it will prove one of the major breakthroughs of the computer field.

On a highly limited basis, character recognition now exists—as with the system used in banking operations that requires a special type. There are, also, crude page readers that will work if the right kind of type is used, if the type is set in the right way, and if other conditions meet restrictions. However, this is only a small step in the direction of the machine



*(Bell Telephone Laboratories, Inc.)*

Fig. 8-1. These sonograms show three different people pronouncing the word "you." The variance in speech patterns clearly indicates why it is difficult to achieve speech recognition with computers.

that will read all kinds of type, and also will read handwriting (especially in its most prevalent "scrawled" form). Researchers are now struggling to teach the electronic superidiots to recognize an "a" from an "o," and a "p" from a "q."

The problem is vast, as Dr. E. E. David, Jr., and Dr. O. G. Selfridge write: "Computer engineers, in a spasm of interdisciplinary enthusiasm, are rediscovering that perception is hard to understand and even harder to simulate. Armed with tautological knowledge that computers *can* do what we tell them to do, we tell them to perceive and then ask the psychologists to fill the gaps in our instructions. They don't know how to do it either, but *they've* known it longer."[27]

There are two categories to the effort—*character recognition,* which refers to letters, numbers, and conventional symbols, and *pattern recognition,* which applies to such inputs as charts and photographs.

The latter development has great promise, as James Tupac, The RAND Corporation, indicates: "One of the steps in programming today is the flow chart. I don't see any reason why someday we couldn't just feed the flow chart into the machine —not have to code the information first, but just the flow chart as it is."

In order for pattern recognition to be accomplished, photographs first must be digitalized. Today it is being done in a very rudimentary fashion, and improvements in the technique can prove of major benefit in such applications as the interpretation of military reconnaissance photographs and, also, in the analysis of photographs taken by the orbiting weather satellites.

*Speech analysis and synthesis* is a special form of pattern recognition research. The aim of this activity is to build machines that will recognize spoken words, identify the speaker, and will synthesize speech. The means of input is to translate the sounds into patterns that the computer can "see"; unfortunately, the same words spoken by different individuals do not look alike. (see Fig. 8-1).

A computer "speaks" by responding to instructions that link together phonetic symbols that make up words and sentences. Dr. John L. Kelly, Jr., and Dr. Louis J. Gertsman of Bell Telephone Laboratories, Inc., have programmed a computer to recite Hamlet's soliloquy. The machine gives a rendition that is intelligible but mechanical-sounding, and poses no threat to flesh-and-blood thespians.

*Information needs, uses, storage, and retrieval* form a giant area of research; projects underway worldwide number in the hundreds. The problems are so vast that a variety of methods are being studied in efforts to find acceptable solutions to the handling of the mushrooming store of information. It has been estimated that 50 percent of all research and development since the dawn of history has been conducted in the last decade, and that the accumulation of data will continue to double each decade. If the knowledge log-jam thus created is to be broken, it will be through the efficiency and capacity of computerized systems. The beginning point on this huge effort cannot be the development of the equipment to handle the data, but it must reach back to determine the information needs of the various groups of users; studies also are being conducted concerning human attitudes toward computer use and results.

The Council on Library Resources, Inc. has recently completed a survey, the results of which are available in a Government Printing Office publication entitled, *Automation in the Library of Congress*, dated January 21, 1964. It answers in the affirmative the possibilities of automating the Library of Congress prior to the year 2000. Henry J. Dubester, Library of Congress, comments upon the problem: "The past decade has witnessed an explosion of literature in forms for which traditional library organization has not been designed. . . . The size and subject scope of research libraries require computer memories together with rapid access capabilities which the present technology cannot now provide but which may soon be realized. . . . Concomitantly, the active realization of the improved library system will require a closer relationship to the user, the scholar, and research worker, who will also have to accept the responsibility of expressing in explicit terms the requirements which the library must serve."[28]

Systems Development Corporation has about ten projects centered around information retrieval and linguistics. A study in *automatic abstracting* is searching for the criteria by which humans judge what should be abstracted from a document. Another study, relating to *association indexing*, is following two approaches—the automatic generation of word association maps based on lists of words from the text, and representations based on the numbers of times words appear in the text.

## Artificial Intelligence

*Artificial intelligence*, which is concerned with the enormous problem of making machines behave intelligently and use the processes of thought, is the most startling and challenging of all areas and is, indeed, the peak of the research effort. Among the many potential applications is that to the field of information retrieval, since it involves complex intellectual processes.

