IBM

World of Numbers

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1 Introduction

A compelling urge to understand the "how" and the "why" of the world has given a spark and a continued vitality to the growth of civilization. Men have constantly sought and found answers to their questions. They have created inventions for their needs. Their ingenuity has led to better and better ways to harness the forces of nature and has produced an endless list of new products and discoveries.

In the early days of civilization, each man had to depend upon his own imagination and intelligence to devise his few conveniences. Perhaps centuries went by before some flash of insight led to a crude bow and arrow for hunting. Many more years of trial and error probably elapsed before this invention was perfected. But answers, new inventions, discoveries and insights gradually were accumulated to create a gigantic fund of knowledge which every man could use to stimulate his thinking and to enrich his living.

As the storehouse of knowledge and understanding has grown, the rate of progress has increased tremendously. For example, airplanes have been improved from hazardous mono-planes to sleek multi-engined jets within the last fifty years. Yet, men have dreamed of sustained flight since the birds first gave them the idea. This desire appeared as early as a story in Greek mythology in which Icarus and Daedalus tried to fly using large wings attached to their arms. Hundreds of years later, Leonardo da Vinci drew brilliant plans for a "flying machine." But the fulfillment of the dream had to wait until the 20th century. It had to wait until the knowledge and techniques for translating ideas into useful products could catch up with men's imagination.

Today — scientists, engineers, and businessmen are inventing, developing, and improving a myriad of new products and conveniences with amazing rapidity. To these men, the most promising tools among the technical developments of recent times are machine methods for processing the complex data on which business and science depend. But data processing machines did not "just happen." Their development has been the result of an intensive, never-ending research program which has utilized knowledge accumulated over the centuries.

At the beginning of civilization, *communication* was one of the first problems of the men trying to band together into groups. Sounds, gestures, pictures, and signs — symbols which represented an idea — became essential for men to convey their thoughts and discoveries and to pass on knowledge to their children. As verbal symbols were refined and improved, the resulting language grew to become an effective method for speaking. Later, written symbols began to develop into a large vocabulary for permanently recording ideas.

Before long, men found a need to express many of their ideas more accurately. Rather than say a rock was "big," they wanted to say "how big." Rather than say another village was a long distance away, they wanted to say "how far." So special written symbols — numbers — were devised to represent length, size, and quantity. As these numbers were applied to more and more ideas and situations, men began to think with new precision. Thus, mathematical ideas began to grow — ideas which have made a tremendous contribution to every branch of human knowledge.

Today, many languages are used in various parts of the world. Specialized vocabularies are required in certain industries and professions. But in the endless applications of mathematics there is one universal language—the language of numbers.

When you see the numbers 21, 515, or 1099, you can recognize a definite *quantity* immediately. There is no room for misinterpretation. They mean the same thing to you as they meant to Galileo and to Sir Isaac Newton. When you add, subtract, multiply, or divide numbers, you perform the same operations and get the same answers as other people obtain in all countries of the world.

From the brief story of numbers which follows, we shall see where and when the numerical symbols we use today were invented and how they were improved to reach their present usefulness. These symbols and the rules of mathematics for handling them have given reality to a machine age, then an electronic and atomic age — now, a space age.

2 The Story of Numbers

As soon as primitive man was able to satisfy his basic needs for shelter and food, he started searching for ways to express himself. His first "written" expressions were probably the picture symbols he used to decorate the rock walls of his cave. Initially, these were crude imitations of the objects he found in nature. Symbols for the sun and moon were frequently used in primitive art.

Soon, however, he made an attempt to express "how many": how many animals he had killed in a hunt; how many children belonged to his family. During earliest times man eventually grew to understand elemental concepts of quantity. He used the terms "one," "several," and "many." The next big step forward was when he began to draw pictures on the walls of his cave in order to *represent* quantity: one picture stood for one animal, "two" animals were symbolized by two pictures. But as he continued to apply the budding genius of his reasoning mind, the thought of using a special symbol or notation to represent a quantity occurred to him. This marked a tremendous leap in his imagination for it enabled him to think about an exact quantity as an *abstract idea*. For example, he no longer had to spend the time and effort to draw five pictures in order to represent five animals. He began to use a special symbol to represent the quantity "five" — a number which could be applied to other objects and compared to other quantities. Thus, a "number language" grew to become an accurate and convenient method for counting and measuring.

At first, man counted on his fingers. Then he tried crude but effective methods of notation to record quantities: scratches on stones, or notches in sticks.

As civilization grew more complex and commerce advanced beyond simple bartering, a systematic scheme of numbers became necessary. By the time of the first dynasty in Egypt, as early as 3400 B.C., simple hieroglyphic forms for the units and tens of a decimal system had been developed. They were not only used for more complex business transactions, but also were applied to architecture and astronomy.

Only a few hundred miles away, another system for representing numbers was developed in the Babylon of Nebuchadnezzar. Damp clay tablets were engraved with wedge-shaped (cuneiform) symbols. Since the tablets were carefully baked and hardened in the sun, we can still study these symbols fifty centuries later.

On the other side of Asia, the Chinese culture of 2800 B.C. devised an advanced decimal system. The Chinese could count in high numbers, record time and measure angles.

Near the shores of the Mediterranean, other number systems were being devised. The ancient Greeks developed an alphabet and used certain characters as numerals.

The Hebrews also applied their alphabet to units, tens, and hundreds.

The Romans took letters to represent sums from units to thousands and even devised a primitive subtraction principle ("40" was "50" minus "10"). The use of Roman numerals continued for centuries.

Our own numbers – the so-called Arabic numerals – are probably of Hindu derivation as well as Arabic. Scholars have traced the resemblance back to Sanskrit characters . . . and to tenth century Eastern Arabic.

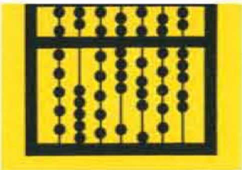
It has been the art of recording quantities, beginning with the crude scratches of the cavemen, that has helped civilization to grow through the ages. Numerals had to come first before man could invent the ingenious methods for handling and manipulating numbers which we call mathematics . . . in order to build temples and churches, to construct roads and ships, to draw maps and to develop commerce, to fire the spark of invention and scientific discovery, and to extend man's knowledge beyond the boundaries of his own planet. Were it not for numbers and the branches of mathematics which they have encouraged, the world as we know it today could not exist in this, the 20th Century.

3 From Numbers to Mathematics

As mathematics grows, so grows civilization.

Men of ingenuity and imagination were not satisfied with just counting. They looked for and invented methods to manipulate and apply numbers. These methods became important tools for exploring, measuring, and defining some of the mysteries of the world. We call these tools "Mathematics."

