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INTRODUCTION TO AUTOMATIC DATA PROCESSING

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U. S. ARMY

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HEADQUARTERS
U. S. ARMY SIGNAL SCHOOL
FORT MONMOUTH, NEW JERSEY

1 October 1959

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CHARLES M. BAER
Brigadier General, USA
Commandant

OFFICIAL:
WILLIAM B. WARE
Lt. Colonel, Signal Corps
Secretary

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AUTOMATIC DATA PROCESSING MACHINES AND SYSTEMS

Section I. GENERAL

1. PURPOSE, SCOPE AND DEFINITION

a. The purpose of this text is to describe the basic concepts of automatic data processing. It contains descriptive information on automatic data processing systems (ADPS), outlines the procedures involved in their use, and presents some of the actual and potential values of ADPS to the U. S. Army. Electronic computers are currently being used in diverse operations ranging from satellite tracking to supply management. The information contained in this text has been selected to demonstrate the most significant concepts of ADPS as applied to the command and management function.

b. The term Automatic Data Processing Systems (ADPS) includes the recording, filing, computing, data production, and sequential and automatic processes required for operation of the equipment in a business-type operation which involves the handling of supply, personnel, financial accounting, production control and statistical data.

2. NEED FOR AUTOMATIC DATA PROCESSING SYSTEMS

a. The existence of a modern tactical Army has created a pressing need for faster and more efficient methods of information processing. In order to control a $20 billion inventory and more than a million men, military management is turning to automatic data processing techniques. The application of electronics to Army data processing is a significant step toward effective planning, organization, and control of a mobile and diversified fighting force. What is needed is a flexible, efficient, and responsive combat support system. Design, engineering, and operation of such a system present a myriad of problems to the Department of the Army.

b. The primary problem is one of methods. How can we handle records, statistics and analyses more expeditiously while at the same time reducing the clerical army of human processors and increasing the speed and accuracy of the information? Time is one of the most important factors in military operations. Time means dollars saved, lives saved, battles won, and perhaps even the difference between final victory or defeat. The solution to this problem is an improvement in data flow that will facilitate more precise planning, organization, and control. Development, improvement, and refinement of electronic circuitry have simplified and partially solved this pressing problem. The electronic components and associated circuitry can be assembled into an efficient tool to simulate the functions of several thousand eyes, hands, and brains. Information converted to the language of electronics can be processed at the phenomenally high speed of electric current passing through a wire. The computer, or automatic data processing, is a significant step toward timely and efficient military decision and action in time of peace as well as war.

3. VALUES OF ADPS

The primary value of ADPS lies in its ability to digest large volumes of information, perform programmed (or preplanned) operations on this information, make computations based upon established criteria, perform additional tasks as the result of these computations, and at the same time transmit the final information or compilation to the action command. ADPS can receive, retain, add, subtract, multiply, divide, compare, sort, and put out large volumes of data at electronic speeds. Some of the more specific benefits which the Army may derive from utilization of ADPS are --

a. Provision of timely data for close control and coordination of the administrative, logistical, and operational activities of a widely dispersed and highly mobile field army.

b. Economy through conservation of personnel, materiel, and dollars.

c. Over-all improvement in the speed and accuracy of data processing previously effected by manual or mechanical methods.

d. Accomplishment, through the versatility and capabilities of the system, of functions never before possible.

e. Greater speed and effectiveness in collecting, processing, and reporting tactical information in such varied functional areas as combat intelligence, bomb damage assessment, meteorology, fire control and fire support.

f. Ability to perform functions at alternate sites.

g. At the present time ADPS is being used in air defense systems such as Sage and Missile Master. Although these are examples of special computers, it is anticipated that future systems will employ general types of variable programming computers.

4. PREREQUISITES FOR ARMY UTILIZATION OF ADPS

Before the Army can effectively utilize ADPS for these objectives, it must develop --

a. System concepts and conversion to detailed operational procedures.

b. Research and development to provide the equipment with military characteristics.

c. Equipment and system tests.

d. Personnel resources needed to install, operate, and maintain the equipment.

Section II. BACKGROUND OF ADPS

5. BEGINNINGS

The Chinese abacus, invented over a thousand years ago, is a simple computer that facilitates addition, subtraction, multiplication, and division. However, the abacus requires a human operator to guide it through each step of the operation. It is limited to the speed and accuracy of the operator, is severely limited in its capacity to store numbers and is, in effect, a speeded-up device for completing only one step in a mathematical process. Limitations of the abacus and similar devices led to early experimentation and development of mechanical calculating machines.

6. EARLY DEVELOPMENTS

In 1834, Charles Babbage designed the first analytical machine, which embodied in theory most of the basic principles of today's electronic computers and automatic data processing machines (ADPM). Most significant was the fact that his machine would automatically carry out a predetermined sequence of mathematical operations and make limited logical decisions based on the results of its own computations. The Babbage device had only limited speed and reliability, and it was many decades before Babbage's theories of mechanical processing were coordinated with the science of electricity to produce faster and more reliable data processing equipment. A number of technological advances, such as manual and electromechanical desk-type calculators, punch-card systems and, finally, the electronic computers and data processing machines as we now know them, evolved from Babbage's basic concepts.

7. PUNCH-CARD TECHNIQUES

The next milestone in ADPS was the development, between 1890 and 1900, of punch-card techniques and machinery. The basic principle of punch-card operations is the recording of data (numbers and letters) on a card in the form of coded combinations of punched holes. Eighty or ninety characters can be punched on a single card. This permanent record card may then be processed through a series of electromechanical machines to verify, sort, merge, reproduce, compare, compute, and prepare printed statistical reports.

8. NEW EMPHASIS

The advent of the punched card also introduced a new concept in volume record-processing techniques. Since punched-card processing was essentially mass information on record handling, it could no longer depend on a single machine processing approach. Emphasis was placed on the system and its logical work flow, rather than on a specific machine function. In this respect, the machines became tooling stations along the assembly line of job processing. Each of the components was designed to perform a specific and limited operation that was previously done manually.

9. LIMITATIONS OF PUNCH-CARD SYSTEM

The limitations of the punch-card system become more and more obvious as the need for high-speed data processing increases. Excessive data volume causes accumulation of bulky quantities of cards for processing. Since each machine performs a limited operation or series of operations, someone must carry the card records to the machine, stand by, load them by batches, and subsequently transport them to the next processing location. Someone must also maintain lengthy active files, and must sort, merge, search, and revise them frequently -- a further illustration of the inflexibility of punch-card processing.

10. ADPS

The automatic data processing system solves many of the above problems, since it integrates and expedites the processing steps. The military ADPS is another of the evolutionary steps which started over 1,000 years ago with the abacus. ADPS is a precise tool, designed to prepare information to assist the commander in controlling his organization.

Section III. ADPS CHARACTERISTICS

11. MAJOR CLASSIFICATIONS OF COMPUTERS

a. The names of the two major classifications of computers very accurately describe the computers themselves. Analog computers operate by analogy; that is, they compute using physical quantities which represent the variables of the problem being solved. Digital computers operate on digits; that is, they compute using numbers to represent all the variables of the problem. It is not possible to make a blanket statement as to which method is better; the choice depends on the application.

b. Many different types of physical quantities may be used to represent problem variables. Examples are length, water pressure, shaft rotation, mass, voltage, and wind velocity. An analog computer measures these quantities. Common devices which work by measuring (and hence are analog computers) are planimeters, slide rules, hour glasses, towing tanks, wind tunnels, and governors. These, however, are special devices, each designed for a particular job. There are general purpose analog computers available, too. The first of these was the Mechanical Differential Analyzer, an analog computer designed specifically to solve general differential equations. It used shaft rotations as its variable physical quantity. (Differentials were represented by speed and acceleration of shaft rotations; integrals were performed by counting shaft rotations.) This type of machine was supplanted by the Electronic Analog

Computer, a machine designed to handle general differential equations and associated problems similar to those handled by the mechanical machine. The physical variable is voltage. Functional operations are performed by altering the voltages, as, for example, by adding several voltages or differentiating them.

c. Digital computers have no physical variables to be measured; rather the quantities are represented by discrete (discontinuous) quantities -- digits. Many different devices may represent these digits. The most common are gear positions and electric or magnetic conditions. In every case, however, these devices are not continuous; they have only distinct states, such as on or off. A desk calculator or adding machine, for example, uses separate gear positions to represent quantities. In one column there are only the digits 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, with nothing between digits. An electronic computer uses a current which is either on or off, or a magnetization which is either one way or the other. Various values of current or strengths or magnetization are not considered.

d. Accuracy of these two classifications of computers is an important consideration. In the laboratory, under very carefully controlled conditions, measurements can be made to an accuracy of about one part in one million. This precision cannot be obtained at any reasonable cost in an analog computer. These machines are generally limited to one part in one thousand, or at best one part in ten thousand. There is no way of extending the precision of an analog computer without altering the machine itself, generally at very great cost. In a digital computer, however, where variables are represented by exact numbers, accuracy is limited only by the length of the number. If the normal length of numbers within the machine is not enough for the problem at hand, the machine may be programmed to consider numbers stored in groups as one number several times longer than normal. It may be said, therefore, that the accuracy of a digital computer is unlimited.

e. There are other differences between analog and digital computers that may determine which type to use in a given situation. For example, a digital computer is generally more flexible in its ability to handle various types of problems. Analog computers will not be considered further here.

f. Data which are available to a digital computer for processing are often generated by analog devices, however. A radar system is one example. Here the data are available as continuous measurements of angles and time (and sometimes frequency). Since a digital computer handles discrete data, it is necessary to convert this analog information to digital information. There are many devices, both electronic and electromechanical, designed to make this conversion with little loss of accuracy. There are also devices for making the conversion from digital to analog information when it is necessary to use the computer to control some physical device -- for example, a gun director.

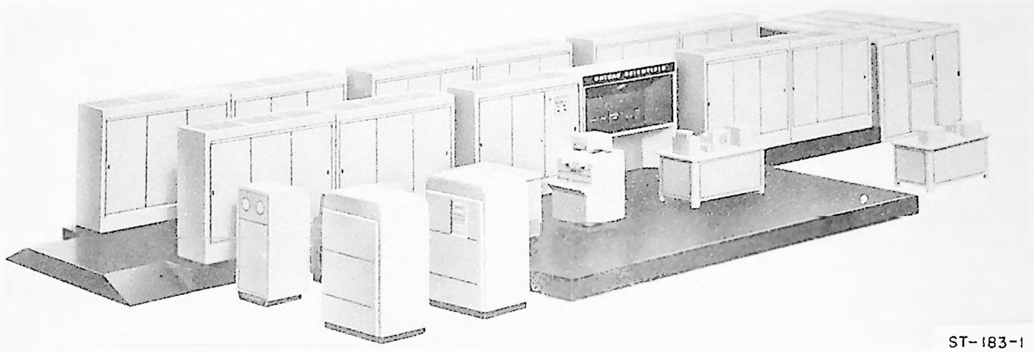
12. TYPES OF DIGITAL COMPUTERS

There are various types of digital computers, including the special purpose, the scientific, and the business-logistical.

a. The special purpose computer, which is similar to those used in weapons systems, is designed for a special operation.

b. The scientific type (fig. 1) takes in small quantities of information, performs vast amounts of mathematical and logical operations, and provides, as output, an answer which is usually short.

c. The busines-logistics type computer (fig. 2) takes in vast quantities of data, performs relatively small amounts of processing, and puts out large quantities of data.



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Courtesy of Remington Rand Division, Sperry Rand Corporation

Figure 1. Type ADPS (Univac Scientific 1103A).

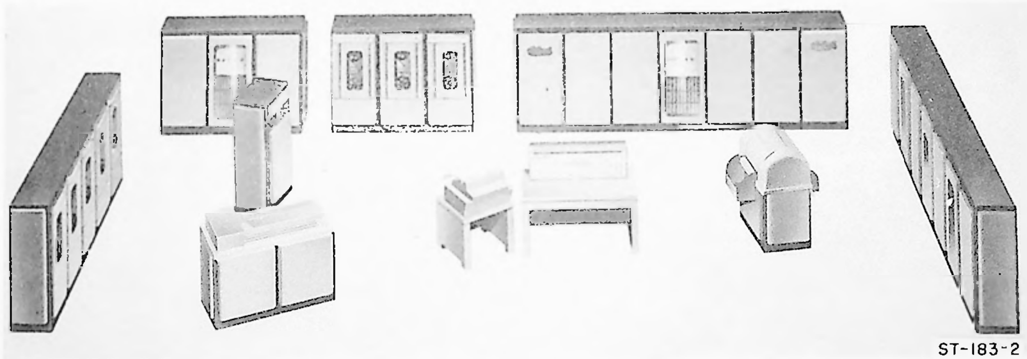

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Figure 2. Type ADPS (NCR 304). Courtesy of The National Cash Register Company

13. FUNCTIONAL ELEMENTS OF THE SYSTEM

An electronic data processing system generally consists of six functional elements (figs. 3 and 4).

a. Input. The input consists of all devices that will accept, convert, and transport data into the machine. The internal language of the machine is a series (or train) of electrical currents flowing in the system. This is obtained by alternately (according to a fixed pattern) turning the electronic flow on and off. This fixed pattern determines in code the letters, numerals, or characters which the machine will recognize. Thus, the input to the machine translates punched cards, punched-paper tape, magnetic tape, and the key strokes of an operator into the language of the machine.

b. Storage. Storage is normally subdivided into two basic parts: internal storage (or the memory unit) and external storage. The memory unit is used to store data and instructions during processing. Data can be read from cards or tape into the memory unit; thereafter, it is referred to by location (memory address). The ADPS memory unit may be visualized as a number of boxes, each of which can store a certain amount of data. Each box may be examined and information extracted for use during processing. Since the data used for computational purposes (processing) is not necessarily removed from the memory unit, the same information may be used an indefinite number of times. To remove information from the memory unit, new information must be written in on the same location.