The seeds of present efforts were planted early, by the work of such brilliant men as Dr. Norbert Wiener, the father of cybernetics; Dr. John von Neumann, who theorized on the computer and the brain; Dr. Alan Turing, who devised the Turing Game, in which participants try to guess whether their opponent is a man or a computer; Dr. Claude E. Shannon, who formulated the Theory of Information; Dr. Gray Walter, who experimented with "tortoises"; Dr. W. Ross Ashby, who postulated a Homeostat; and Professor Marvin Minsky, who simulated a self-organizing network.

In 1955, an important session regarding learning machines was held in conjunction with the Western Joint Computer Conference; the ideas presented there fell into two general categories: (1) those relating to a feature of the human nervous system and human senses, and (2) those concerning the organization of processes that symbolically perform "thinking."

The use of the word "think" has brought avalanches of criticism. Entire books have been written in condemnation of the idea that a machine can ever perform such tasks. This attitude has not rendered a particularly favorable climate for research, and perhaps could be somewhat dissipated by clearer understanding of terms and meanings.

*What is thinking?* Dr. Richard Hamming, Bell Telephone Laboratories, Inc., ponders the question: "Very frequently 'thinking' is defined to be what Newton did when he discovered gravitation. By this definition most of us cannot think! . . . I have . . . tentatively considered the hypothesis that 'thinking' is not measured by what is produced but rather is a property of the way something is done."[29]

John D. Williams, The RAND Corporation, projects this, "It seems inescapable to me that the brain of man, like that of other vertebrates, is an item, of random design, to meet one basic purpose: survival. There is some doubt these days whether it will in fact meet this criterion, but there is no reason to suppose that it is well designed to perform intellectual man's proudest function: namely, to think. The fact that it has out-thought things like saber-toothed tigers is no evidence that it is particularly apt for abstract thinking. It may be argued that I dismiss the survival-tested mechanism too quickly, and perhaps I do. The question arises when we ponder how to motivate advanced machines. I am confident we will discover means to do so, and I will be astonished if we are reduced to threatening them with tigers."[30]

But before loud protestations are made regarding man's superiority and machine's admitted limitations, perhaps this view will clarify the comparison, as stated by Paul Armer: "Intelligent behavior on the part of a machine no more implies complete functional equivalence between machine and brain than flying by an airplane implies complete functional equivalence between plane and birds."[31]

The emotionally disturbing elements of the work might well be removed, if not resolved, by considerations of semantics—instead of terming it "artificial intelligence," a more acceptable name might be "mechanical problem solving." Research is concerned with how people make decisions, toward the aim of building a scientific theory on decision making.

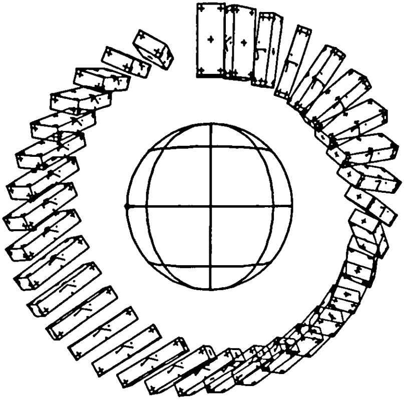


Fig. 8-2. These drawings of an orbiting box are a sample of the remarkable computer-made movies being developed at Bell Telephone Laboratories, Inc.

Says Dr. Herbert A. Simon, "If a geologist wanted to describe a mountain to another geologist, he could describe its shape, what kind of rock it has, and other characteristics. Yet, a decade ago, if you wanted to discuss the process of people making decisions, it was not clear what you should say about it, what terms should be used, and how to put together statements so that it becomes an objective description that two different people could interpret in the same way. So, first in the study, a scientific language was needed to describe the decision-making process."

Existing computer languages were not suitable for this research. Associative or list languages had to be developed, such as IPL, Information Processing Language, that deal in symbols rather than in numbers.

Present capabilities are summarized in this manner: (1) computers can manipulate symbols as well as numbers, (2) programs can be written that employ symbol manipulation to simulate human processes of thinking and learning, and (3) such programs can be regarded as theories of human processes. It is no longer doubted that machines can simulate human thinking.

This study has enabled men to learn much about themselves. The very fact that a child can absorb information more readily as he matures proves that children learn to learn. Advanced concepts have applied this process to a program called GPS, General Problem Solving, which was developed by Dr. Allen Newell, John C. Shaw, and Dr. Herbert A. Simon; their work has been done in cooperative projects between The RAND Corporation and the Carnegie Institute of Technology.