Mathematics has now grown into many specialized branches of knowledge such as algebra, trigonometry, calculus, and statistics. Several of these branches and the contributions they have made to our way of life are described in the following outline.



Arithmetic

In the beginning there were numbers.

Arithmetic began as a spoken language and later developed into a written system of notation for counting and measuring. As improvements such as multiplication and division were devised, arithmetic provided an extremely useful method for manipulating quantities.

Although our modern number system is very similar to that used by our ancestors, arithmetic still makes a vital contribution to daily living. A grocer adds up your bill, a bus driver makes change for you, you keep score of an athletic game or a bridge game, and budget your money—all these things and many others would be impossible without a knowledge of arithmetic.

In addition to its direct usefulness, arithmetic has also stimulated ideas which have gone far beyond simple counting—the ideas of mathematics. After we consider some of the inventions and physical sciences which it has vitalized and advanced, it will be evident how justly mathematics is called "Queen of the Sciences."

Geometry

The road to design is paved with precise lines.

Geometry includes some of man's earliest discoveries about the physical relationships around him. It is concerned with the study and measurement of the shapes and sizes of things. Geometry seeks relationships and laws which govern figures and their parts.

Geometrical discoveries, such as the relationships among triangles and other common figures, led to a tremendous growth of architecture, construction, and art. Gothic architecture is based on the triangle. The dome and the arch are products of geometric knowledge.

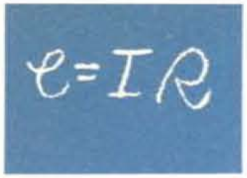
Trigonometry

A hypotenuse is judged by the sides it keeps.

Trigonometry is the science for investigating the laws governing relationships between the angles and sides of a triangle.

This branch of mathematics developed from first examining the properties of a right triangle in which such relationships are apparent. In a right triangle—one with a 90° angle—the "sine" of an angle is defined as the ratio of the length of the side opposite the angle, to the length of the hypotenuse (the longest side of the triangle). This ratio is a numerical value which is the same for a given angle, no matter how large the triangle may be. If the size of one angle and the length of one side are known, the length of an unknown side can be found without actual measurement. It can easily be calculated by referring to tables of sine values.

Later, the science of trigonometry was extended to a variety of triangles and the resulting principles were applied to many problems. With a knowledge of trigonometry, surveyors can determine the heights and distances of inaccessible objects such as mountains and landmarks, navigators can determine their location at sea, and engineers can improve the accuracy of their construction.



Algebra

Great equations from many situations grow.

Algebra is a technique which uses special symbols as well as numbers to represent quantities. The relationships among quantities may be expressed by shorthand methods called equations or formulas. Algebraic laws were devised which govern the manipulation of these symbols and equations so that they will yield meaningful answers to a great variety of problems.

For example, algebra may be applied to the following problem: A plane has a ground speed of 330 miles per hour. Due to headwinds, a 2600 mile trip from San Francisco to New York took 10 hours. How fast were the headwinds blowing?

We may state the logical relationships of this situation in terms of the variables involved: The distance traveled (d) equals the rate of travel (r) multiplied by the time of travel (t). Or in algebraic terms: $d = rt$. In this problem dealing with two rates of speed, we know that the effective speed of the plane will be reduced by the headwinds. If we let r represent the speed of the plane and w represent the speed of the headwinds, then the effective speed of the plane may be represented by $(r-w)$. By substituting the numerical values in the equation, we find:

$$2600 = (330 - w)\,10$$
$$2600 = 3300 - 10w$$
$$10w = 700$$
$$w = 70 \text{ mph, the speed of the headwinds}$$

Calculus

Hitch your mathematics to infinitesimals.

Many complex problems cannot be handled conveniently by algebraic techniques alone and here is where calculus enters the picture. Essentially, calculus is concerned with examining the effect that a change in one variable has on other variables of an equation. To do this, calculus breaks down any such change into a series of small changes called "increments." It then examines these changes under a "mathematical microscope" in order to reach final conclusions about their effect on the equation itself.

This branch of mathematics helps us to answer certain questions about rates and curved motion such as the flight of a projectile. We may also examine complicated problems involving summations—the volume of an irregular solid, for example. Other problems which we may analyze by the techniques of calculus include situations dealing with a *rate of change* in shape or volume as when sand is poured into a conical pile.

The movement of atomic particles, the behavior of gases, the laws of heat or thermodynamics and other scientific advancements, all have been helped by the precise analytical techniques which calculus has provided. Industry has applied these discoveries to develop heating systems, nuclear power units, and communications. Many major contributions to the basic principles of business machines have been made by calculus whose techniques can now be handled by the very machines they helped to make possible.

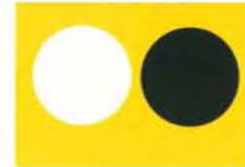
Statistics

To count is human, to find truth, immortal.

The science of statistics applies mathematical techniques to a series of similar events in which there may be a trend or a "general conclusion" but in which all events will not be exactly the same. Data such as that concerning the popularity of a TV program, or the average height of a group of people may be collected and then analyzed statistically.

For example, we might statistically find from a large number of measurements that the average height of 21-year-old Americans has increased 0.05 inches since last year. However, we probably made certain measuring errors which could have a profound effect on our results. Hence, the results are meaningless until we can include a value which indicates our probable measuring error. If we find from calculation that our most probable error falls within the range ± 0.01 inches, we would then say that 21-year-old Americans are from 0.04 to 0.06 inches taller than they were last year. By attaching an error we give a significance and a reliability to our answers.

Statistics is also concerned with much more complicated ideas than our example. These include the study of data distribution over a given range of values and the determination of the validity of samples.