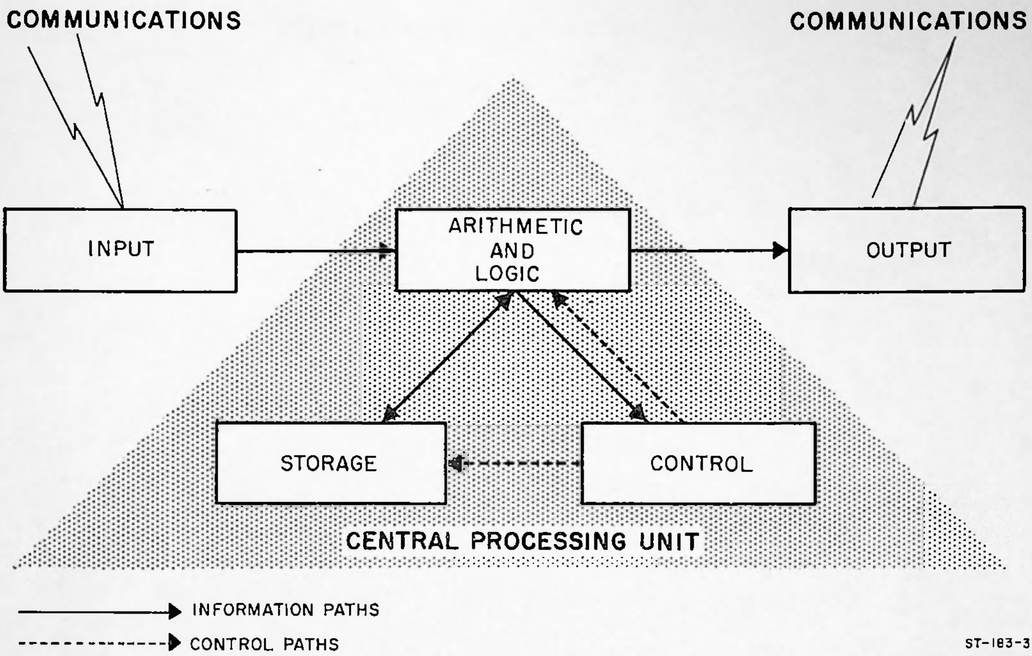


Figure 3. Functional elements of an ADPS.

c. Arithmetic and Logic. This unit is the heart of the automatic data processing system, since it is in this circuitry that the system performs its computations and makes its decisions. By manipulating information in these circuits and by issuing the proper instructions, the ADPS is able to accomplish many computations in a fraction of a second. These computation circuits are known by such names as adders, counters, registers, and accumulators. Although they function somewhat as memory devices and, in fact, extend the capacity of memory, they do, in addition, aid in the modification and fabrication of information. Thus, it is possible to set up a number in a register from the main memory; bring in another factor from memory; multiply, add, or otherwise manipulate the two numbers; and have the results available for replacement into the original record. All of this is directed by the stored instruction program within the machine.

d. Control. The control unit is that portion of the machine which governs the operation of the system. This control may be either internal or external, or a combination of the two.

(1) Internal control facilities interpret machine instructions and activate proper circuits. The circuitry which controls the sequence of operations is also included in this section. The typical internal control section contains two main units: the instruction register and the address counter. The instruction register examines and interprets the operational part of the instruction, and the address counter keeps track of the instructional sequence. Thus, the next instruction location (address) is set up in the address counter while the system is completing the previous step.

(2) The manual functions, performed at the operator's console, are considered to be external controls of the machine. Through a series of switches, buttons, and lights, the operator is able to control and supervise the various operational areas of the machine. The operator can, by means of the control console, exercise manual control of the machine, determine the status of machine circuits, indicate and allow for correction of errors, display machine or program error conditions, display memory, enter information into the system, or diagnose machine failures.

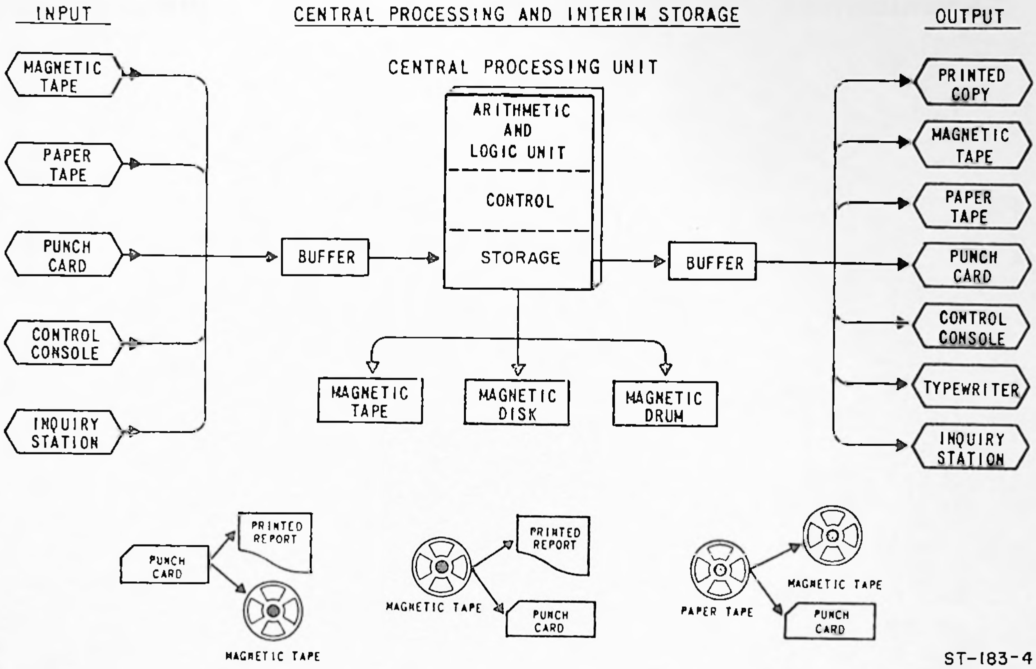


Figure 4. Composite ADPS schematic.

e. Output. The output consists of all devices that will convert and transport data out of the machine. The output of the machine is taken from the memory unit after processing and is transmitted to the output device.

f. Communication Link. The sixth and final essential element of the electronic data processing system is its supporting communication linkages.

(1) To be suitable for large-scale operations, such as those of the Army and big business, any data processing system must have high-speed communications integrated with the capabilities of the electronic computer. Without this communication system, the whole setup could well prove to be an expensive tool that would perform only a part of the job.

(2) The fact that automation is being extended through the communication system emphatically points up the need for an intimate relationship between computer and communication procedures. This relationship indicates the need for an integrated data processing-communication system.

(3) True data sources for the machine are the units in the field (posts, camps, stations, and headquarters throughout the world). Computer installations for business-type applications have invariably involved an increase in communications requirements. The purpose of this communication system is to deliver data to its destination in the same format and form in which it is received from the sender. The Army cannot economically afford a separate system for voice, teletypewriter, facsimile, video, and other communication means. Therefore, the Office of the Chief Signal Officer (OCSigO) has formulated a long-range plan for the development of a universal digital communication system capable of handling the various types of data and information presented for transmission.

Courtesy of International Business Machines Corporation

Figure 5. Magnetic tape equipment.

14. MEANS AND METHODS OF INPUT

a. Punched cards are a primary form of input for many data processing systems. However, this means is relatively slow; the paper composition of the card and the electromechanical characteristics of the reader limit the processing speed of a job. Thus, in many instances, it is expedient to convert punched cards to magnetic tape prior to machine processing. In certain cases, the original medium must be converted to make the direct input medium compatible with the system design. For example, cards are converted to magnetic tape for use in a system that accepts only magnetic tape as input. Most manufacturers offer auxiliary component equipment to perform these conversions without tying up the central processing unit. Conversion to tape takes as much time as reading the cards into the machine, but time is saved by performing the conversion while the central processing unit is operating on another job. The average reading device available today accepts cards at a rate of 100 to 1,500 per minute; however, there are devices in development which will approach 2,000 cards per minute.

b. Magnetic tape (figs. 5 & 6) is a frequently utilized method of input. It has the following characteristics:

(1) Physical characteristics. Plastic or metallic base tapes range from 1/2 to 3 inches in width and 250 to 3,600 feet in length.

(2) Density. Tape may be prepared at a density of from 50 to 534 characters per inch. This permits storage of a maximum of 24,800,000 alphabetic (37,200,000 numeric) digits of information, or the equivalent of 310,000 alphabetic (465,000 numeric) 80-column punched cards, on one reel of tape.

(3) Read-write speeds. Tape may be read or written at speeds of from 6,000 to 90,000 characters per second. Tape is passed through the machine at speeds ranging from 50 to 150 inches per second.

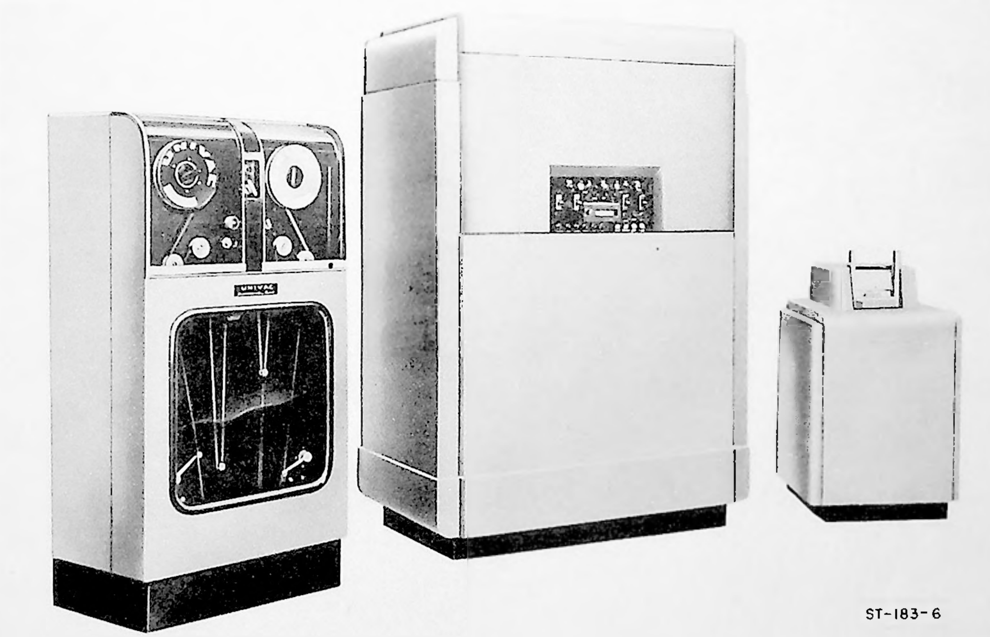
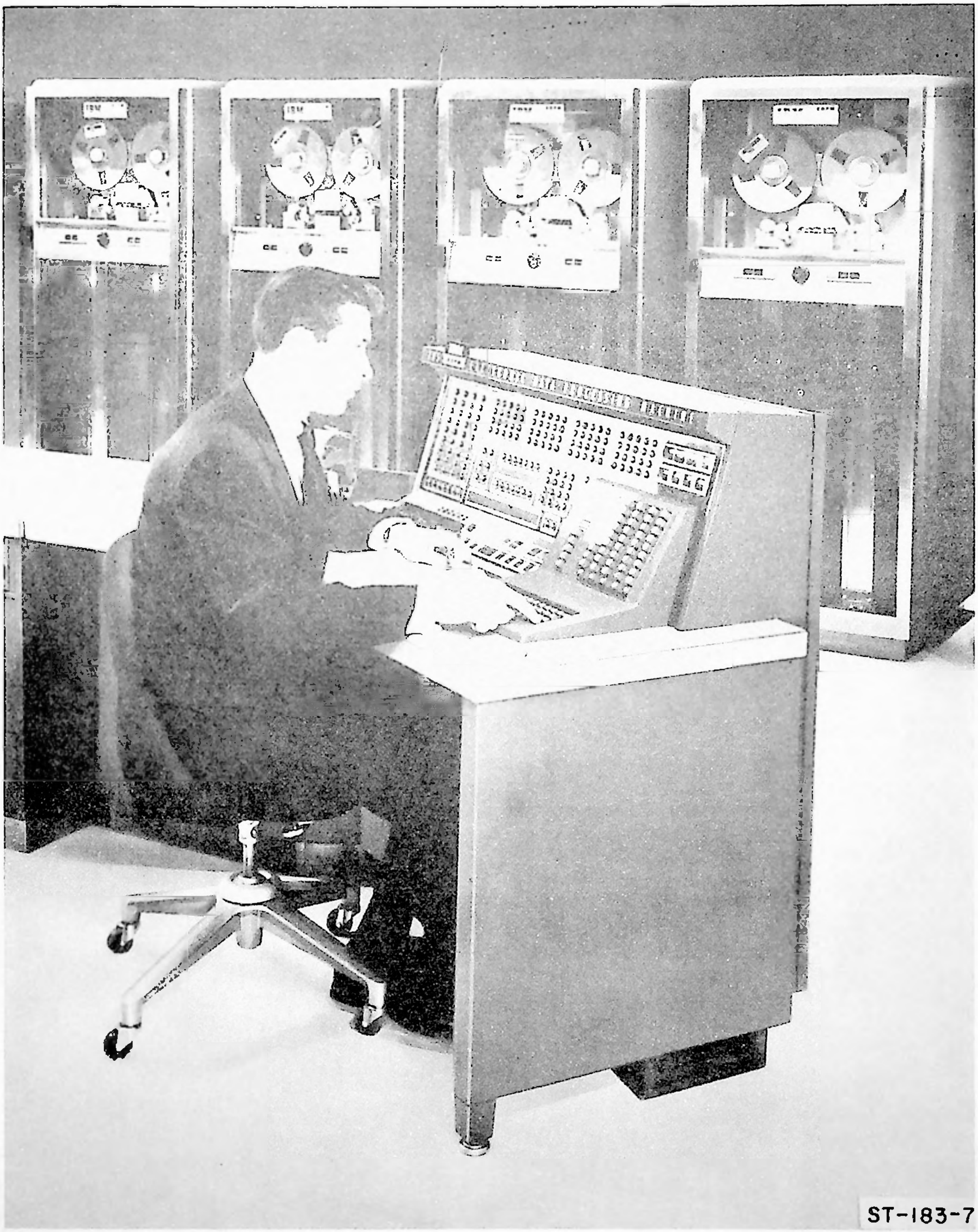
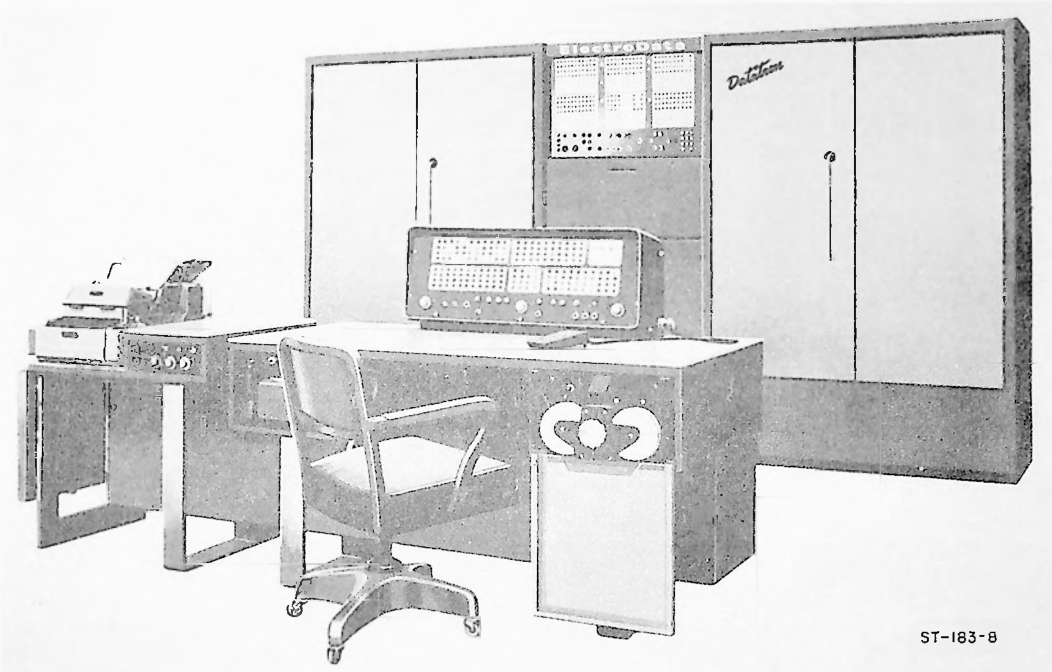