One of the puzzles given to GPS to solve is that of the

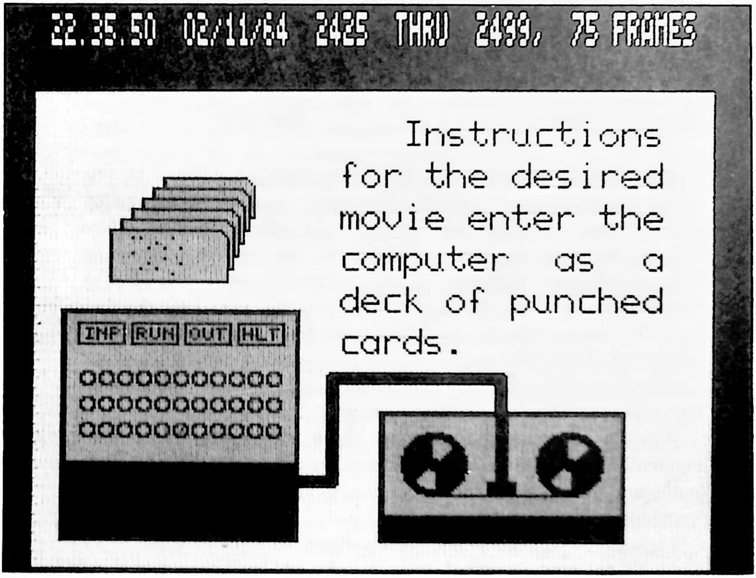



Fig. 8-3. Animated movies by computer have been developed by Bell Telephone Laboratories. The computer, programmed in BEFLIX language, generates a tape; the tape is fed to a General Dynamics Microfilm Recorder that produces a picture on the face of a cathode ray tube. These images are photographed, and make up the frames of the film.

Missionaries and the Cannibals: "There are three missionaries and three cannibals on the bank of a wide river, wanting to cross. There is a boat on the bank, which will hold no more than two persons, and all six members of the party know how to paddle it. The only real difficulty is that the cannibals are partial to a diet of missionaries. If, even for a moment, one or more missionaries are left alone with a larger number of cannibals, the missionaries will be eaten. The problem is to find a sequence of boat trips that will get the entire party across the river—without the loss of any missionaries."[32]

By studying such puzzles, or by programming computers to play chess, researchers are probing into the processes of the human mind. They are learning the patterns of heuristics, the rules of thumb, the skills with which businessmen make decisions, or children learn to speak.

Even though a computer can do only what it is told to do, in one sense, it is possible to write a program that presents a problem but not the method of solution, and the computer then searches through a vast number of solution attempts until it finds the correct one. The key is to develop schemes for reducing the search.

Says one of the leading researchers in the field, Dr. Marvin Minsky, ". . . we are on the threshold of an era that will be strongly influenced, and quite possibly dominated, by intelligent problem-solving machines."[33]

# 9

## Future

Explosive rates of growth have been the rule in fields of scientific applications that have resulted from man's imagination. However, when it comes to predicting the future, his imagination has not kept pace—even wild-eyed dreamers consistently fall short in this attempt.

We review the past for indications that will aid in predicting the future. *Over the past decade, the speed at which computers calculate has increased by a factor of a million!* What conclusions can be drawn for the future?

Speed is now nudging the upper limits in computers, according to Einstein's accepted theories, so it is likely that the next quantum leap will be primarily concerned not with speed but, rather, will introduce incalculable sophistication into computer application. Tomorrow's machines will not be doing the same things faster, but will be venturing into vast untried utilizations.

"About 99 percent of all technological effort so far has been oriented toward solving 1 percent of the important problems—the 'do-able' ones that use precise computation or logical manipulations, such as accounting problems or scientific problems. So far there have not been developed the tools and techniques for solving the great bulk of the problems—abstruse ones that confront people in every category of life. To try to undertake this mass of problems with existing equipment is to use a brute-force approach. We must, instead, analyze and define this newer class of problems, and develop machines that can deal with them efficiently," says Dr. Harold Hamilton, Director of Advanced Research, Librascope Division, General Precision, Inc.

In what direction does development of equipment with such capability lie? Present organization of machines has been likened to the functioning of the human brain—which is about one-hundredth the size of a computer, yet possesses ten-thousand times more components in the form of neurons.

Machines can now cope with problems involving more variables than man can grasp. Computers next can search for patterns that may be a basis for creating new theories, necessitating the philosophical acceptance that there may be theories existing within intricate electronic equipment that are too incredibly involved to be understood by any man!