Logic

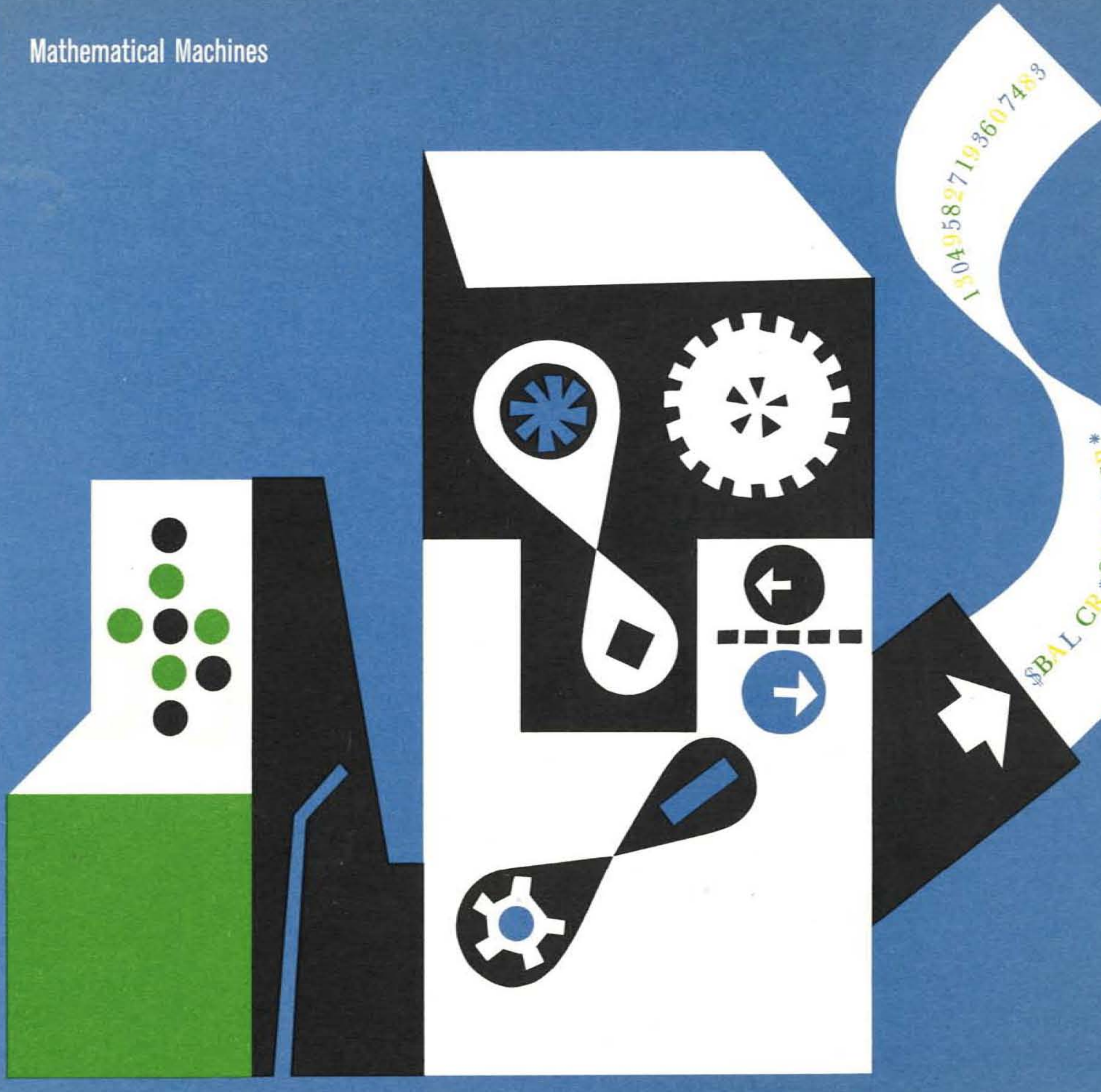
Reasoning is next to understanding.

A relatively recent application of mathematics is to the field of logic. Logic is concerned with expressing *qualitative* as well as quantitative ideas in mathematical form. By applying mathematical techniques to these expressions, a new tool for discovering truth is available. A simple example of logic is the syllogism: If b follows from a, and c follows from b, then c follows from a. For example, I am a man. All men are mortal. Therefore, I am a mortal.

However, we must strictly observe the rules for handling these expressions, or we will reach meaningless conclusions. Consider the inaccurate syllogism: All elephants are animals. All mice are animals. Therefore, some mice must be elephants.

Studies in logic can become very complex. For example, we use *symbolic logic* in its more advanced forms to help design a modern electronic computer. Thus, simple electronic elements can be efficiently combined to perform very complicated operations.

4 Mathematical Machines



Not only have the fundamental principles of mathematics made great contributions to our civilization, but many of our modern activities would be impossible without the machines which mathematics has directly inspired. For example, business machines have become so valuable that they are now used in virtually every phase of business and industry.

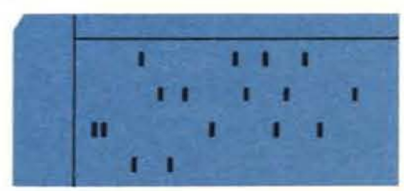
With modern methods of measuring and testing, a huge quantity of information accumulates which must be processed quickly and accurately. A vast amount of data constantly pours into such places as retail establishments, weather stations, insurance companies, and tax bureaus. In addition, our rapidly expanding scientific investigations need faster and faster methods for carrying out increasingly complex calculations. To meet these demands, machines which can compute, select, and correlate data at electronic speeds have been developed.

Machines to handle data were a natural sequel to mechanization. Machines theroetically can be built to perform almost any action—sewing a button, for example. If this seems far-fetched, it is probably because you are picturing a person sewing a button by hand and are thinking of a machine doing this task in the same way. Machines, however, are frequently designed to use methods entirely different from manual ones. If we broaden the picture to that of an assembly line where workers are sewing thousands of buttons on garments, hour after hour, the economic need for machines becomes obvious.

Thus, functions can be mechanized efficiently and economically when they are sufficiently *repetitive*. In the factory where mechanization first began, it became apparent that certain operations could be handled by machines. Hence, the drill press, lathe, milling machine, and grinder were invented.

In a similar way, equipment was invented to mechanize paper work. One of the first "paperwork machines" was the ink stamp, possibly because the operation of applying a date or name was so obviously repetitive. As additional mechanization was applied to paper work, machines

began to take over the long and painstaking tasks of accounting.



An invention which led to the growth of automatic machines to handle data was the punched card invented in 1889 by Dr. Herman

Hollerith. The principles of his tabulating system are the basis of all the well known and widely used IBM punched card machines. On punched cards, the scientist or businessman can "code" data so that the machines can "read" the information and handle it automatically. The results from machine computations can be produced in the same code and quickly converted into printed reports.

In business, a vast quantity of original information has to be processed. Documents are received in all sizes, shapes, and conditions from many different sources. Because the very basis of accounting is assembling "like" items, the accountant must classify and rearrange these items, visually refer to them, write them down over and over again, perform the necessary calculations, and store the results for years in many different forms or records.

Although accounting applications of business machines require a certain amount of arithmetic such as accumulating totals and balances, the problem is principally one of *processing* data. A large amount of information is fed into these machines ("input") and a large quantity of information is produced ("output"). Hence they are called "Data Processing Machines."

The first data processing machines had to handle information in a series of individual operations. These included punching information into cards, sorting and classifying cards, producing totals and balances, and finally printing the results. Intermediate results from one machine had to be transferred to another, and many human decisions and interventions were necessary for a complete accounting procedure.