Figure 6. Card to magnetic tape converter.



Courtesy of International Business Machines Corporation

Figure 7. Operator console for large-scale computer.



Courtesy of ElectroData Division, Burroughs Corporation

Figure 8. Operator console for medium-scale computer.

c. Perforated paper tape is seldom used as a primary medium of input. Instead, the tape is converted on auxiliary equipment to punched cards or magnetic tape. The fact that some office machines produce paper tape as a by-product makes it an excellent information-gathering medium for further ADPS processing. Perforated tape possesses the following characteristics:

(1) Compatibility in certain instances with teletypewriter transmission.

(2) Reading speed of 10 to 1, 800 characters per second.

(3) Density of approximately 10 characters per inch.

d. The control console keyboard (figs. 7 and 8) is designed primarily as a supervisory input unit. In most systems, the operator can key in information or instructions as he desires. Because this type of input is slow, the keyboard is normally used only for error correction and interrogation.

e. The inquiry station is primarily an interrogation device. It allows us to introduce inquiries and to extract replies and miscellaneous messages without interrupting processing. Inquiry stations may be located at varying distances from the computer.

15. MACHINE LANGUAGE

An understanding of machine language is essential before we discuss the other components of the machine. An electronic computing device must have a language which it understands, and which can also be interpreted by the operator. Basis for the language of most electronic data processing machines is the binary system of notation, which is little more than a different numbering system. It is, however, a convenient method of presenting data in a form compatible with electronic circuitry.

a. One of the systems of numbers used in mathematics (the one with which we are most familiar) is the decimal form of notation. Starting with the right-hand digit and counting left, the positions in the decimal system represent units, tens, hundreds, thousands, etc. For example, the number seven thousand and twenty six is written in decimal notation as 7026. The value of the number is obtained as follows:

7	0	2	6
(thousands)	(hundreds)	(tens)	(units)

b. The binary system is also positional. But in the binary system the magnitude of each position, instead of increasing in powers of 10, increases in powers of 2. In other words, each position, shifting from right to left, doubles in value, so that the first five positions in the binary system are valued (in our decimal system) at 1, 2, 4, 8, and 16. A further difference between the two systems lies in the fact that the binary system uses only the two binary symbols, 0 and 1, instead of the ten digits 0 to 9. Although 0 and 1 are called binary digits, they have no actual similarity to the 0 and 1 of the decimal system. They are merely used to indicate two possible states or conditions which may exist -- for example, the on or off condition of an electric circuit.

c. An example of a decimal number represented in binary form will serve to illustrate the system. The number 25 (decimal) would be represented in binary notation as 11001, which is derived as follows:

1	1	0	0	1
(16)	(8)	(4)	(2)	(1)
(2^4)	(2^3)	(2^2)	(2^1)	(2^0)

or

$$\begin{aligned} 1 \times 16 &= 16 \\ 1 \times 8 &= 8 \\ 0 \times 4 &= 0 \\ 0 \times 2 &= 0 \\ 1 \times 1 &= \underline{1} \\ & 25 \end{aligned}$$

Basic arithmetical operations of addition, subtraction, etc., may be performed on numbers in binary form by using the rules of binary arithmetic.

d. In the binary coded decimal system that is used in most data processing machines, each digit of a decimal number is represented individually. Instead of representing the number 25 as 11001 as previously shown, the digits 2 and 5 are represented separately as 0010 and 0101. The number 7026 would be written as follows:

Positional Values	8421	8421	8421	8421
Binary Form	0111	0000	0010	0110
Decimal Form	7	0	2	6

e. A comparison of the decimal digits 0 to 9 and their binary equivalents is given below. Note that four binary positions are required to represent the digits 0 to 9.

DECIMAL	BINARY
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

f. Alphabetical characters may be represented by adding two more positions, called zones, to the left of the four numerical positions. To represent the 26 letters of the alphabet (and certain special symbols), we use three series of the above ten notations for numerical information, prefixing each series with a different zone. These zones are one-one (11) for the first set of ten letters, one-zero (10) for the next set of ten, and zero-one (01) for the final set. The zone for numbers is zero-zero (00).

Letter	Zone	Numerical
A	11	0000
B	11	0001
C	11	0010
*	*	****
K	10	0000
L	10	0001
*	*	****
U	01	0000
V	01	0001
W	01	0010

g. The remaining possible combinations of these six binary digits are used for special characters.

h. The fact that binary notations use only two digits makes this system of notation particularly adaptable to the electronic circuitry of ADPS. Any device which is capable of being in one of two stable conditions may be used to represent 0 or 1. A switch may be on or off, a relay may be opened or closed, an electric current may flow or be turned off, a magnetized spot may be present or absent, a magnetic element may be polarized in either of two directions, or a vacuum tube may conduct or turn off current. These are the devices that are most widely used to represent the binary digits in electronic data processing.

i. A binary digit is often referred to by its contraction, bit (bi for binary, it for digit); or, less consistently, as a binary bit. The term bit has the apt connotation of something very small.

16. STORAGE (MEMORY)

One of the fundamental and most essential characteristics of an electronic data processing machine is its ability to remember information. What does storage actually mean? When you remember something, you recall or recreate it instantaneously from a storage area within your brain. In some respects, the storage unit of an ADPS is similar to the storage area of the human brain. In an ADPS, data (numbers and alphabetical characters) are stored in binary language form in an electronic device which has the capability of rapid recall. But an electronic storage unit does not possess the creative faculty of the human mind. Therefore, each digit or series of digits must be specifically located in an addressable place; and each instruction which requires use of stored information must make reference to the exact location of the data.

a. Internal Memory. Since business-type applications usually require large memories, the ADPS storage unit is physically broken down into two general areas: internal storage (or memory) which is used during processing, and external storage (or file storage). Internal memory is the storage area where we store data and instructions during processing. After data are read from cards or tape into the memory unit, they are referred to by location. This location is known as the memory address.

b. Basic Unit of Data. The basic unit of data is called a word; it is transported throughout the system in constant form. An address is a word; an instruction is made up of words. Some systems divide the word into a specific number of characters (which are numbers, letters, or functions). Other systems do not break the word into characters, but rather define it as specific number of bits. Some computers have additional flexibility in that they permit use of a variable word length.

c. Stored Program Concept. The ability of the computer to store information in its memory or storage makes possible the entire concept of automatic data processing. Since the stored information can be anything we can represent in numerical form, we can cause the computer to store in its memory not only data, but also coded instructions or operations. A group of these instructions located in memory is referred to as a program, and this capability of the computer is referred to as the stored program concept. Since the coded form in which an instruction appears is the same as a number, it is important to remember that there is no distinction between a number and an instruction in the memory.

17. COMMON MEMORY DEVICES

There are almost as many different types of memory devices as there are automatic data processing systems. One common method of classifying and evaluating memory devices involves the access speed; this is the average time taken to obtain data from any memory location. Access time is the actual time required to locate the specific address in memory, activate the proper circuits and switches, and transport the data to the desired location in the system. Some of the types of memory devices are described in this paragraph.

a. Early Devices. Earlier forms of memory devices, such as electrostatic storage utilizing cathode ray tubes (fig. 9), and acoustic delay lines utilizing mercury tanks (fig. 10), required a constant source of power. Constant power was needed by the electrostatic storage device to continually regenerate the binary symbol images and by the acoustic delay lines to continually recirculate the binary pulses. A great disadvantage of either system was that in the event of a power failure the memory was lost. Consequently these devices are not used in newer computers, but may be encountered in earlier machines which are still in service.

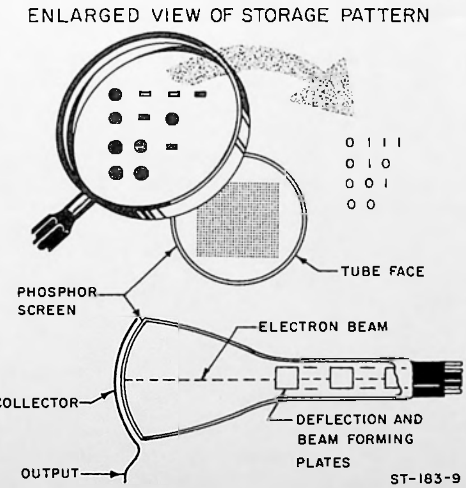


Figure 9. Electrostatic storage tube.