Not only will the programs contained within such machines be beyond the grasp of man, but the machines themselves will defy human design. Dr. John von Neumann did not live to complete his theory of artificial self-reproduction. But, likely, it is emerging as our knowledge compounds, and it will create machines that will produce ever more complicated machines.

Next, consider the belief of M. O. Kappler, Computer Sciences Corporation, which is that in a decade from now, a computer will be needed not only by every business but, also, by every individual.

The depth and breadth of existent information is already too gigantic for individuals to "learn." As it continues to compound in the future, man's best hope of coping with such vastness is to tap it on a reference basis. This can be done by using portable computers the size of a cigar box, into which has been stored the totality of human knowledge.

The retrieval of any information in one-millionth of a second from these personal computers may be accomplished by the spoken word, or by thought—the current use of the computer in analyzing brain waves may presage such a development.

Thus may men truly be relieved of mental drudgery, and be given powerful support in the application of their creative abilities.

There also has been discussed another possibility—that computers may be used as an additional mechanism for the control of men. It is indeed a sobering warning, yet it reverberates with an all too familiar ring. Throughout the course of civilization, every major advancement has been heralded with dire prophecies from some people that it portends human destruction.

The assumption that men will not utilize computers for their degradation may be based on two premises—faith in the human spirit, and the record of past events. Despite diverting tributaries, men have always contrived to remain in the mainstream of progress. So it reasonably can be concluded that humankind will employ computers to elevate their status.

Dr. Albert Einstein once said, "I just don't believe the good Lord governs the world by shooting craps."[34] Science has proved that there is order and precision in all living forms, ranging down to the sub-atomic world that exists within the nucleus of the atom.

Yet, there has existed less order and precision in the mental world than exists within any realm of the physical world. Decisions are rendered on such random values, and appraisals made on such fragmentary information, that it appears men indeed play at the business of living as if they are shooting craps.

If men will but take advantage of the advanced computer-concepts that will surely evolve in the future, they will gain for themselves a new mental capability. System and precision more nearly can be brought to the actions and decisions of men, hence to the course of civilization, through the full use of all available knowledge. A new dimension to living will emerge.

How desperately this is needed can be gaged by the fact that human knowledge has doubled in the last 10 years. Its continued expansion can inundate men, unless there is also evolved the means for the handling and proper use of the knowledge that is being accumulated. The exploding population will not allow cushions between peoples. If human proximity is not to be abrasive, behavior must be intelligent and disciplined, and actions must be based on all available information.

Happiness and achievement come in ratio to the size of each man's world. The one who lives within himself feeds only on inbred thoughts and stultification. As the scope of his consciousness increases, he becomes cognizant of the positive values within his life, of the potential of the world, and he then is aware of a great purpose for his living.

As the frame of reference for civilization expands from the size of the earth to the dimension of the universe, the opportunities for achievement are expanded exponentially. Current space exploration is reconnaissance preparatory to migration to the planets of our solar system.

Stretching before mankind is the Platinum Age of achievement. This era does not permit men the past habit of using only a small portion of their mental capabilities. Like force operating on force in a circular fashion, the urgent need for human intelligence will be made more intense.

The computer may well be man's most valued assistant in his rendezvous with greatness.

# Footnotes

1. E. A. Feigenbaum and J. Feldman, Ed., *Computers and Thought* (New York: McGraw-Hill, 1963).
2. *Banking* (Oct. 19, 1962), 55:4:48–49.
3. Reed C. Lawler, "Information Technology and the Law," *Advances in Computers,* Vol. 3 (New York: Academic Press, 1962).
4. Committee on Post Office and Civil Service, House of Representatives, "Use of Electronic Data Processing Equipment in the Federal Government" (Washington, D.C.: U.S. Government Printing Office, Oct. 16, 1963).
5. Hearing before the Subcommittee on Census and Government Statistics of the Committee on Post Office and Civil Service, House of Representatives, "Use of Electronic Data Processing Equipment, Part 3" (Washington, D.C.: U.S. Government Printing Office, June 24, 1963).
6. *Los Alamos Scientific Laboratory News* (May 4, 1961).
7. Joseph F. Shey, *Computer Design Problems for the Space Environment* (Address to the Institute of Radio Engineers, Anaheim, Calif., Oct. 30, 1962).
8. *Computing News* (March 15, 1959), 145.
9. B. V. Bowden, Ed., *Faster Than Thought* (London: Pitman, 1953).
10. Jay W. Forrester, *Project Whirlwind,* Report R-142 (Address to Modern Calculating Machinery and Numerical Methods Symposium, UCLA, July 29, 1948).
11. *Business Automation* (July, 1963), 24–29.
12. *New York Times* (Aug. 30, 1963).
13. *Proceedings—Fall Joint Computer Conference* (1962), 225–228.
14. James A. Ward, *The Need for Faster Computers,* DDR&E, Washington, D.C.
15. John Von Neumann, *The Computer and the Brain* (New Haven: Yale University Press, 1958).
16. Gloria M. Silvern, *Computer Programmer Education and Training* (Denver: Press Forum, 1963 ACM Conference, Aug. 27, 1963).