When electronic discoveries were applied, the rate of calculation was vastly increased compared to earlier machines. But more important, a basic new technique was introduced which might be called "intercommunication." Electronic devices were able to provide *internal* methods for transporting data and intermediate results from step to step. Hence, it now appears that data is fed into one end of the *machine system* and results come out the other.

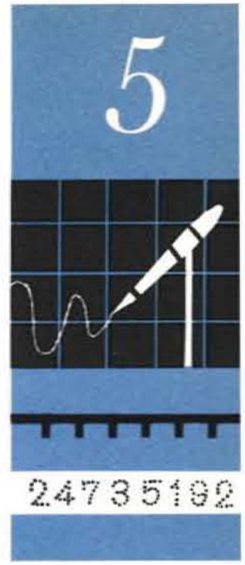
This method, however, is not totally different from earlier ones because each step in a complete procedure must be predetermined and "programmed." Programming is simply the method for giving instructions to the machines. A series of instructions, called a program, is expressed in symbols which a machine system can accept and understand. Since a system has no ability to "think for itself," we must tell it how to handle information in a specific and logical way in order for it to produce meaningful answers. Because electronics has made possible a continuous flow of operations within one system, programming has naturally become very important.

Despite the amazing capacity and usefulness of modern data processing systems, improvements are still needed to keep pace with the growing volume and complexities of business. New problems in business and industry must be solved: How can the businessman determine the best place to locate a new factory or retail outlet to insure maximum profit? How can factory management obtain maximum production from available equipment? Such problems as these are placing growing and continuing demands on the capabilities of automatic data processing systems.

For the scientist, the situation is different. Usually his problems involve a small amount of both machine input (source data) and output (answers). However, there is a tremendous number of computations which must take place within the machine to produce the results. In solving a scientific problem, such as one in a guided missile trajectory, millions of arithmetic operations are performed on only a few hundred initial factors. Hence, the term "computer" accurately defines the machine needed.

In answer to the need for improved machine systems, IBM built the first large-scale calculator, the Automatic Sequence Controlled Calculator. This system has operated successfully at Harvard University since 1944. Its remarkable performance is largely responsible for starting the present lively developments in the field of giant electronic computers.

There is now a great variety of machine systems available for the computing needs of science, business, engineering, and defense. Additions and improvements are being developed with an amazing rapidity. One indication of the progress man has made in handling numbers is to compare the modern electronic computer with earlier methods of counting: One giant computer can operate faster than 500,000 men with desk calculators. Think how long these operations would take with just paper and pencil!



Two Families of Computers

Two types of computers have been developed. They are very different in construction and application. One is *analogue*. The other is *digital*.

Analogue Computers

An analogue computer is essentially a device which accepts continuous measurements and produces continuous solutions to mathematical equations. In an analogue computer the components of electronic circuits, gear mechanisms, and other devices can be arranged to behave just like the relationships of variables in a mathematical equation—to behave *analogously* to an equation. Frequently, the equations are those which have been developed for thoroughly describing a physical situation such as the motions of a projectile in flight.

To handle information, an analogue computer must translate the mathematical relationships of a problem into analogous physical relationships of its operating components—electronic circuit elements, gear ratios, shaft rotation, etc. *Continuous* measurements are then fed into the computer, the machine uses the information to solve thousands of complex, inter-related equations, and answers are produced as a *continuous* record on a calibrated scale. Usually answers are traced on a graph by a pen, are indicated on a plotting board, or shown on a dial.

There are many common uses for simple analogue devices. An example is the slide rule. Instead of multiplying two numbers together, we can accomplish the same thing by adding their logarithms. On a slide rule, we add analogues of the numbers—lengths proportional to their logarithms. The result from adding the two lengths together is translated back into the corresponding numerical value and we have performed multiplication by a simple analogue method.

Another example of an analogue computer is the speedometer in your automobile. It converts the rate of turning of a cylindrical shaft into a numerical approximation of speed in terms of miles per hour. Here, the analogue of speed is a shaft rotation.

The previous examples of analogue computers were quite elementary ones. However, these computers are also used for many complex purposes. Many fire control systems for tracking planes are analogue computers. Variables, such as wind drift, plane speed, ship speed, range, and direction are continuously fed into these devices. Their high-speed computing action produces results which enable gunners to anticipate the changing position of a plane, and fire a round which will hit the plane a few moments later.

Digital Computers

Digital computers have evolved through the ages: first in the form of the abacus, then as a crude adding machine invented by Pascal. Later, Leibnitz invented the ancestor of the desk calculator.

Digital computers owe their name to counting numbers on our ten fingers or "digits." *Counting* on the fingers is one way to obtain exact answers to simple arithmetic. Because we have 10 digits instead of twelve, or six, or eight, most computation is based on the familiar *decimal* system.

We have seen other symbols and number systems once used in Rome, Greece, or China. However, an increasingly important basis for counting is the *binary* number system. If we had just two fingers, our arithmetic might very well be based on the binary method which uses only two digits, 0 and 1.

In the chart, the familiar decimal numbers from zero to thirteen are compared with the corresponding binary symbols.