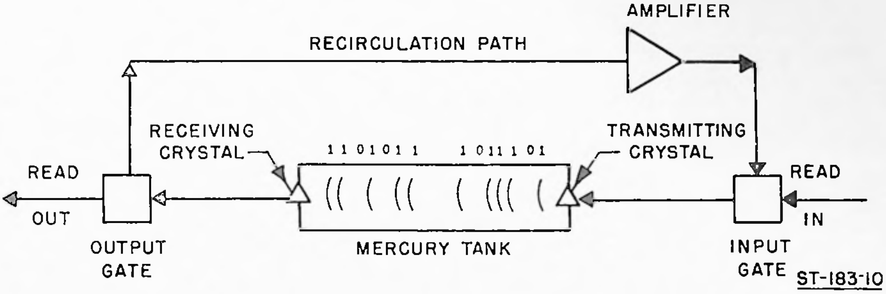
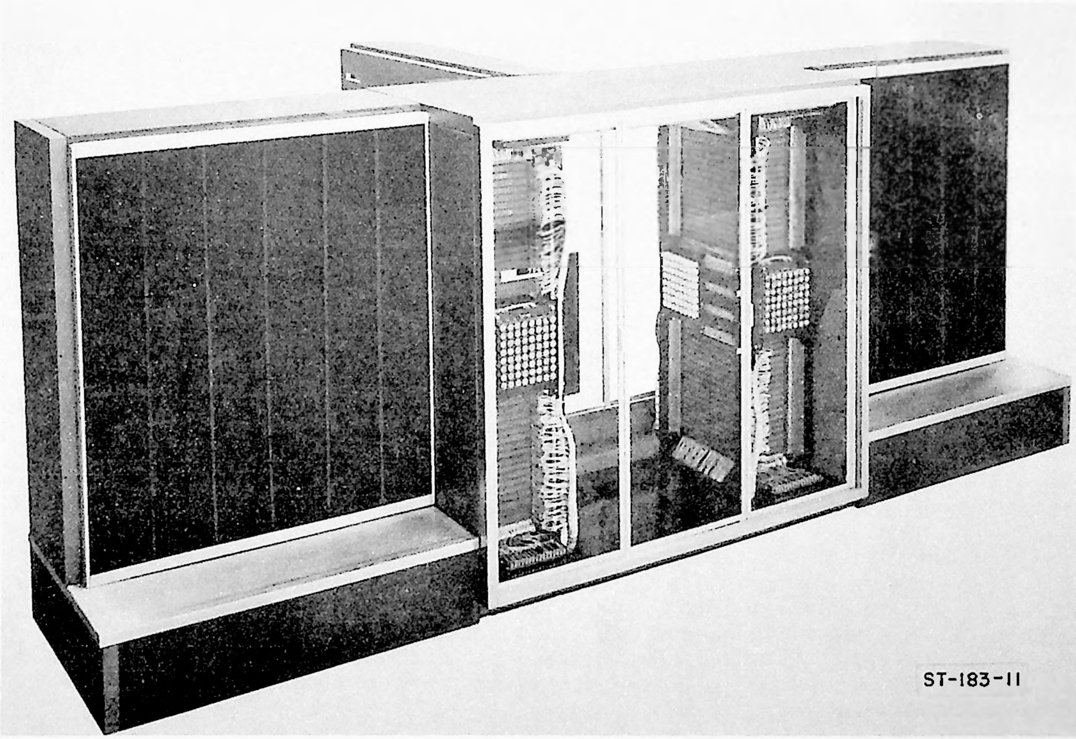


Figure 10. Mercury storage delay line.

b. Magnetic Cores. Magnetic cores (fig. 11) are rapidly becoming the most popular of the high-speed electronic storage devices. High-speed access, large capacity, ease of maintenance, dependability, and improved techniques for mass production are a few of the advantages of core storage.

(1) Magnetic cores are tiny doughnut-shaped (toroid) rings, about 1/16-inch in diameter and made of ferromagnetic material. These tiny cores are strung on frames in a matrix fashion, with one ring for each binary bit. When current of sufficient magnitude is passed through a wire looped around one of these cores, the core becomes



Courtesy of International Business Machines Corporation

Figure 11. Magnetic core storage unit.

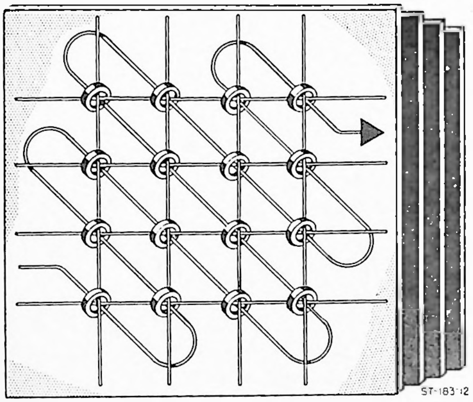


Figure 12. Magnetic core matrix.

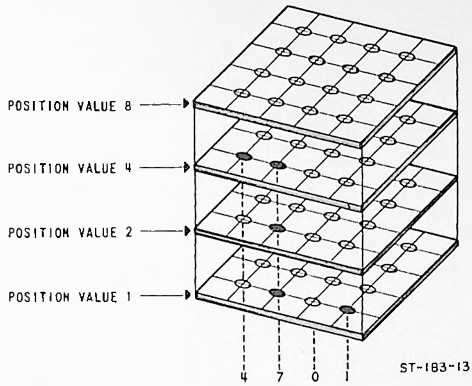


Figure 13. Storing the number 4701 in magnetic core memory.

magnetized. The magnetic polarity depends on the direction of the current in the wire. A core once magnetized will remain so until deliberately changed. (See figure 12.)

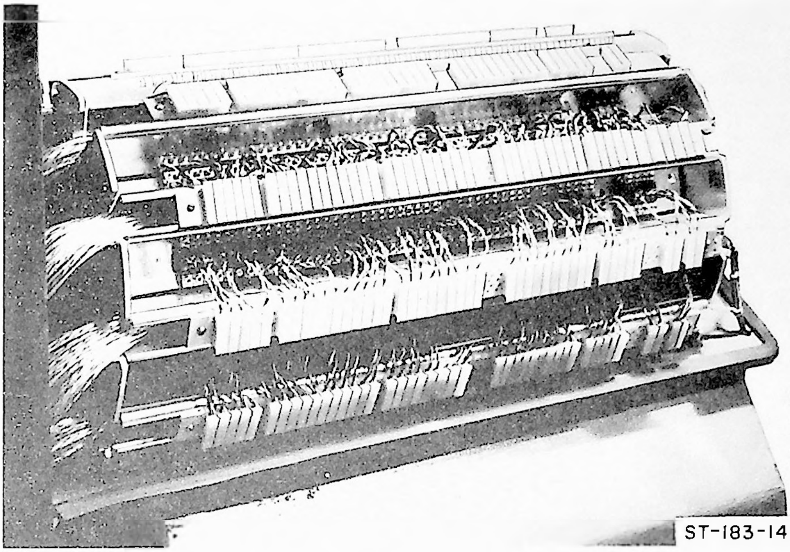
(2) If two wires are passed through the center of a core and half of the required magnetizing current is sent through each wire, the core will be magnetized. If only one wire is carrying current, the core will not be magnetized. This principle is used to select and magnetize a desired core. Thus, any specific core strung on wires within a matrix structure may be selectively magnetized by sending half of the required current through a horizontal wire and half through a vertical wire. Only the core at the intersection of these two wires will be magnetized, and a reversal in current will cause a reversal in direction of the magnetic field.

(3) To simplify the explanation this text will use the terms positive and negative magnetism rather than the direction of magnetic field or current flow. A negatively magnetized core will represent a binary 0, and a positively magnetized core will represent a binary 1.

(4) The manner in which the number 4701 may be stored in a magnetic core matrix is shown in figure 13. Four matrices are used, each consisting of 4 x 4 magnetic cores in matrix-plane over matrix-plane configuration. (In practice, a much larger grid structure is used.) If all cores had been previously set to the negative or 0 state, sending a pulse of positive current results in a positive or binary 1 state. The number so represented will remain until deliberately changed.

(5) Information is read from magnetic core memory by means of a third wire, called a probe or sensing wire, which is laced through each core of a matrix. To read out, the core is selected and set to 0. If a positive or 1 condition is present, a signal will be induced in the probe wire. If it is 0, the signal will be weak or non-existent. This signal operates the reading circuitry. Since the read operation removes the contents of the cores, the circuitry is designed to replace this information automatically.

(6) Magnetic cores are rapid-access devices (average access is about 17 microseconds). The matrix construction of the unit facilitates addressing any character in the memory unit.



Courtesy of International Business Machines Corporation

Figure 14. Magnetic drum storage unit.

c. Magnetic Drum. A magnetic drum (fig. 14) is a high-precision, metal cylinder that is coated with a highly magnetizable material. Data are stored on the outer surface of the drum in the form of magnetized spots. A positive magnetized spot indicates a binary 1, and a negative (or a blank in some machines) magnetized spot denotes the binary digit 0.

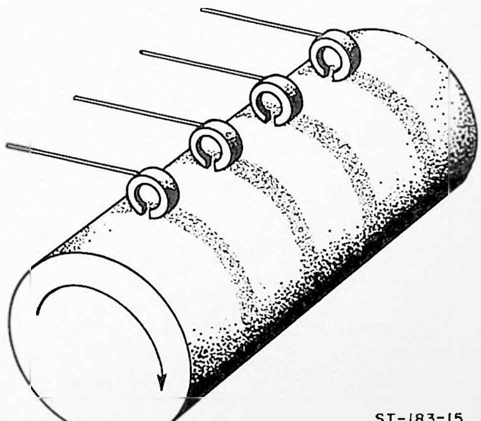


Figure 15. Magnetic drum.

(1) The drum revolves at high speed under a series of heads, each containing a tiny magnetic coil (fig. 15). In the writing operation, current passing through the coil sets up a magnetic field; this places a magnetic spot on the surface of the drum. In the reading operation, a magnetized spot passing under a head induces a current signal in the coil within the head; this signal is then transferred to the operating circuitry. In some systems, the same set of heads is used for both reading and writing operations. Binary bits (magnetic spots) are stored in a series of parallel tracks, and the address of specific data is determined by its physical location on the drum.

(2) Because of its characteristic of continual rotation, the magnetic drum is classed as a medium-access-speed memory device. Information can be written and read only when the desired address passes under the read-write heads, so there is often a delay or latency period. For this reason, only average access time (about 10 milliseconds) can be established for drum processing, and even this average may vary widely, depending on the characteristics of the drum. The physical dimensions, speed of rotation, number and type of heads, and arrangement of data have an effect on the speed of access and drum capacity.

d. Magnetic Disk. Magnetic disk storage (fig. 16) is one of the latest means of ADPS memory. A series of metallic disks, arranged in much the same manner as records in a commercial record player, serves as the storage medium. Information is recorded in magnetic spot form on the disks by means of one or more moving selector arms. The selector arm can locate the specified disk, a certain track on the disk and, finally, a specific record on the track.

(1) The most recent disk unit of the type shown in figure 16 can store up to 10 million characters of alphanumeric information in the form of 100, 000 addressable record locations. Disk-type storage combines the highly important characteristics of large file capacity with random information selection capability.

(2) Disk-type storage, although considerably slower than the memory units previously discussed, has many advantages over the other devices. One advantage is that one disk unit has the storage capacity of an average reel of tape. As with certain other types of storage devices, additional units may be added to increase capacity. Furthermore, it is possible in disk-type storage to locate a given record without a serial search, which is the technique used in magnetic tape.

(3) Disk-type random access storage helps solve two significant data processing problems: (1) the memory may be interrogated at any time by interrupting, but not disrupting, the job in process; (2) the random access feature facilitates in-line processing of incoming records. This feature obviates the necessity of batching and sorting activity records into a predetermined sequence before processing them.

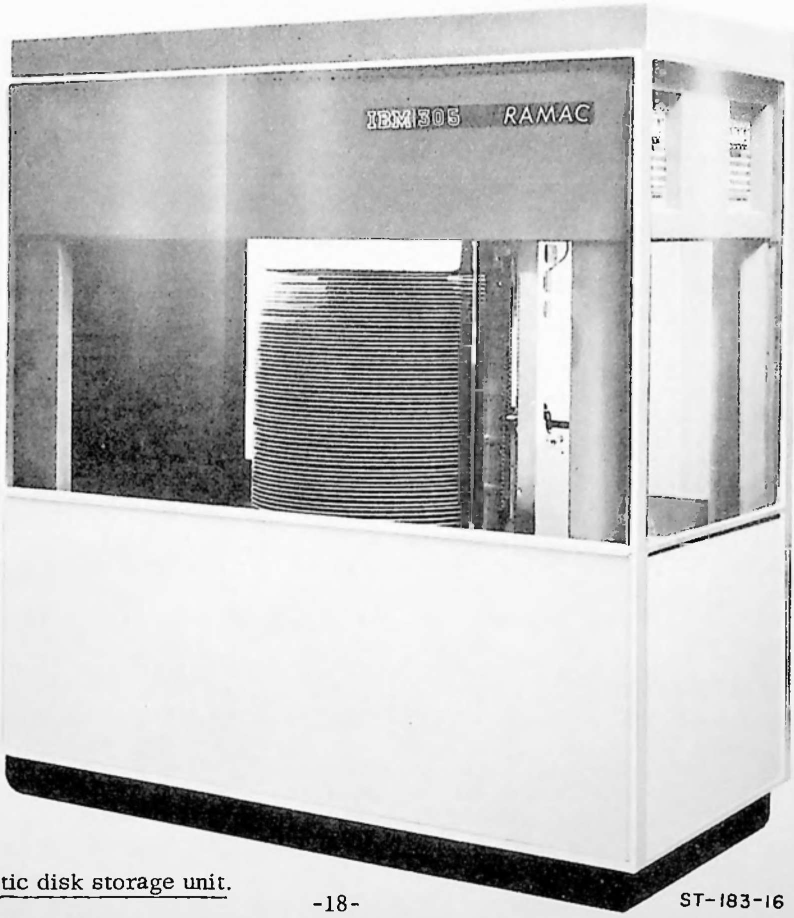


Figure 16. Magnetic disk storage unit.

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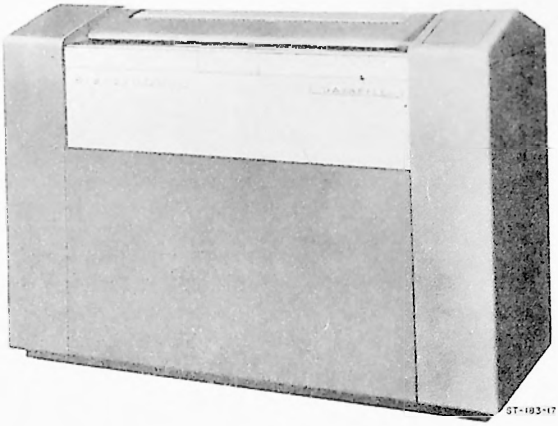
e. Bin Tape. Bin tape storage (fig. 17) is a recently developed type of ADPS memory. The unit consists of 50 separate 250-foot lengths of magnetic tape. Each tape length is capable of sorting 400, 000 numeric characters, and each bin unit has a capacity of 2 million ten-digit words, which may be addressed in 20-word blocks. The tapes are suspended over two bars, with a pair of magnetic read-write heads positioned between the bars on a sliding mechanism. By moving the tapes across the bars and the heads between the bars, any portion of any tape may be selected.