17. *Datamation* (July, 1963), 9:7:31–33.
18. *Datamation* (May, 1963), 9:5:35–36.
19. The National Council of Teachers of Mathematics, "Conference on Computer Oriented Mathematics and the Secondary School" (Washington, D.C.: April 24–25, 1963).
20. *Datamation* (Nov., 1963) 9:11:43–45.
21. *Technology Review* (March, 1963) 65:27–28.
22. *Science* (Oct. 24, 1958) 128:3330:969–977.
23. Murray Tondow, *Data Processing in Education.*
24. California State Advisory Committee on Integrated Data Processing, "The Feasibility of Establishing an Integrated Data Processing System for Pupil Personnel Records" (Sacramento, Calif.: April 11, 1962).
25. *Technology Review* (March, 1964) 66:16–17.
26. Y. T. Eydus and N. I. Yershov, "On the Mechanism of Catalytic Hydropolymerization of Olefins Under the Influence of Small Quantities of Carbon Monoxide in the Presence of Hydrogen" (Reports of the Soviet Academy of Sciences, Division of Chemical Science, No. 9, 1959).
27. *Proceedings of the IRE* (May, 1963), 50:1093–1101.
28. *The American Behavioral Scientist* (Nov., 1962), 5:3:24–27.
29. *The American Mathematical Monthly* (Jan., 1963), 70:1: 4–11.
30. J. D. Williams, *Toward Intelligent Machines* (The RAND Corp., P-2170, Dec. 29, 1960).
31. *Datamation* (March, 1963), 9:3:34–38.
32. *Datamation* (June, 1961), 6:7:18–20.
33. *Proceedings of the IRE* (Jan., 1961), 49:1:8–30.
34. Shirley Thomas, *Men of Space,* Vol. 1 (Philadelphia: Chilton, 1960).

# Acknowledgments

The author conducted personal interviews with the following people as part of the extensive research for this volume; deep gratitude is expressed to each:

Franz Alt, National Bureau of Standards.
Paul Armer, The RAND Corporation.
Eugene Brock, National Aeronautics and Space Administration.
Robert Brown, Aerospace Corporation.
Don Bushnell, Systems Development Corporation.
George Bynum, North American Aviation, Inc.
William F. Cahill, National Aeronautics and Space Administration.
Thomas Connolley, Hughes Aircraft Company.
George Cressman, U.S. Weather Bureau.
Steve Crocker, Computer Club.
John S. Davis, The Bunker-Ramo Corporation.
Paul S. Dickins, Control Data Corporation.
Wilfrid Dixon, University of California, Los Angeles.
J. Presper Eckert, UNIVAC division of Sperry Rand Corporation.
R. B. Freeman, Hughes Aircraft Company.
Frederick Frick, Lincoln Laboratories, Massachusetts Institute of Technology.
Howard Gammon, National Bureau of Standards.
Roderick Graham, U.S. Weather Bureau.
James Grider, *Los Angeles Times.*
Jon Griffin, Hughes Aircraft Company.
H. R. J. Grosch, Consultant.
Fred Gruenberger, The RAND Corporation.
Edmund J. Habib, National Aeronautics and Space Administration.
Harold Hamilton, Librascope division of GPI.
Richard Hamming, Bell Telephone Laboratories, Inc.
Morris Hansen, U.S. Bureau of the Census.
Magnus Hesttenes, University of California, Los Angeles.
Marge Hill, Control Data Corporation.
William R. Hoover, Jet Propulsion Laboratory.
Ruth Horgan, University of California, Los Angeles.
Steve Jamison, IBM.