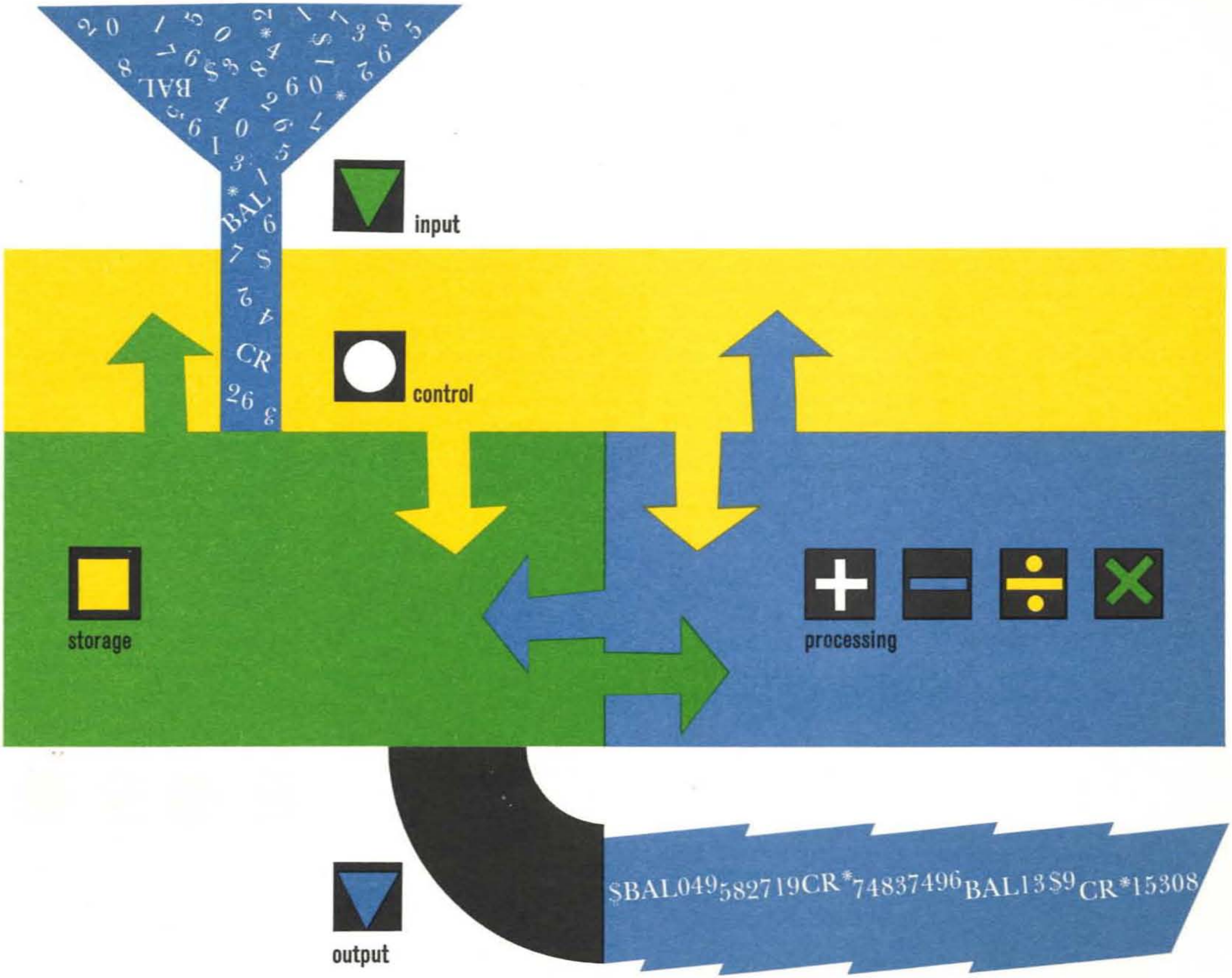
Decimal	Binary
0	0
1	1
2	10
3	11
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010
11	1011
12	1100
13	1101

Notice that shifting a decimal number one place to the left multiplies its value by ten, whereas shifting a binary number one position to the left multiplies its value by two.

Some of the fastest electric and electronic devices use the binary system. Since only two digits are required, binary numbers may be represented in electronic equipment by the physical state of the electronic circuits—on or off. The "on" condition may represent "1," and "off" may represent "0." The binary number 1101, equivalent to the decimal number 13, would appear:

Fortunately, machines have been designed to accept decimal numbers, convert them to binary, compute in binary, and then deliver the answers in decimal—an automatic procedure which greatly simplifies operations.

6 Organization of Digital Computers



A digital computer has the following elements in one machine system:

Input

Digital computers accept numbers, letters, and symbols. Information is fed into the system from punched cards, punched paper tapes, magnetic tape, or inserted manually from a keyboard or switches.

Control

The computer must operate under the direction of a *control* unit. The sequence of steps to be performed must be translated into detailed instructions which the system can understand. A series of instructions is called a "program" and since it is retained in a storage device, it is called a "stored program." These coded instructions in storage are available to the control unit as needed to direct and complete an entire sequence of operations. Special instructions enable the processing unit to make logical decisions based on intermediate results. These decisions allow the system to select the proper course among several alternatives for solving a problem.

Storage

Data can be internally stored in a system by electro-mechanical, magnetic, or electronic devices, until needed. Stored information is readily accessible, can be referred to once or many times, and can also be replaced whenever desired. The information memorized by the system can be original data, intermediate results, reference tables, or instructions. Each storage location is identified by an individual location number which is called an "address." By means of these numerical addresses, a data processing system can locate data and instructions as needed during the course of a problem.

The speed of processing is largely dependent on the "access time"—the length of time required to obtain a number from storage and make it available to other units of the computer system.

Processing

The processing unit can add, subtract, multiply, divide, and compare numbers in a manner similar to a desk calculator, but at lightning speed. Complex calculations are always combinations of these basic operations. The processing unit can make logical decisions. It can distinguish positive, negative, and zero values and transfer this information to other units of the computer.

Output

After doing its work, the computer can transfer answers to storage or "write" them directly. Results may be punched into cards, recorded on magnetic tape, or printed in report form. Printers handle high-speed computer output by printing an entire line of information at one time.

The organization of these components to form a computer may be seen from the illustration. We may compare the functioning of the elements of a computer to the steps in solving a problem by paper and pencil methods. The *input* would correspond to the information given in the problem. The *processing* unit performs the same function as our manual calculations. *Storage* may be compared to the work papers on which we note intermediate answers. A knowledge of arithmetic rules *controls* our handling of the problem and our answers provide an *output*.

7 The Stored Program

"Program" is a concise way to say "series of instructions." A program defines in complete detail exactly what a machine system is to do under every conceivable combination of circumstances. If some instruction is omitted from the program, the system is helpless when it comes to that part of the problem.

Because these systems can interpret numbers, their instructions are also stated in a numerical code. One instruction will tell what operation to perform, another will tell where the factors are stored, and still another will tell what to do with the answer. All of the instructions, in the proper sequence necessary to accomplish a given operation, form the "stored program."

To program a problem on a computer, it is necessary to use an "operation code." A simple operation code might be the following:

Operation Code	*Operation*
10	*"add"*
11	*"subtract"*
21	*"store the result"*

These operation codes might be used in a "stored program" in the following manner:

	Operation Code	*Storage Location*
Instruction #36	*10*	*0679*
Instruction #37	*10*	*0680*
Instruction #38	*11*	*0681*
Instruction #39	*21*	*1027*

Instruction #36 tells the system to "add" the factor stored at location 0679 within the computer.

Instruction #37—to "add" the factor stored at location 0680.

Instruction #38—to "subtract" the factor stored at location 0681.