(1) Bin tape storage may be classified as medium-speed access. It is necessary to locate the desired tape, the storage track or lane on the tape, and the specific record on the lane.



Courtesy of ElectroData Division, Burroughs Corporation

Figure 17. Bin tape storage unit.

(2) Separate tapes, with two separate lanes on each tape, provide bin tape storage with a means for random information selection. The process time can vary from 1/2 second to 16 seconds depending on the distance the read-write head has to travel before it locates the proper read position. Advantages of this type of storage are much the same as those previously mentioned for disk-type storage.

18. CENTRAL PROCESSING UNIT: OPERATING ELEMENTS

The central processing unit of a computer includes the arithmetic and logic unit, the memory unit, and the control unit. (See figure 3.) Information flows in a complex fashion between these elements, and it is important to keep track of this information as well as to coordinate its processing and movement from place to place. It is this last function, coordination of the processing and transfer of information, that is performed by the control unit. (It is the programmer's problem to keep track of information.)

a. Control Unit. The rules for processing information are given by the program that is fed into the computer. The rules for the transfer of information are given partly by the program and partly by built-in instructions in the control unit. Therefore, the control unit must be able to take an instruction from the program, interpret it and supervise its execution, as well as follow certain built-in rules governing the transfer of information. Since there are numerous instructions in a program (sometimes many thousands), the control unit must know where to find the next instruction.

(1) Functions. These requirements may be expressed as the two major functions of a control unit:

(a) It keeps track of where the next instruction is to be found.

(b) It controls the execution of the present instruction.

(2) Components. The control unit has three basic components that aid in its functions:

(a) The instruction address counter (IAC) holds the memory location of the next instruction.

(b) The instruction register (IR) holds the instruction presently being executed.

(c) The decoder (D) translates the binary coded order or operation (held in the instruction register, such as ADD, MULTIPLY, SHIFT, etc.) and determines which control lines in the computer should be activated to execute this operation.

b. Distribution Register (DR). Information from the memory, in general, goes to one of two places: the arithmetic and logic unit, if the information is a piece of data to be operated on, or the control unit, if the information is an instruction. To facilitate this transfer decision (should this word go to the arithmetic or control unit?) a distribution register (DR), or memory buffer register as it is sometimes called, is used. Any information read out of a memory location goes directly to the distribution register. The control unit then decides whether this information should be used by the control unit as an instruction word, or by the arithmetic unit as a data word, and causes the proper transfer. In addition, any word written into memory usually passes through the distribution register. This operation is required not only for circuit simplification, but also because the word is checked here for accidental changes which may occur during transfer to and from memory.

c. Accumulator (ACC). All of the data processing is accomplished in the arithmetic and logic unit. Some computers accomplish everything with just one register, called the accumulator. Other computers use several registers, and are consequently capable of much more complicated commands. For the purpose of this discussion, it will be assumed that the accumulator is the only register in the arithmetic and logic unit, and that all data processing is done in the accumulator.

19. CENTRAL PROCESSING UNIT: TYPICAL OPERATIONS

In a single-address computer, the instruction contains an order and an address. The order tells the machine what to do; the address generally gives the location of the data to be operated on. The majority of computers on the market today are single-address and these, therefore, will serve as the best example. Other types of instructions are discussed in paragraph 29.

a. The control unit's operation may be broken into two phases during the execution of each instruction: the instruction phase and the execution phase. These will be abbreviated as IP and EP. Further, each phase has two separate parts. Therefore, the control unit's cycle is broken into IP 1, IP 2, EP 1, and EP 2.

IP 1: During the first part of the instruction phase, the computer locates the next instruction by interpreting the contents of the instruction address counter. The instruction is read from memory into the distribution register.

IP 2: Two operations occur simultaneously here:

(1) The contents of the distribution register are transferred to the instruction register.

(2) "One" is added to the instruction address counter so that it will hold the address of the next instruction.

EP 1: Using the address given by the instruction, the computer locates the number to be operated on and reads it from memory into the distribution register. There are some orders that do not require this, such as shift, store, and transfer; in such cases the computer ignores this operation. It also performs any part of the instruction that can be performed without a number from memory, such as shift the contents of the accumulator, or clear the accumulator.

EP 2: During this portion of the execution phase, the computer executes the operation (add, multiply, divide, etc.) using the number in the distribution register and the contents of the accumulator.

b. In brief review, these phases are:

IP 1: Locate the instruction.

IP 2: Put instruction in instruction register; step address counter.

EP 1: Locate number to be operated on; perform certain orders.

EP 2: Execute the operation.

20. CENTRAL PROCESSING UNIT: EXECUTING A SPECIFIC INSTRUCTION

The operation of the control unit is best illustrated by examples. A single-address computer is still assumed. Figure 18 shows the components of the computer, their abbreviations, and the lines that will be used in the examples to indicate the type of operation taking place. Note that along with the contents of the memory, a space is included to show its location. Note also that the contents of the instruction register are split into two parts -- an order and an address -- as was previously discussed. Dotted lines between the components indicate control pulses. Solid lines indicate actual information flow between registers. Only those control pulses originating from the instruction register and instruction address counters are shown. Several such pulses occur that are independent of the instruction but, for clarity, these are not shown.

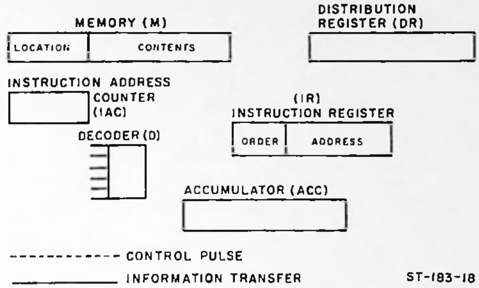


Figure 18. Operation of the control unit: functional schematic of computer components.

a. Example 1. Assume that the instruction address counter holds the address 1015. Figure 19 represents a series of instructions starting with the one specified by the instruction address counter -- that is, the instruction stored in memory location 1015 -- and shows the state of the computer during each part of each phase.

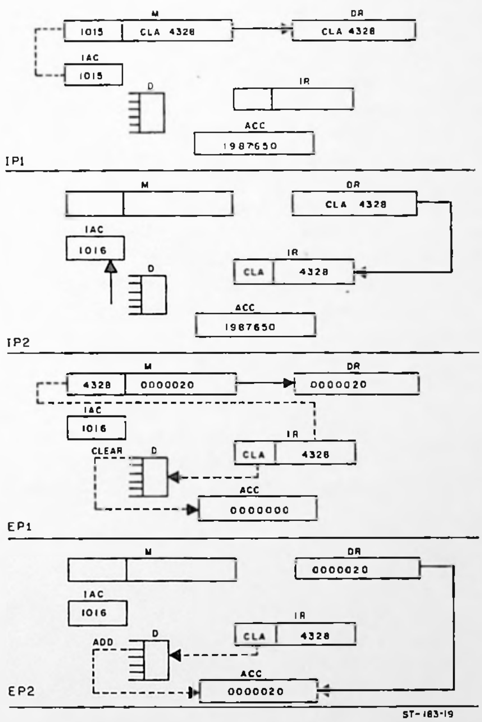


Figure 19. Operation of the control unit: example 1.

(1) In IP 1, the instruction address counter holds the address of the next instruction (1015) and this instruction is read from memory location 1015 into the distribution register. The instruction is "CLA 4328", or "clear the accumulator (CL) and add (A) the contents of memory location 4328 to the accumulator."

(2) During IP 2, "one" is added to the address counter (1015 becomes 1016) and the contents of the distribution register (CLA 4328) are transferred to the instruction register.

(3) During EP 1, the operand, or number to be operated on, is located in the memory and transferred to the distribution register. (The location of this number is given in the address portion of the instruction.) In this case, part of the order (clear the accumulator) can be executed in this part of the operation phase, since this operation does not depend on getting the operand from memory.

(4) During EP 2, the number in the distribution register is added to the accumulator. The instruction "CLA 4328" has now been executed; the accumulator has been cleared and the number stored in memory location 4328 (which is 0000020) has been added to the accumulator.

b. Example 2. The instruction address counter now holds the address 1016, and during the next IP 1 (fig. 20) the instruction located in memory location 1016 is transferred to the distribution register. The instruction is "STO 4000", or "store the contents of the accumulator in memory location 4000."

(1) During IP 2, this instruction is transferred to the instruction register, and "one" is added to the instruction address counter.

(2) There is no number to be read out of memory in this case during EP 1, since the machine is merely storing in memory, but the contents of the accumulator must pass through the distribution register to be read into memory (see the review on memory). Therefore, during EP 1, the number in the accumulator is transferred to the distribution register.

(3) During EP 2, the number in the distribution register (0000020) is read into memory location 4000. The command "STO 4000" has now been executed. The number in the accumulator has been stored in memory location 4000.

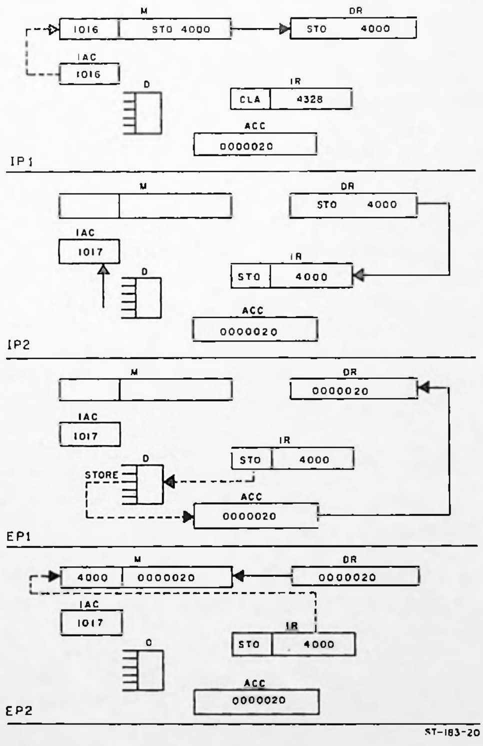


Figure 20. Operation of the control unit: example 2.

21. OUTPUT

The output of an ADPS may be defined as modified or updated input information. Output may be in either semifinished or finished, readable or nonreadable, form.

a. Information in finished and readable form appears as a printed page, or hard copy, which is readily usable by the staff without further processing. Such data as stock status, inventory, personnel or accounting reports, would normally emerge as finished copy in prepared format, ready for immediate distribution. Checks, shipping documents, orders, invoices, and various other individually distributable messages computed and created by ADPS would also appear in finished and readable form.

b. Semifinished or nonreadable output may take many forms, but the most frequently utilized types are magnetic tape and punched cards. There are two primary reasons and one secondary reason for preparing output data in semifinished form.

(1) First, output may be written on magnetic tape and held for off-line, hard-copy reproduction when the speed of the available on-line printer limits the production or output of the system. Off-line tape-to-printer conversion takes advantage of the relatively high speed at which tape can be "written" as compared to the speed of direct, on-line printing. This operation, in effect, eliminates tie-ups and blocks that restrict the high computing and processing speed of the central processing unit. Much valuable processing time is lost when the central processing unit must wait for the printer to catch up.

(2) Second, preparation of output material in semifinished form facilitates further processing. For example, today's newly created and updated inventory file can serve as tomorrow's input, or a payroll record for this week can serve as next week's source input. It should be noted here that most systems allow for simultaneous production of both a finished and a semifinished copy. Thus, a daily stock status report may be prepared in finished form, while an updated tape file is created in the semifinished form.

(3) A third reason for creating an intermediate output is to facilitate further processing on a similar system at a remote location.

22. UTILIZATION OF OUTPUT MEDIA

a. Magnetic tape is one of the most popular and widely used media of output. Some systems utilize magnetic tape as a primary method of output and provide high-speed, off-line, tape-to-printer operations. Other systems offer an option of on-line printing or tape creation with auxiliary conversion equipment.

(1) Use of magnetic tape as a file storage device is widely accepted. For example, we can easily maintain and update an inventory or payroll file and can run a print-out or report whenever we desire. As a rapid access file device, however, magnetic tape has limitations. It is necessary to search each record on the tape file until the desired one is located. Considering the fact that searching through a tape requires approximately 5 to 10 minutes, it is a cumbersome method of file storage when there is need for random access to individual records.

(2) Utilization of magnetic tape provides high-speed writing or creation; large capacity for storage of information; ease of handling; a facility for use as a file that can be readily maintained and regularly updated; and a facility for off-line conversion to printed copy, thereby saving and economizing on central processing unit time.

(3) The use of magnetic tape is economical. We can store the information from 20,000 punched cards on one reel of tape and use it over and over again. It is perhaps the cheapest storage medium available today. As a permenent storage device, it is effective from the standpoint of compact size and durability.

b. Punched Card. This has little utilization as a primary output device for ADPS, since the speed of punching averages only about 100 cards per minute. Any significant volume of card output would severely delay the operating efficiency of the central processing unit, thereby extending job time. Despite the slowness of card creation, such cards are compatible with Electric Accounting Machine (EAM) equipment and provide a single source document for each record. Cards may be created from tape on certain off-line tape-to-card conversion equipment (fig. 21).