Joseph Jarecki, Department of the Air Force.
M. O. Kappler, Computer Sciences Corporation.
Edward F. Kearns, RCA.
Thomas Keenan, University of Rochester.
Donald Knuth, California Institute of Technology.
Donald Laird, National Science Foundation.
Sidney Lechter, National Aeronautics and Space Administration.
J. C. R. Licklider, ARPA, Department of Defense.
G. D. McCann, California Institute of Technology.
M. A. Melkanoff, University of California, Los Angeles.
Joseph Mount, IBM.
Donald Muller, Hughes Aircraft Company.
A. O. Oettinger, Harvard University.
William C. Perkins, Autonetics Division, North American Aviation, Inc.
John A. Postley, Advanced Information Systems Company.
Robert Rector, Aerospace Corporation.
Ida Rhodes, National Bureau of Standards.
Barkley Rosser, University of Wisconsin.
Herbert A. Simon, Carnegie Institute of Technology.
Dale Smith, North American Aviation, Inc.
Gordon Smith, Autonetics Division, North American Aviation, Inc.
Clay Sprowls, University of California, Los Angeles.
Herbert Stottler, National Aeronautics and Space Administration.
Jack Strong, Computer Sciences Corporation.
Burris Taylor, Aerospace Corporation.
Maj. Gen. G. H. Terhune, Jr., Department of the Air Force.
Charles B. Tompkins, University of California, Los Angeles.
James Tupac, The RAND Corporation.
Frank Wagner, Informatics, Inc.
Willis Ware, The RAND Corporation.
A. H. Westburg, The Bunker-Ramo Corporation.
Joe Weyl, Office of Naval Research.
Robert Williamson, Librascope Division of GPI.
Burton R. Wolin, Systems Development Corporation.
R. M. Worthy, Librascope Division of GPI.

The author also wishes to acknowledge her indebtedness to Margaret R. Annis, Annis & Thomas, Inc.

# Related Reading


Alt, Franz L., Ed. *Advances in Computers.* Vol. 1–4. New York: Academic Press, 1960–63.

*Applied Mathematics.* Washington, D.C.: U.S. Government Printing Office.

*A Third Survey of Domestic Electronic Computer Systems.* Washington, D.C.: U.S. Government Printing Office.

*Bibliography.* Technical Note #193 (714 references). Washington, D.C.: U.S. Department of Commerce, National Bureau of Standards.

Booth, Andrew D. *Automation and Computing.* New York: Macmillan Co., 1959.

Borko, Harold. *Computer Applications in the Behavioral Sciences.* New York: Prentice-Hall, 1962.

Bowden, B. V., Ed. *Faster Than Thought.* London: Pitman, 1953.

Bushnell, Donald D. "The Role of the Computer in Future Instructional Systems." *AV Communication Review.* Vol. 11, No. 2, Supplement No. 7, March–April 1963.

Eckert, W. J., and Jones, Rebecca. *Faster, Faster.* New York: IBM, 1955.

Englehardt, Stanley L. *Computers.* New York: Pyramid, 1962.

*Employment Outlook for Electronic Computer Operating Personnel Programmers.* Washington, D.C.: U.S. Department of Labor, U.S. Government Printing Office.

*European Computer Market.* Netherlands Automatic Information Processing Research Centre, Amsterdam, 6, Stadhouderskade, Netherlands.

Greenberger, Martin, Ed. *Management and the Computer of the Future.* New York: MIT Press and Wiley, 1962.

Gruenberger, Fred J. and McCracken, Daniel, Ed. *Introduction to Electronic Computers—Problem Solving with the IBM 1620.* New York: Wiley, 1963.

Halacy, D. S., Jr. *Computers, the Machines We Think With.* New York: Harper, 1962.

Hamming, Richard W. *Numerical Methods for Scientists and Engineers.* New York: McGraw-Hill, 1962.

Laird, Donald, and Laird, Eleanor C. *How to Get Along With Automation.* New York: McGraw-Hill, 1963.

*Machine Translation.* Washington, D.C.: OTS, U.S. Department of Commerce.

*Manpower Reports.* #6 and #7 (Automatic data processing in the Government, and Reading Machines). Washington, D.C.: U.S. Department of Labor, Manpower Administration, Office of Manpower, Automation and Training.

Morrison, Philip, and Morrison, Emily, Ed. *Charles Babbage and His Calculating Engines.* New York: Dover, 1961.

*Organization Guide:* to Library, Documentation, and Information Services of 449 International Scientific Organizations. Washington, D.C.: Library of Congress, U.S. Government Printing Office.

Postley, John A. *Computers and People.* New York: McGraw-Hill, 1960.

*Programming Technique.* Washington, D.C.: U.S. Department of Commerce.

*Soviet Literature, 1962–63* (Teaching Machines and Programmed Learning). Washington, D.C.: U.S. Department of Commerce, Office of Technical Services, Joint Publications Research Service.