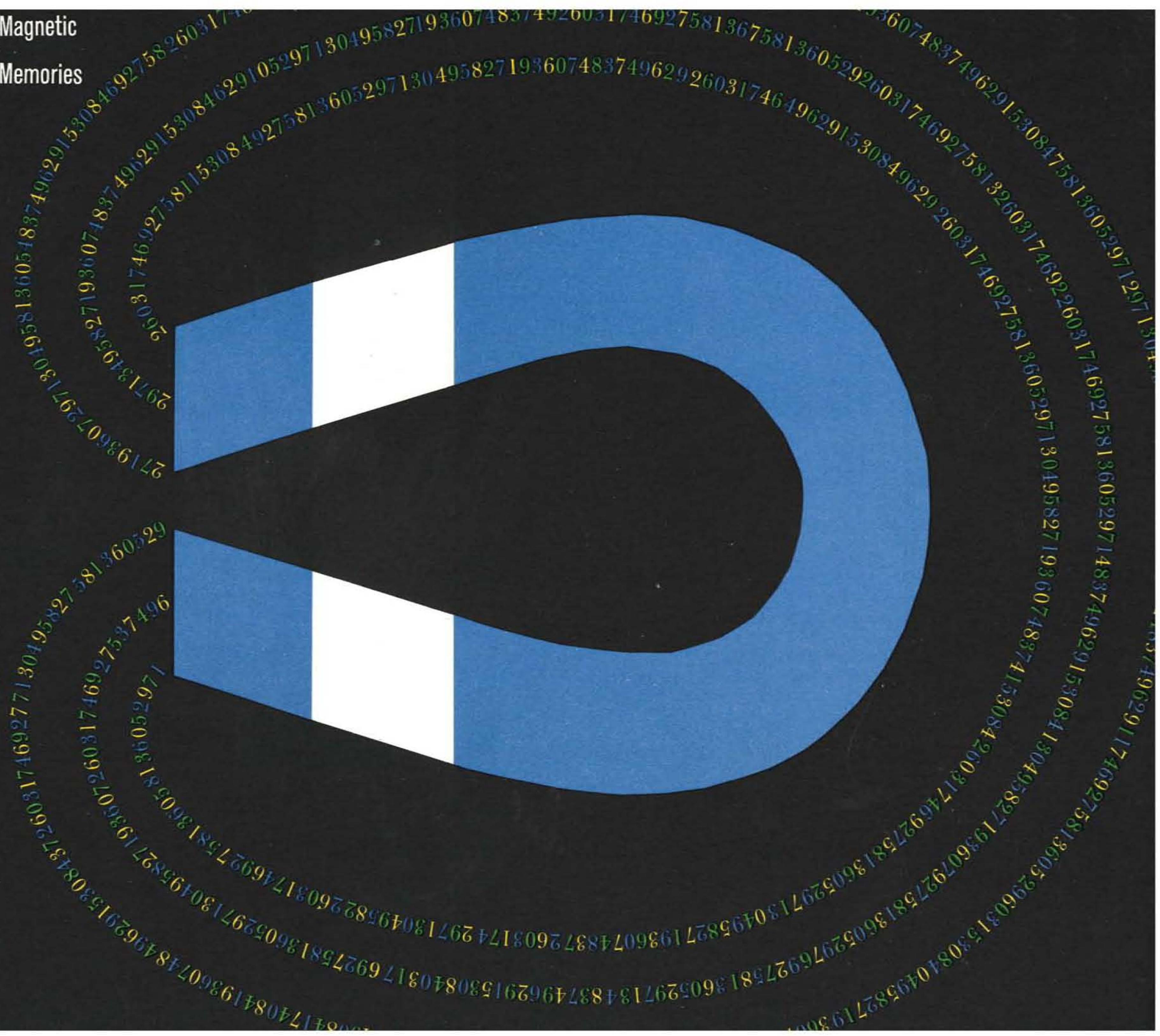
Instruction #39—to "store the result" of the two additions and the one subtraction at location 1027.

The number of instructions required for the complete solution of a problem may be a few hundred or many thousands, depending upon the problem. They are stored in the internal memory or storage unit of the computer. The system refers to them one after another, or it can be instructed to make the logical decision of skipping over certain instructions depending on intermediate results and circumstances.

What does this decision-making ability mean in terms of applications? For one thing, it enables computers to handle exceptions to standard procedures. A system will remember the proper instructions for dealing with the exceptions and will automatically handle any kind of a situation that develops.

Although today's systems are amazingly powerful, future computers will be able to handle much larger and more complex operations than present models.

8 Magnetic Memories



The electronic computer depends on memory devices which have the ability to store and remember fantastic quantities of information. Although computer engineers have been able to increase the speeds of calculation and data transfers by improving processing circuits, recent developments in data processing systems are largely discoveries and improvements in *storage* methods. Because of their capacity and flexibility, these storage components have prompted new approaches to the control and internal organization of machine components.

Modern storage methods—tapes, drums, disks, and cores—are all based on ingenious ways of utilizing magnetic principles. However, continuing research efforts are concerned with exploring other principles for storing information.

Magnetic Tape

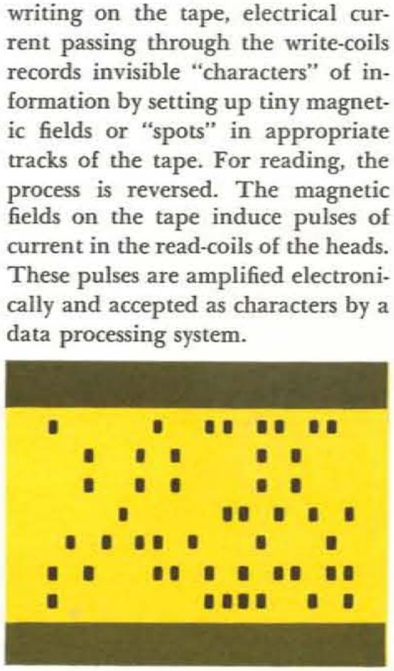
One of the newest storage media is magnetic tape. In addition to storage, magnetic tape is also used for both input and output.

Although the principles of magnetism have been known since the end of the last century, practical magnetic recording is a comparatively recent achievement. Many radio programs and phonograph records are first recorded on tape. Even television sound and pictures are recorded on tape for later transmission. Now, numerical and alphabetic data may also be recorded and stored on tape.

The ancestor of magnetic tape is punched paper tape. Paper tape has made important contributions to such fields as railroading, stock brokerage, and inventory accounting. But the magnetic record is far more versatile, more compact, and has opened up many new areas of application.

Like punched paper tape, magnetic tape comes in a continuous strip. The magnetic tape is usually ½″ wide and made of plastic or metal. It has a surface coated with a material which can be easily magnetized and will retain the magnetized condition. As is the case with punched paper tape, magnetic tape is divided into parallel channels or "tracks" along the length of the tape. A typical tape might have seven tracks: six of these could store the coded representations of numbers, letters, or symbols; the remaining track could be used for a system of checking the accuracy of reading and writing.