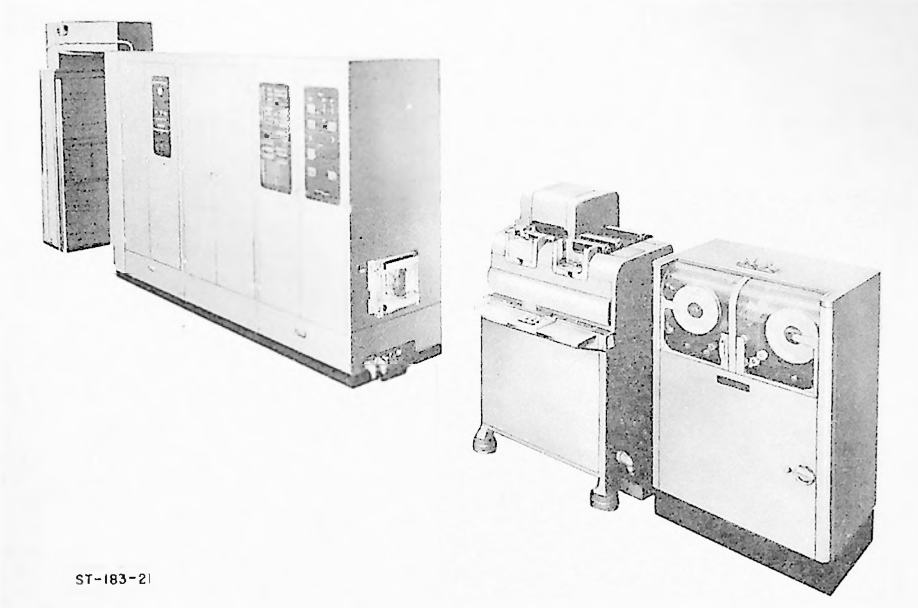


Figure 21. Magnetic tape-to-card converter.

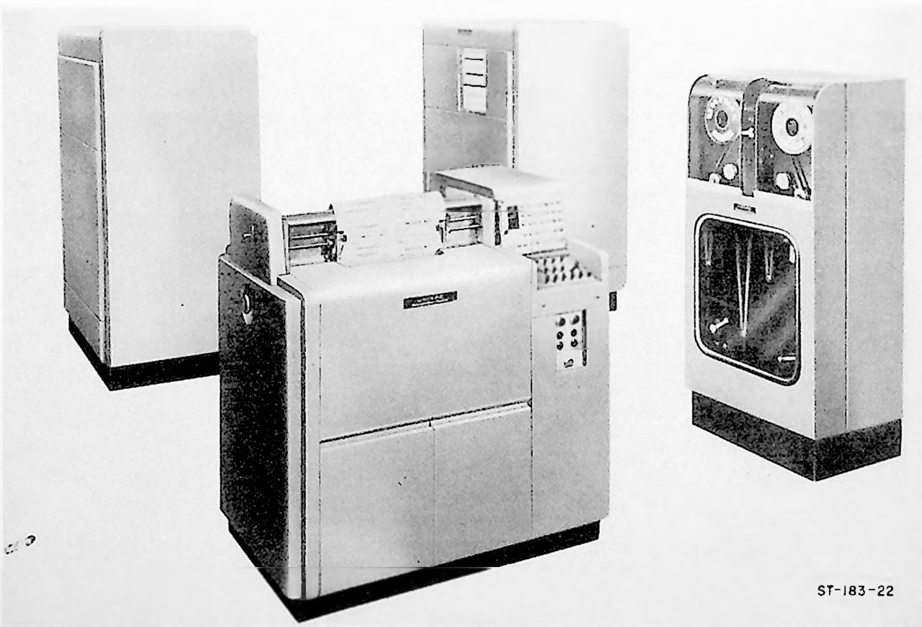


Figure 22. High speed printer.

c. Perforated paper tape is available as an output medium in certain systems. For the most part, however, paper tape is not used as a primary output device because of its relatively slow creation speed.

23. OUTPUT DEVICES

a. Every ADPS includes one or more printers (fig. 22). As previously mentioned, certain systems cannot print directly from memory, but require off-line tape-to-printer conversion equipment. Printers are available in speeds ranging up to 1,000 lines per minute. The demand for very-high-speed printers has been reduced somewhat by the availability of off-line conversion equipment. The decision, therefore, as to a high-speed printer versus off-line printing depends on the urgency of the work, the nature of the job processing, and the comparative costs of the two systems. Printing is done on continuous paper forms by means of individual characters (typewriter, type wheels, wire matrices, and metal bars).

b. A typewriter is usually available as an output device, but its relatively slow speed (average 10 characters per second) dictates that it will be used primarily for operator control purposes. In a control sense, the typewriter provides the operator with key messages for program supervision. These key messages are developed as part of the program and will appear automatically when the specific conditions occur. Examples: "Change tape on tape unit 1," or "Incorrect input card," or other typical conditions which require operator interception.

c. Optical printers are entering the field of data processing. In these printers, which attain speeds of approximately 5,000 lines per minute, the mechanical operations are confined solely to the movement of the paper during the print-out process. Information in bit language is translated into images of numbers and letters in a television-type tube. These images are then projected onto a light-sensitive drum which is sprinkled with dry ink that sticks to the areas of the drum which have been exposed to the light. These figures of dry ink are then printed on a continuous roll of paper.

24. SYNCHRONIZATION AND BUFFER STORAGE

This storage is required to balance the varying circuits in ADPS. Because the input, central processing, and output devices all process at varying speeds, it is necessary to balance the components to eliminate delays in job processing and keep all areas operating as much of the time as possible.

a. Employment of off-line auxiliary operations is one method of economical utilization. Before processing, cards and paper tape are converted to the faster input medium of magnetic tape, and the computer creates a magnetic tape as direct output to be used in performing an off-line printing operation. This reduces the possibility of a tie-up in the central processing unit.

b. Another way to coordinate the operations of the system is to increase the operating speeds of the slower components. For example, we can increase the speeds of the input and output devices to provide more synchronized production and effective use of the system. In line with this, it has already been mentioned that there is a possibility of 1,000-card-per-minute readers and up to 1,000-line-per-minute printers. The electromechanical construction of these devices, however, limits the speeds to which these components can be increased.

c. A highly effective method of coordinating the components of the ADPS involves use of buffer storage units. Buffer storage may be defined as a means whereby data may be temporarily stored while the system continues to process. Input buffer storage is a device which allows temporary storage of information between the input reading device and the central processing unit (CPU). Because of the disparity in operating speeds of the input media and the central processing unit, we may wish to interpose a buffer or high-speed temporary storage between the two units. The time to transmit a record of information from the buffer to the CPU is instantaneous as compared to the time to transmit between the reader and the CPU. A buffer unit permits the reader and the CPU to operate for a greater portion of the time, since it eliminates the delay involved when one unit must wait while the other operates. In other words, the second record may be placed in high-speed buffer storage and readied for transmission while the first record is being processed. We can also place output buffer storage between the central processing unit and the output device to speed processing operations further.

d. Some systems offer buffer storage as an auxiliary device, not regularly included in the system. In this case, evaluation and analysis of the job determines the need for buffer storage.

25. ADPS RELIABILITY

Data processing requires accurate presentation of all alphabetical and numerical data. Exact information and error-free processing are essential requirements of ADPS. A minor error occurring during an intermediate processing stage often appears greatly magnified when carried through to the output. The number and type of reliability check features incorporated in a system depend upon the size and complexity of the system as a whole and the characteristics of the jobs to be done.

a. The operational components of automatic data processing systems require extensive reliability checking features. Specifically, this is because of the --

(1) Large number of major components, and the many operational areas within each component.

(2) Great number of operations performed by each component.

(3) Complex interactions between components and functional areas.

b. One technique for improving system reliability uses built-in, self-checking, electronic circuitry. One such self-checking method utilizes a machine code which always maintains an odd, even, or fixed number of positive condition (1) binary bits per character. An extra checking bit called a parity bit is introduced in this technique.

c. Duplication of circuitry and an automatic comparison at the completion of operations is another self-checking feature used by certain systems. Once an error has been detected by a duplication of circuits, the machine automatically repeats the operation.

d. Another self-checking method involves the use of program instructions and duplicate processing to determine accuracy by comparing results. When an error is detected by programming instructions, it is corrected by either repeating that operation or repeating a portion of the program. As programs are divided into routines and subroutines, error-checking instructions can be used at the completion of each routine. This obviates the necessity of rerunning the entire program when there is a random error.

e. A final method of error detection involves the use of control totals similar to those used in normal accounting procedures. This method is put into effect by programming the desired checks.

Section IV. PRINCIPLES OF PROGRAMMING

26. INTRODUCTION

The ADPS is often called an electronic brain; if it were actually a brain it would be a relatively stupid and unimaginative one, having no creative ability. The system can merely carry out instructions; it does this, however, with extreme accuracy and high speed. In addition, it possesses an internal means of checking what has been done and it can signal the operator in case of error. Aside from its mechanical characteristics of accuracy and high speed, however, the electronic computer in its present state of development does not surpass but is, in fact, dependent upon the mental processes of those who direct its operation.

27. WHAT IS PROGRAMMING?

a. Programming is the term used to describe the conversion (in steps) required to process the job from the present method of operation into the instruction language of the automatic data processing system. Since the machine does nothing on its own initiative, each step, whether it be one of transposition or of computation, must be distinctly specified.

b. Armed with a knowledge of the machine and its operational components, it becomes the task of the programmer to list every step or basic element of the job in a language form that is compatible to the machine. This portion of programming, which is called coding, requires a careful and exacting study of the flow charts, block diagrams, and related information pertaining to the job to insure accurate application of operation codes understandable to the machine. Because ADPS can do only what it is instructed to do, the programmer must take into consideration all exceptions and conditions which may occur in processing a job. When the machine is called upon to compare two numbers and follow different routines (depending on the result of the comparison), the programmer must also consider each step of each subroutine. In other words, human minds must do the prethinking for the system.

c. It then becomes the task of the machine to commit these detailed instructions to memory and, subsequently, operate on them and guide information through the system. While the programmer is stepping out the job in machine language, he is at the same time specifying where, within the system, the operations are to be performed.

28. PRELIMINARY ANALYSIS

a. Before beginning actual programming operations, a detailed analysis of the current method of processing should be made. This method study serves two purposes:

(1) It closely examines the job for overlap, wasted time, and isolation of excess and outdated processing.

(2) It provides the basis for laying out the job in logical flow-chart form.

b. This aspect of programming is discussed in greater detail in chapter 2. This section is concerned with programming the actual instructions to the computer.

c. After the job is set up in generalized logical flow-chart form it is worked on by the programming team. From this point on the staff must use detailed information on machine programming and job procedures.

29. INSTRUCTIONS

An instruction is a coded group of numbers, or alphabetical characters and numbers, which directs the performance of a certain operation. An instruction, by definition, must point out what and where. It consists basically of two parts: an operation part and an address part. The address part of an instruction tells the machine the locations where information can be found and where it should be placed for processing. Addresses may be locations in memory, in specific registers or accumulators, or in various input and output devices.

a. Classes of Instructions. In general there are four classes of instructions:

(1) Instructions which move data. These include instructions which bring information into the system from the input device, move the data from one location to another within the system, and transfer data to the output medium. Examples of these instructions are: write, read, transfer.

(2) Arithmetical instructions. These instructions perform arithmetical operations, such as addition, subtraction, multiplication, and division.

(3) Logical instructions. These instructions compare the magnitude of two quantities and set up the procedure for pursuing alternative operations based on the results of the comparison. Compare and transfer on high [equal, low, or zero] conditions are examples of logical operations. Use of these instructions facilitates the logical operations of file search, sorting, collating, and matching.

(4) Control instructions. These instructions select input and output devices, backspace and rewind tape, and prepare the internal information format as well as a number of other specialized orders.

b. Types of Instructions. Among computers, the control unit will vary as to the type of instruction used. Some of the instruction types found as design characteristics in various computers are discussed in this subparagraph.

(1) Single address. The instruction of a single address computer contains an order and an address. The order tells the machine what to do; the address generally gives the location of the number to be operated on. For instance:

ADD 3106	Add the contents of memory location 3106 to the contents of the accumulator.
STORE 4000	Store the contents of the accumulator in memory location 4000.
TRANSFER IF MINUS 1000	If the sign of the accumulator is negative, take the next instruction from memory location 1000. Otherwise go on to the next instruction.

In a single address machine, the instruction address counter is stepped sequentially. That is, after the execution of each instruction, the number 1 is added to the instruction address. The only exception to this is in transfer instructions; in such instructions the address presently held by the address counter is replaced by the address specified in the instruction.

(2) Two address modified (or one-plus-one). In this type of instruction, there is an order and two addresses. The first address has the same function as the address in a single address instruction, as just discussed. The second address gives the memory location of the next instruction. For instance:

MULTIPLY 3100, 1500	Multiply the contents of the accumulator by the contents of memory location 3100. Find the next instruction in memory location 1500

With this type of instruction, the instruction address counter is not stepped sequentially, but rather holds the second address of the instruction. When the computer looks for its next instruction, it will find its location as usual in the instruction address counter. This type of instruction is especially useful on a drum-type computer, since the next instruction can be placed in such a position on the drum that it appears under the reading head at the instant the previous instruction is completed, thus eliminating wasted time in waiting for the drum to come to the proper position.