Stibitz, George R. and Larrivee, Jules A. *Mathematics and Computers.* New York: McGraw-Hill, 1957.

*The Theory of Automata.* Washington, D.C.: OTS, U.S. Department of Commerce.

von Neumann, John. *The Computer and the Brain.* New Haven: Yale University Press, 1958.

Wiener, Norbert. *Cybernetics; Control and Communications in the Animal and the Machine.* New York: MIT Press and Wiley, 1961.

Williams, J. D. *The Compleat Strategyst.* New York: McGraw-Hill, 1954.

Wooldridge, Dean E. *The Machinery of the Brain.* New York: McGraw-Hill, 1963.

# Glossary

Access time. The time required to transfer information from the storage to the arithmetic unit, or *vice versa.*

Address. The identification of a register or location in storage.

Analog computer. A machine that continuously measures physical variables, such as temperature, distance, voltage, pressure; the processed data is presented in continuously available form.

Arithmetic unit. The section of the computer where arithmetic operations are performed.

Assembly. The computer process of changing instructions, written by the programmer in a symbolic form, into machine language.

Automatic programming. A technique that employs the computer to translate a program from a computer language into a machine language; compiling and assembling are examples of automatic programming.

Binary code. A coding system that represents decimal digits by means of only two symbols—zero and one.

Bionics. The science of systems that function in a manner resembling living systems; the use of biological data in system design.

BIT. An abbreviation of *bi*nary digi*t*; a single character in a binary number.

Block diagram. A diagram representing the computer functions involved in the solving of a problem; it is less detailed than a flow chart.

Branch. The choice between alternate paths that the computer makes based upon a criterion.

Character reader. A device that can read, either optically or magnetically, special type faces.

COBOL. *C*ommon *B*usiness *O*riented *L*anguage; a language for business data processing.

Code. A system of symbols that represents information in a computer.

Coder. A person who performs coding—the converting of flow charts to machine language.

Compiler. An automatic computer coding system that translates a program into machine language.

**Console.** The portion of the computer from which an operator can manually control its operation.

**Control unit.** The section of the computer that directs all operations.

**Conversational mode.** A technique for communicating with the computer that requires few detailed instructions and allows great freedom.

**CPU.** *C*entral *P*rocessing *U*nit; the main frame of the computer that contains the storage, arithmetic unit, and special register groups.

**Cybernetics.** A subject named by Dr. Norbert Wiener. He subtitled it "Control and Communication in the Animal and Machine." It is a comparative study, with the aim of understanding and improving communication, of information-handling machines and living nervous systems.

**Data phone.** A device that transmits computer information via telephone lines.

**Data processing.** The preparation and handling of data by procedures that classify, sort, etc.

**Debug.** The detection and correction of errors in a computer program.

**Digital computer.** A machine that uses numbers or other symbols to process data.

**EDP.** *E*lectronic *D*ata *P*rocessing.

**External memory.** A unit separate from the computer that stores information in machine language by such means as magnetic tape, paper tape, or punched cards.

**Flow chart.** A diagram that represents the major steps to be taken in the solving of a computer problem; the flow chart provides information from which the block diagram is prepared.

**FORTRAN.** *For*mula *Tran*slator; a programming language for problems that can be expressed in algebraic notation.

**FOSDIC.** *F*ilm *O*ptical *S*ensing *D*evice for *I*nput to *C*omputers; a mechanism for reading film by optical methods.

**Glitch.** An unidentified failure somewhere in a complicated mechanism.

**Hardware.** The physical components of a computer system, including the mechanical, electronic, magnetic, and electrical devices; this is opposed to the software, which is the program that operates the computer.

**Heuristic program.** A routine in which the computer solves a problem by a trial and error method; this may involve a learning procedure by the computer.

**Hollerith cards.** Punch cards named after their inventor, Dr. Herman Hollerith.

**Housekeeping.** Operations within the computer that must be performed for a machine run; they are usually accomplished before the processing begins.

**Input.** The introduction of data into the computer by such devices as a card reader, tape reader, or keyboard.

**Integrated circuits.** A complete electronic circuit that is contained in a chip of semiconductor material that may measure 5/1000 of an inch thick and 1/16 of an inch long, or smaller.

**Internal memory.** A storage unit within the computer.

**Internally stored program.** Instructions stored within the computer in the same facilities as the data.

**IPL.** *I*nformation *P*rocessing *L*anguage; a computer language that deals in symbols rather than in numbers.

**IR.** *I*nformation *R*etrieval; the recovery of specific information or data from a collection.

**Keypunch.** A device that punches holes in cards or tape; the holes represent numbers, letters, or symbols.

**Location.** A position in the internal storage unit that can store a computer word; each location is identified by an address.