Seven reading-writing devices called "heads" are spaced across the tape, one for each track. The heads are tiny electromagnets wound with a read-coil and a write-coil. When writing on the tape, electrical current passing through the write-coils records invisible "characters" of information by setting up tiny magnetic fields or "spots" in appropriate tracks of the tape. For reading, the process is reversed. The magnetic fields on the tape induce pulses of current in the read-coils of the heads. These pulses are amplified electronically and accepted as characters by a data processing system.

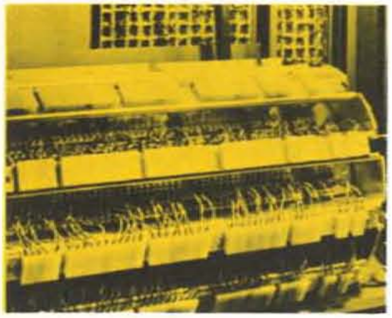


A particular reel of tape can be either read or written upon during any one cycle through the tape unit. It can be used one time for reading and the following time for writing if there is no need to save the data previously stored on the magnetic tape. A reel of tape can be used thousands of times. Writing new information automatically erases data written in a previous operation.

A typical tape might contain a series of unit accounting records, one following the other in a definite sequence. When used with IBM systems, the length of the unit record is completely flexible, although records of the same type generally will be the same length. Because the magnetic recording is closely packed, a single reel of tape may contain many thousands of unit records—the exact number depending upon the size of individual records. It is possible to have as many as 25,000 unit records of 80 characters each on a single reel (2400 feet of tape). This compactness is one of the most important advantages that tape has to offer.

A data processing system can have a number of separate tape units attached to it. Thus, it is possible to introduce data from many files into the same operation and to select records at will from various tape units as required by the application. Additional tape units can be utilized to write new records resulting from the processing. It is this "multiple file processing" feature, coupled with the great speed of tape reading and writing, that enables input and output of the system to keep pace with the rate of electronic computations.

Magnetic Drum



Another recent development is the magnetic drum. Essentially the same process of recording on magnetic tape can be accomplished with *drums,* but with important differences.

If you were to take forty lengths of five-track magnetic tape, and wind them side-by-side around the outside of a cylinder, you would have a magnetic drum in principle. Each track on the drum has a read-write head for reading and recording data—five heads per circular section. These 40 sections are each divided into 50 specific locations so that a total of 2,000 "addresses" are available for storing information. By means of the numerical addresses, a data processing system can locate both data and instructions as needed to handle a problem.

The drum is mounted on a shaft. A motor rotates it, causing the surface to travel past the heads thousands of times a minute. The control unit of a system can switch to the read-write head for any track almost instantly. This means that all the information stored on the drum is available thousands of times every minute.

However, a drum cannot store as much information as a reel of tape, simply because it doesn't have as great a total magnetic surface area. Depending upon its size, the drum can store from 5,000 to upwards of 100,000 characters. Each of these characters can be read or written in a few thousandths of a second—a speed which gives drums a major advantage over tapes. It usually takes much longer to find a record at random on magnetic tape since the information wanted may be in the middle of the reel or at the other end.

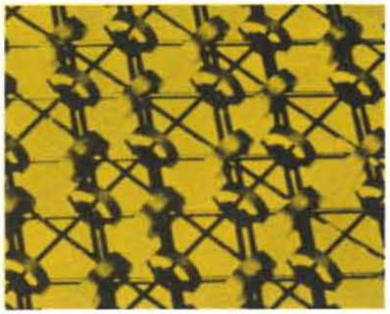
Magnetic Disk

A new storage method is used for IBM RAMAC® Data Processing Systems. RAMAC—Random Access Method of Accounting and Control—is based on magnetic disks. As the name implies, information in the storage device can be quickly located at random without searching through all the records.

A typical memory unit consists of 50 magnetic disks slightly separated from each other and mounted on a central vertical shaft. Data is recorded on both sides of the disks so that 100 disk faces are available for storage. Each disk face has 100 circular recording tracks, and each track holds five 100-character records. Stored records are available to the system through electronically controlled "read-write" arms which move vertically and horizontally at very high speeds when searching for a particular storage location on a disk face. Any address in memory can be located in a fraction of a second, and each unit will store millions of characters of information.

The RAMAC System now makes "in-line" data processing possible. Business transactions once had to be accumulated and then processed in batches. But RAMAC now allows each transaction to be processed as it happens. In addition, all files affected by the transaction are brought up to date in one processing step.