(3) Three address. Here, the instruction contains an order and three addresses. The first two addresses give the location of the numbers to be operated on. The third gives the location where the result is to be stored. For example:

ADD 2894, 2480, 3005	Add the numbers stored in memory locations 2894 and 2480. Store the result in location 3005.

c. Program of Instructions. Programs of instructions are designated by the programmer. By using the available instructions, the programmer directs the machine to process and complete the work. A series of sequential instructions which completes one segment of a job is called a routine. A combination of many routines comprises a program. The program is a complete set of instructions designed to process all conditions which may arise in completing a job. These instructions are recorded in a form compatible to the machine (punched cards, magnetic tape, etc.) and are fed into the memory of the machine in much the same manner as data to be processed. They are automatically examined in the control unit and sequentially followed as the program progresses.

30. CHARACTERISTICS OF A TYPE COMPUTER

To discuss programming fundamentals we must use a hypothetical computer. This type computer will have the same characteristics as most general purpose computers in the field today.

a. Input-output. The input-output units will not be described for our hypothetical computer. Input-output units differ greatly in different machines, and the basic function of bringing in information from input equipment and sending out information to output equipment is about all that is common to the different computers in the field today. For the computer used as an example, it will be assumed that all the necessary instructions and data have already been put into memory and that the results, after computation, will be stored in memory.

b. Storage. The memory unit of the type computer consists of a number of storage locations where information can be stored and extracted when needed. These storage locations retain information which remains until replaced by new information. Obtaining information from a storage location does not destroy or change its contents. Each of the storage locations (or pigeon holes) is identified by a number; this number is its address. In the computer used for illustration, memory will consist of 4,096 locations. Memory for this machine will be a magnetic drum on which information may be written or from which it may be read in much the same manner as voice frequencies are recorded on a tape recorder. The drum will be divided into 64 tracks addressed by numbers 00 through 63:

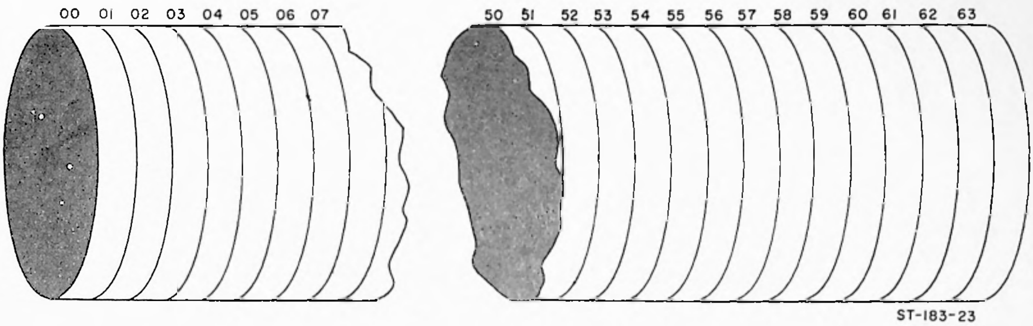


Figure 23. Type magnetic drum: Showing 64 tracks.

Each track is divided into 64 sectors addressed by numbers 00 through 63:

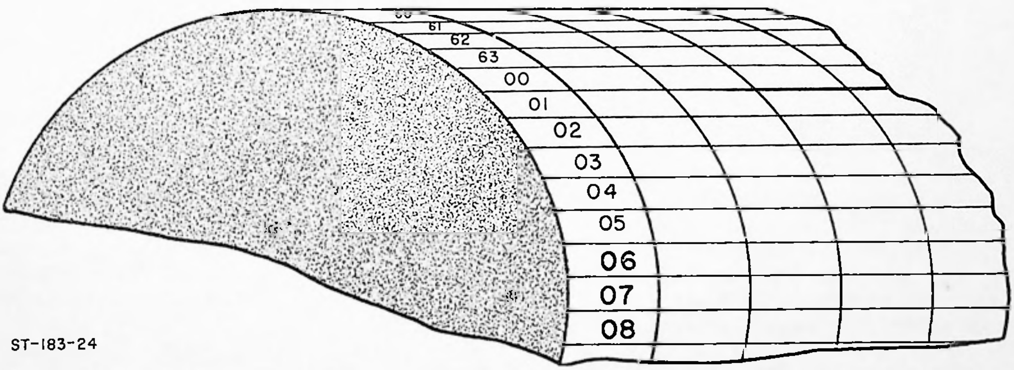


Figure 24. Type magnetic drum: Showing 64 sectors per track.

Thus, if there are 64 tracks, each track consisting of 64 sectors, there are 4,096 locations (64 x 64) addressable in the storage element. Each of the locations has the capability of storing 9 decimal digits and a sign (any number from 0 through ± 999,999,999) or one instruction.

c. Central Processing. The control unit and the arithmetic and logic unit of the computer used for discussion will operate in the manner described in section III of this chapter.

d. Data Word. A data word in the computer contains 30 binary bits and a sign bit. With 30 binary bits 9 decimal digits can be represented.

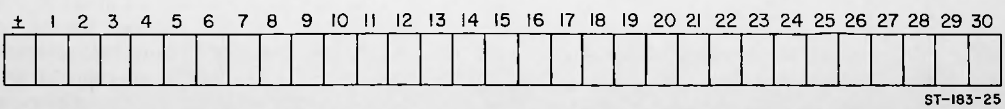


Figure 25. Type computer: Showing capacity of data word.

e. Instructions. The type computer we are discussing has been provided with eight instructions. They are:

Pseudo Code	Binary Code	Effect
B	0001	Bring
A	1110	Add
S	1111	Subtract
M	0111	Multiply
H	1100	Hold or store
T	1011	Transfer if minus
U	1010	Transfer unconditionally
Z	0000	Stop

f. Instruction Word.

(1) An instruction word in the computer also contains 30 binary bits plus a sign bit which is immaterial. Only 16 of the 30 usable bits are used to code an instruction. Four bit positions (12-15) are used to represent the operation, 6 bit positions (18-23) represent the track, and 6 bit positions (24-29) represent the sector. Thus the two parts of an instruction are the order or operation and the address. Six binary bits count to 64. Thus, allowing 6 bits for track and 6 bits for sector, we can address any one of the 4, 096 storage locations on our drum.

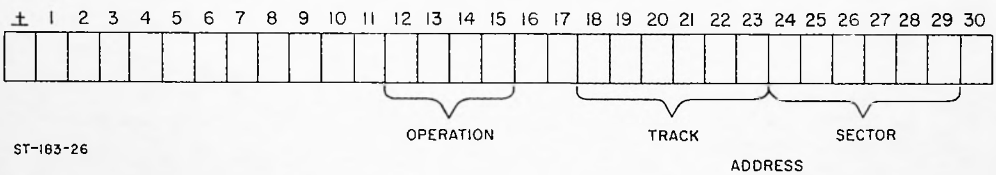


Figure 26. Type computer: Showing layout of instruction word.

(2) If we want the computer to add the contents of location 0810 -- that is, the contents of sector 10 of track 08 -- to the accumulator the instruction would be stored in memory as:

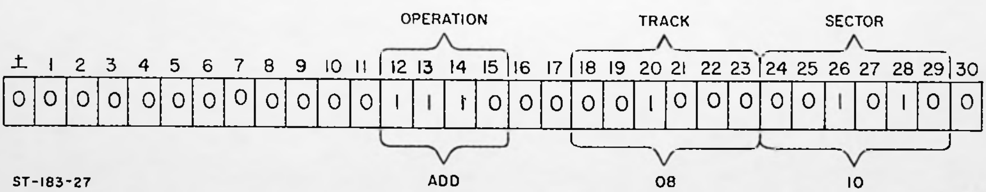


Figure 27. Type computer: Showing typical instruction.

Again the sign of an instruction word is immaterial. It should be noted that the instruction in its coded form is a binary number representation no different from a data word representation in binary. The only thing that identifies an instruction to the computer is that it is brought into the instruction register under control of the instruction address counter.

g. Execution of Instructions.

(1) The bring, add, subtract, and multiply instructions perform standard arithmetic operations. The bring instruction brings the contents of the location specified in the address part of the instruction to the accumulator. The add instruction adds the contents of the location specified to the contents of the accumulator. Subtract operates in a similar manner. The multiply instruction multiplies the contents of the accumulator by the contents of the location specified.

(2) The hold or store instruction is used to transfer information from the accumulator back to the memory. Its operation is similar to a bring instruction in reverse.

(3) Execution of the unconditional transfer instruction is simple. Upon this signal the control unit loads the instruction address counter with the address of the transfer instruction. The instruction address counter is not increased by one as in the normal operation but a new address is loaded into it. Thus the instruction provides the programmer with the ability to break the sequence in which instructions are obtained from memory.

(4) Transfer if minus is a conditional transfer depending on the condition present in the accumulator. If the number in the accumulator is negative the computer executes an unconditional transfer. But if the accumulator is not negative then the transfer if minus instruction does not change the sequence in which instructions are obtained from the memory. This conditional instruction makes it possible for the programmer to write programs which take different courses of action depending upon the result of previous computations.

(5) The execution of the stop instruction stops the computer, leaving the contents of all registers and counters unchanged. The address part of this instruction has no effect on the computer.

31. EXAMPLES OF PROGRAMMING

a. Program I. The first program to be discussed adds 2 numbers and subtracts from that sum a third number, then stores the result in the memory. Let a, b, and c be stored in memory locations whose addresses are 2000, 2001, and 2002. The program will make the calculation and store the result in memory location 2003.

PROGRAM I

Location	*Instruction*		
of Instruction	*Operation*	*Address*	*Effect*
0000	B	2000	Brings (a) into accumulator.
0001	A	2001	Adds (b) to (a) in accumulator.
0002	S	2002	Subtracts (c) from (a + b) in accumulator.
0003	H	2003	Stores (a + b − c) in location 2003.
0004	Z	0000	Stops machine.

b. Program II. The second program evaluates the expression $ax^2 + bx + c$. The memory locations whose addresses are 4000, 4001, 4002, and 4003 contain a, b, c, and x. The result is stored in location 4004.

PROGRAM II

Location of Instruction	Instruction Operation	Instruction Address	Effect
0000	B	4000	Brings (a) into accumulator.
0001	M	4003	Multiplies (x) times (a) in accumulator.
0002	A	4001	Adds (b) to (ax) in accumulator.
0003	M	4003	Multiplies (x) times (ax + b) in accumulator.
0004	A	4002	Adds (c) to (ax^2 + bx) in accumulator.
0005	H	4004	Stores (ax^2 + bx + c) in location 4004.
0006	Z	0000	Stops computer.

c. Program III. The programmer's ability to write programs that give the computer the power of making simple decisions is provided by the inclusion of conditional instructions in the operation structure. The transfer if minus instruction incorporated in a computer is such an instruction. Our third program is an example of the use of the transfer if minus instruction in making decisions. This program examines 3 numbers -- a, b, and c -- and determines the largest, storing it in location 1003. It will be noted that not all of the instructions are executed for any one case. The programmer should pretend to be on the level of capability of the computer and try to forget the purpose of each step. By following each instruction to the letter he may find errors in the logic of the program.

PROGRAM III

Location of Instruction	Instruction Operation	Instruction Address	Effect
0000	B	1000	Brings (a) into accumulator.
0001	S	1001	Subtracts (b) from (a).
0002	T	0005	If accumulator is negative transfers to 0005.
0003	B	1000	If accumulator is not negative brings (a).
0004	U	0006	Unconditionally transfers to 0006.
0005	B	1001	Brings (b).
0006	H	1003	Stores either (a) or (b) in location 1003.
0007	S	1002	Subtracts (c) from either (a) or (b).
0008	T	0010	If accumulator is negative transfers to 0010.
0009	Z	0000	If accumulator is positive stops with largest in 1003.
0010	B	1002	Brings (c).
0011	H	1003	Stores (c) in 1003.
0012	Z	0000	Stops computer.

d. Program IV. Much of the versatility of digital computers lies in their ability to have instructions operate on other instructions in a program as if they were numbers. To show this ability we will expand the third program into Program IV to find the largest of 63 random unequal positive numbers. This technique is called a cyclical program. If enough memory registers were available we could do this by adding more comparison instructions to the third program. Such a program would be doing the same kind of operations over and over. However, we can write a short cyclical program which will execute the required comparison instructions, change the address parts of those instructions, and then execute the modified instructions again. A test is required during each execution to determine if all the numbers have been compared. At the end of the program the largest number will be stored in location 1502.

PROGRAM IV

DATA AND CONSTANTS FOR PROGRAM IV

Location	*Contents*
1000 thru 1062	63 random unequal positive numbers
1500	B 1063 (an instruction that will be used as a constant to find out if all numbers have been checked)
1501	"1" (a plus one for modifying the addresses by 1 during each repetition)
1502	Working storage location (used to store the base)

Location of Instruction	*Instruction Operation*	*Instruction Address*	*Contents of Accumulator*	*Effect*
0000	B	1000	1st number	Brings first of random numbers into the accumulator.
0001	H	1502	1st number	Stores that first number as a base for comparison.
0002	B	(1001)	Next number	Brings next number from random numbers into the accumulator.
0003	S	1502	Next number minus base	Subtracts the base of comparison from the next number in the accumulator.
0004	T	0007	Next number minus base	Tests, if result in accumulator is negative (base larger) transfers control to step in location 0007.
0005	B	(1001)	Next number	If test result is positive in accumulator, brings compared number into accumulator.
0006	H	1502	Next number	Stores that number as a new base of comparison as largest number yet found.
0007	B	0002	B 1001	Brings instruction from location 0002 into the accumulator.
0008	A	1501	B 1002	Adds one to the address part of the instruction in the accumulator.
0009	H	0002	B 1002	Stores modified instruction back into program step 0002.
0010	H	0005	B 1002	Stores the same modification back into program step 0005.
0011	S	1500	B 1002 minus B 1063	Subtracts a constant, that is an address one greater than the last data address, from the instruction presently in accumulator.
0012	T	0002	B 1002 minus B 1063	If accumulator is negative all of the numbers have not been compared, so transfers control to 0002 for another repetition.
0013	Z	0000		If accumulator is positive all of the numbers have been checked so the program stops the computer.