**Machine-oriented language.** A language for use by the computer without translation.

**Magnetic core storage.** A unit in which binary data are stored by means of the direction of the magnetization of tiny magnetic rings.

**Magnetic tape.** A tape (contained on reels) upon which information may be placed by means of magnetized spots.

**Mark sensing.** A method of reading information put onto cards by special pencil marks, and of automatically punching the cards.

**Mechanical translation.** The translation of data from one language into another language by means of a computer.

**Microelectronics.** The microminiaturization of electronic components.

**Monte Carlo method.** Any procedure that involves statistical sampling techniques in order to obtain a probabilistic approximation to the solution of a mathematical or physical problem.

**Off-line.** A system in which the peripheral equipment is not controlled by the central processing unit.

**On-line.** A system in which the peripheral equipment is controlled by the central processing unit, and in which information is immediately introduced.

**Operand.** A portion of the instruction, such as the address.

**Output.** The transferring of processed information from the computer by such means as punched cards or magnetic tape.

**Paper tape.** A strip of paper into which holes representing information are punched.

**Parallel operation.** The simultaneous performance of several actions.

**Pattern recognition.** The capability by the computer to recognize shapes—handwriting, speech shapes, physical contours, etc. Also called *character recognition.*

**Problem-oriented language.** A language that states the problem (not the means of solution) and has little resemblance to machine language.

**Procedure-oriented language.** A language, such as FORTRAN, that describes how the solving of the problem is to be accomplished.

**Program.** The sequence of instructions given to the computer for the solving of a problem.

**Programmer.** A person who prepares flow charts and who may write routines.

**Punch card.** Stiff card with either 80 or 90 columns of punched holes that represent information that can be read by the computer.

**Random access.** A method of getting data into or out of storage wherein the time is not dependent upon the previous data placed into or taken out of storage.

**Read.** The copying of data from one storage (usually external) to another storage (usually internal).

**Real-time operation.** A speed of operation that is virtually concurrent with the incoming data.

**Routine.** A subdivision of a program; a set of coded instructions.

**Routine library.** A collection, usually on magnetic tapes, of routines and subroutines that may be used to solve parts of problems.

**Self-organizing machines.** Computers that organize their own elements.

**Serial operation.** A method wherein information flows through the computer at the rate of one digit or word at a time.

**Simulation.** A procedure in which a computer is programmed to model some entity, such as a physical system.

**Software.** All of the programs and routines used to operate computers; this is opposed to hardware, which is the computer equipment.

**Systems analysis.** The examination of a business or other activity, and the determination of what objectives must be accomplished.

**Time-sharing.** The use of a central computer by many different consoles.

# Index

# Holt Library of Science

| | | |
|---|---|---|
| Vol. 1 | Animal Photoperiodism | Beck |
| Vol. 2 | Antarctica | Eklund and Beckman |
| Vol. 3 | Flying | Caidin |
| Vol. 4 | Glaciers and the Ice Age | Schultz |
| Vol. 5 | Human Evolution | Lasker |
| Vol. 6 | Interplanetary Navigation | Park and Magness |
| Vol. 7 | Life and the Physical Sciences | Morowitz |
| Vol. 8 | Our Animal Resources | Fitzpatrick |
| Vol. 9 | Ours Is the Earth | Sollers |
| Vol. 10 | Pathways to Probability | King and Read |
| Vol. 11 | Radiation, Genes, and Man | Wallace and Dobzhansky |
| Vol. 12 | Satellite Tracking Facilities | Thomas |
| Vol. 13 | A Tracer Experiment | Kamen |
| Vol. 14 | Cancer | Woodburn |
| Vol. 15 | Computers | Thomas |
| Vol. 16 | Experiments in Psychology | Blough and Blough |
| Vol. 17 | Oceanography | Yasso |
| Vol. 18 | Optics | Gluck |
| Vol. 19 | Orbital Space Flight | Seifert and Seifert |
| Vol. 20 | Our Plant Resources | Fitzpatrick |
| Vol. 21 | Photosynthesis | Rosenberg |
| Vol. 22 | Protozoa | Hall |
| Vol. 23 | Viruses, Cells, and Hosts | Sigel and Beasley |
| Vol. 24 | Wings into Space | Caidin |

Holt, Rinehart and Winston, Inc.