Magnetic Cores

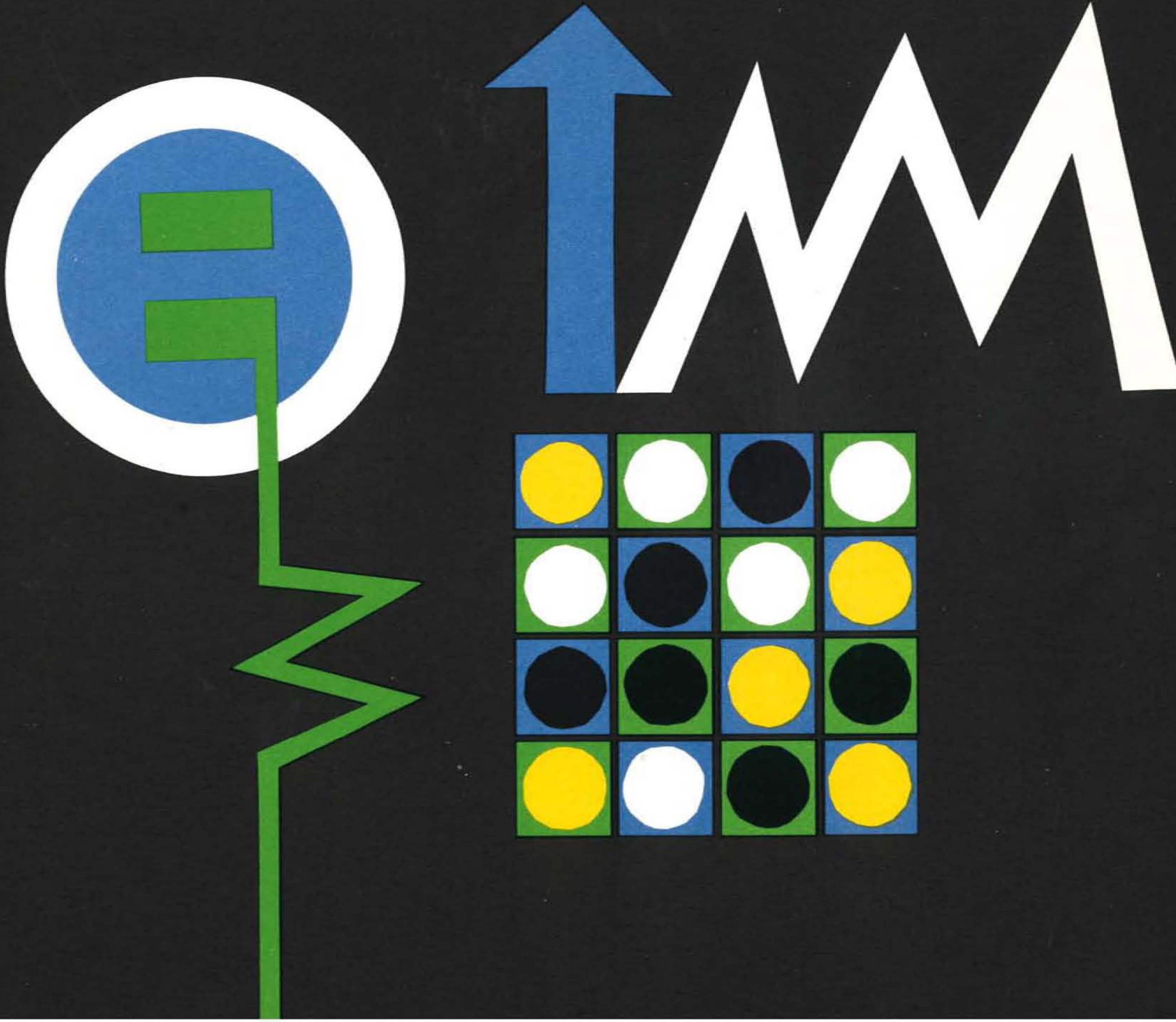


The most powerful memory devices use core storage. These memory units are composed of thousands of tiny, doughnut-shaped, ferro-magnetic rings threaded on wires. A magnetic field is set up by passing an electrical current along a wire through a core. When the current is removed the core remains magnetized. Passing current in the opposite direction reverses the magnetic field. Thus, the direction of the magnetic field represents a 0 or 1, a + or −, a "yes" or "no" condition. For machine purposes this is the basis of the binary system used for storing information.

Core storage provides two big advantages—dependability, and "instantaneous access" to stored information. It provides access to data and instructions in a few millionths of a second and can remember information for as long as needed.

9

Looking into the Future



In less than a decade, the use of giant computers has expanded far beyond the original intention for which they were designed. Initially built to handle scientific and engineering problems, modern computers have become known as electronic data processing systems—invaluable servants to businessmen and scientists alike in a world of numbers. In the office, the laboratory, the factory, these data processing systems are accomplishing prodigious feats by untangling and simplifying an avalanche of calculations and paperwork. There is more time for creative work. Clerical personnel are freed from monotonous tasks. The businessman has timely reports of increased accuracy—often information which would have required hundreds of man-years to compile manually.

Recent developments – increased processing speed, larger storage capacities, and an ability to make logical decisions—have now made it practical to apply electronic computers to an ever-widening area of use. One promising new computer application is "simulation and risk" studies. These applications are among the most fascinating developments in business and engineering for they are minimizing the trial and error which formerly was necessary. New design features of airplanes can now be simulated and studied on digital computers before building expensive test models. The entire distribution network of a public utility can be simulated. Electronic systems can take much of the risk out of designing a proposed industrial machine by calculating whether or not a particular design will operate successfully. Some of the risks of investing capital in new equipment for industrial expansion can be programmed. The most strategic places to locate new factories or retail outlets for maximum customer convenience and volume of business can be determined.

The applications of electronic computers seem to have no limit. Now, data processing systems have started to be applied to an even more significant problem—the management of business itself.

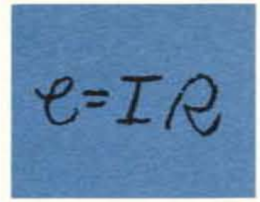
There has always been a subjective quality to business. Experience, application of knowledge, business aptitude, and vision are several of the factors which can produce a "good businessman." However, several of these factors are somewhat vague: "business aptitude" cannot be pinpointed to a definite set of rules and principles. Perhaps it never will. But there are many decisions in business management which are directly dependent upon *facts* and *logical factual relationships*. It is to this area that computers can be applied to produce a more scientific method for operating a business. We might call this new idea "Management Science." Businessmen have already started to use the term.

To put this concept into operation, vast amounts of the data describing a business must be collected and analyzed. Several automatic data collecting systems are now becoming available, including the IBM APR (Automatic Production Recording) System. This machine system can collect, correlate, store, and record accurate production data such as quantity, weight, length, pressure, and temperature. It thus eliminates the time lag and possible errors of manually collected information. Data collected by APR can be used as input for further data processing to produce on-the-spot reports to factory supervisors. Consequently, management is assured of receiving accurate and timely production information to improve control over industrial operations. We might say that APR keeps a continuous record of the pulse of the assembly line.

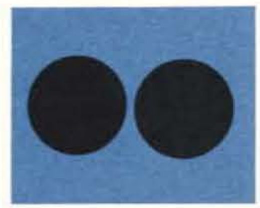
Facts collected in this and other ways are now fed into data processing systems and analyzed under the direction of stored programs of instructions. The studies of machine logic have made it possible to program instructions and procedures so that the system can make "decisions" among various possibilities presented to it. By applying a "success criterion" such as minimum costs, the computer can determine which possibilities will tend to produce the desired results. It will not be long before computers will receive information from the assembly lines, and then make automatic decisions which will vary and control production procedures by issuing instructions *directly* to the production machines on the assembly line.

But businessmen and business judgment will not be replaced by machines! Just as accounting machines freed people for more creative work, electronic computers will not only provide information never available before, but will free businessmen from the drudgery of making routine decisions based on tedious details and reports.

The age of electronic data processing systems is just beginning. The future is limitless. Today, business machines handle magazine subscriptions, checks, telephone bills, purchases, and income taxes. Machines enable scientists to "fly planes" on a computer, and to control the air defenses of a nation. Tomorrow's computing systems will help solve traffic problems, unemployment problems, nuclear power problems – even psychological problems.



In only a few short years, electronic computing systems have been invented and improved at a tremendous rate. But computers did not "just grow." They have evolved from the simple beginnings of numbers. They are a culmination of mathematical thought—thinking founded on the building blocks of arithmetic, algebra, geometry, and trigonometry, and nourished by the advancements of calculus, logic, and higher mathematics. They were born and they are being improved as a consequence of man's ingenuity, his imagination . . . and his mathematics.



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