32. OTHER FACTORS IN PROGRAMMING

The programs used as examples show, of necessity, only the most basic of the techniques used to program a general purpose digital computer. One programming problem of great importance not mentioned above is scale factoring. This is the problem of keeping the magnitudes of data, intermediate results, and final results within the range of the computer registers. Also, computers usually have a number of shifting instructions, address-modifying instructions, instructions that control input and output equipment, and various logical instructions. Long programs are written by combining these basic techniques to form very sophisticated programs. Each computer in the field today has a unique coding system but no matter what system is used the basic techniques mentioned above are always present.

33. PROGRAM DOCUMENTATION

Most problems solved on digital computers are not truly static. Situations change in both business and scientific application. These changes require modification and revision of the program. Proper documentation of the programs will facilitate the task of making these changes. A well-documented program will contain:

a. Logical flow charts.

b. Notes concerning operations.

c. Samples of data input and output formats.

d. Computer print-out of program.

e. Operating instructions for the computer operator.

34. AUTOMATION OF THE PROGRAMMING PROCESS

It is often desirable for the person with the problem to do his own programming, and if he can do it easily, valuable time and money will be saved. But computer programming becomes rather tedious if it is done day in and day out, and people with imaginative minds soon rebel at the tedious coding procedures. Moreover, such people seldom have the time or inclination to learn a special code so they can write programs. But if an algebraic problem, for example, can be stated in the usual language of algebra, the programmer need not learn any special language. Therefore many advantages are gained if the coding process can be simplified so that the computer can be made to do the tedious work.

a. The general name for the process of letting the computer do the tedious parts of the coding job is automatic programming. This does not mean that the machine does everything, but it does mean that once a problem is specified, it can be stated for the machine very simply in a language that the user already understands. At this point automatic programming takes over.

b. There are four basic reasons for automatic programming:

(1) Programming is expensive.

(2) There is a shortage of manpower for programming.

(3) It is often necessary to cut down the time from presentation to solution of a problem.

(4) The computer itself may have shortcomings that would be nice to overcome.

c. There are several limitations to automatic programming which must also be considered:

(1) Automatic programming systems are slow and may take an excessive amount of machine time to use.

(2) The program systems may take more storage space than is available, or they may severely limit the space for data.

(3) These systems are difficult and expensive to prepare correctly, although they may be available from manufacturer's libraries.

(4) Automatic programming systems may be limited in their applications on a particular machine.

35. PRINCIPLES OF AUTOMATIC CODING

a. There are two basic types of automatic programming routines: interpreters and compilers. They work on the same principles as far as input is concerned, but they differ as to what they can produce. The purpose of both routines is to enable the machine to receive a pseudo-code as its input and to translate it in some way to machine language. An example of a pseudo-code would be algebraic letters and symbols (perhaps punched on paper tape) which the machine would convert to its own code.

(1) Interpreter. The interpretive routine automatically translates the simplified instructions (pseudo-code) into detailed computer instructions and then proceeds to execute these instructions as it gets them. It may have to make use of various subroutines which it has stored in its own library (often a tape unit). The interpretive type of routine produces the answers to the problem itself. The only major effect of this type of routine is that it enables the machine to translate the pseudo-code at the input. The major difficulty with the interpretive routine is that it occupies storage which might also be needed to store the program or data for the problem being solved.

(2) Compiler. The compiler routine eliminates the major difficulty stated above. It does the same translation of a pseudo-code at the input, but instead of using these machine-coded instructions immediately, it produces a machine-coded program which may be used later. Two advantages are gained by this routine. First, while translation is being carried out, the machine can devote its entire storage to the translation. When the program is run later, no space is taken up by the compiler routine itself. Second, the compiler operates only once on the main program and converts it, while the interpretive routine must usually translate the pseudo-coded orders each time they appear for use. Hence, if the program involves a loop which is passed through many times, much time can be wasted while the interpretive program translates each instruction every time the computer runs through this loop.

b. Since either type of routine can translate a pseudo-code into machine language, the programmers who write automatic programs can be given a rather free hand in designing a pseudo-code. Each code may be developed in conjunction with the group of people who will have to use it. A group of statistical analysts might like a pseudo-code using the symbols and terminology of statistics. The programmers must design a program which will translate this pseudo-code into machine language and must also set limitations on the use of the automatic program. Whether the automatic program is an interpreter or a compiler depends on the job to be done. Systems which involve special arithmetic operations, such as floating point, usually require an interpretive routine; such variations on arithmetic processing often require many machine orders which would produce an excessively long machine program if a compiler were used.

36. UTILITY ROUTINES

To aid the programmer in running and testing his program, utility routines are available to perform many of the routine jobs which the programmer might otherwise have to do. These are generally one-purpose routines. They may be broken down into two major categories by their usage: subroutines and external routines.

a. Subroutines. A subroutine is a program designed for performing a specific calculation or operation. The operations chosen are usually the more common ones which are often needed by programmers. Subroutines are generally of two types: mathematical subroutines for such things as forming square roots, sines, exponentials, and sums of squares; and logical subroutines for sorting, collating, merging, comparing, and transferring information to and from magnetic tapes. A subroutine is called upon by the main program simply by transferring control from the main program to the subroutine. After the subroutine has been used, it will transfer the control back to the main program where it left off.

b. External Routines. External routines are those routines which are not part of the main program but are generally used as aids for running and testing the main program. (Output routines are sometimes used as part of the main program but are usually considered external routines.) There are several different types of external routines: loading and output routines, which make it possible to get programs and data into and out of the computer, or which determine and print (or punch) out the contents of various registers to aid the programmer in deciding what went wrong with his program; trace routines, which help the programmer by recording the path of operation through his program; drum zero routines to place zeros in all memory registers; conversion routines to change number systems (such as decimal to binary) or to change codes; and diagnostic routines, which test the functioning of either the machine or a program.

37. SIMULATING A COMPUTER

A technique which is often valuable is that of simulating one computer by using interpretive routines in another. One major use for this technique is to make it possible to write and test routines for use on a new computer as soon as it is delivered. An interpretive routine which translates one code to another is used in this simulation, but the technique is slow since every operation requires translation.

Section V. SUMMARY

38. AUTOMATIC DATA PROCESSING

Automatic data processing is the mechanization, automation, and integration of accounting and record keeping. In our previous definition of automatic data processing, we indicated that no matter how data are processed, the information must be gathered, put in workable form, processed (revised, extended, sorted, etc.), and finally arranged and presented in usable form. In the quest for a faster, more accurate, and more economical method of data processing, the conventional punched-card system evolves as a satisfactory but temporary measure, since the punched-card tabulating system mechanized only a part of the information flow. We still had to gather information and present it to the system in usable and compatible form. Presentation in this form was through the medium of the key-punched card. Each punched card, however, was a vehicle for only one record of information, and in each instance we had to transport, handle, and feed the card manually to the machine. This system did mechanize sorting, extending, and printing, thus eliminating to a significant degree that most costly of all data processors -- the man with the lead pencil.

39. INTEGRATION OF DATA PROCESSING

a. The problems of excessive card handling, large volumes of data, and slow speed of electromechanical card processing were still major barriers to the integration of data processing. The need to eliminate physical handling and individual line item documents (one fact per card) called for a system to further speed up and consolidate data. The automatic data processing system, has, in effect, gone a step further towards the integration of data processing.

b. The system has consolidated many of the component and functional aspects of standard machine processing. Instead of physically transporting card records between electric processing units, the ADPS reads the record in at one location, transports electronically converted data between components (through the various machine operational areas by means of electronic circuits and cables), and ultimately releases it in desired form. This is, in effect, a network of transportation and processing facilities, which converts the information into machine language and guides it through the system to its ultimate preparation and output in the desired intelligible form.

40. AUTOMATIC INFORMATION FLOW FEATURES OF ADPS

Although the medium of the punch card has advantages in a single source card for each record, when we examine ADPS processing we find that electronic processing can do far more than conventional punch-card equipment. This comparison is cited to demonstrate the unique automatic information flow features of ADPS, which can be summarized as follows:

a. A sequential follow-through of stored instructions which convert, transport, and process raw data into finished and usable form.

b. A utilization of electronic circuitry to achieve high-speed processing.

c. An ability to perform logical comparison and to process routine and/or exceptional cases that may occur.

CHAPTER 2

MANAGEMENT ASPECTS OF ADPS

Section I. ADPS AS A MANAGEMENT TOOL

41. INTRODUCTION

a. Perhaps the most important management commandment is, "Be aware of all new internal and external developments." The degree to which management is able to keep abreast of current developments is directly related to its ability to maintain a progressive organization. The field of automatic data processing is an area that should be examined and investigated by every alert management group, regardless of the size of its organization.

b. Management is primarily concerned with controlling the elements of men, money, minutes, materials, and machines. To use these five essential resources effectively, management must have accurate and up-to-date facts. The automatic data processing system can serve as an invaluable, analytical control device to provide these facts. Operations and functions of the ADPS have been discussed in the preceding chapter; this chapter will discuss some of the more important management aspects of the system.

42. GENERAL ASPECTS

ADPS is both revolutionary and evolutionary in scope.

a. It is revolutionary from the standpoint of certain operating features outlined in the previous section. Briefly, these are:

(1) A sequential follow-through of instructions, which permits the completion of a processing job almost entirely within the physical confines of the system.

(2) A record-by-record processing at a high rate of speed by electronic circuitry.

b. ADPS is evolutionary in that it not only performs the work currently being done manually and by conventional machinery, but it also mechanizes the data processing function from the origin of source material through the preparation of finished documents. ADPS centralizes data handling, thereby making it possible to prepare certain reports and information which could not be prepared by previous methods. ADPS reduces those problems associated with the sheer volume of the workload. A further important feature of ADPS is its logical ability to recognize exceptional cases and pursue a particular procedure for their handling. This ability to routinize exceptions relieves the need for human processors to observe and act upon thousands of daily routine decisions.

43. CAPABILITIES FOR IMPROVED CONTROL

a. Data processing and information flow are the basis for planning, control, and decision. Therefore, methods, accuracy, and speed of information processing are of major importance. ADPS provides capabilities for --

(1) Greater timeliness of information received.

(2) Doing important jobs on a volume basis. (Previously these jobs could be done only on a sampling basis or not at all.)

(3) Considering more facts during processing.

(4) Increased reliability of resultant data.

(5) Providing exception-type data to permit "management by exception."

(6) Decreasing dollar cost in the development of essential information for management decisions.

(7) Economy in clerical and associated costs.

b. These capabilities are being derived from system installation. Yet automatic data processing is by no means a solution for all management problems. ADPS is primarily a methods device, and it creates a series of problems of a specialized nature. Introducing high-speed data processing into an organization may have far-reaching effects on the entire organization. It is seldom possible to install a system without gearing it to other operations of the organization. Care should be taken in examining it, therefore, to show all the problems which may arise when considering replacement of the existing method.

44. FUTURE USES

Many of the capabilities of ADPS are yet to be discovered. As faster and more versatile equipment is developed, alert programmers will continue to extend data processing system capabilities. Jobs are now being done which, five years ago, were considered impossible. This capability has significant implications regarding correlation of data for the projection of future needs and requirements.

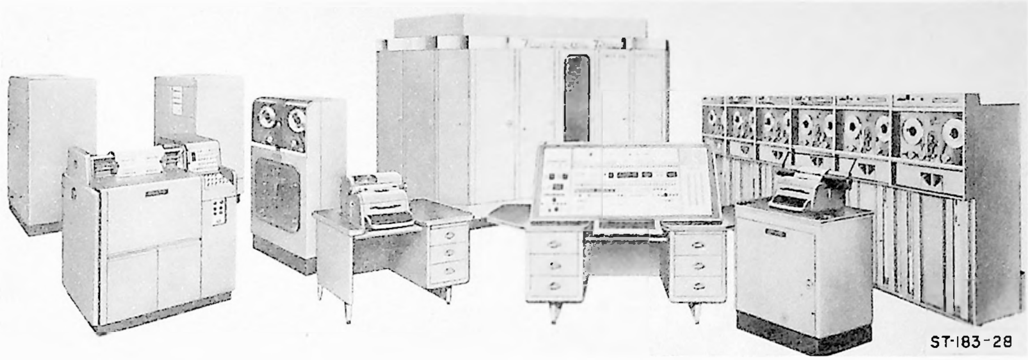
Section II. COST CONSIDERATIONS OF ADPS

45. GENERAL

During one phase of feasibility studies, the various elements of cost must be analyzed. The investigating and evaluating group must be able to produce answers to command's inevitable challenges, "Is it worth it? And if so, show me how and why." Justification of operations on a cost basis is therefore another of management's considerations for decision. Many of the decisions may not be clearly defined for accurate cost evaluations, yet some estimate or some projection may be made to serve as a tangible basis for justification. Frequently we cannot specifically calculate indirect costs and indirect cost savings at the moment a decision is to be made. Therefore, many decisions are based on a value judgment of the benefits (and drawbacks) associated with the decision. Installation of ADPS involves many considerations of such character. In the following paragraphs, an attempt will be made to define some of the questionable cost areas faced by management.

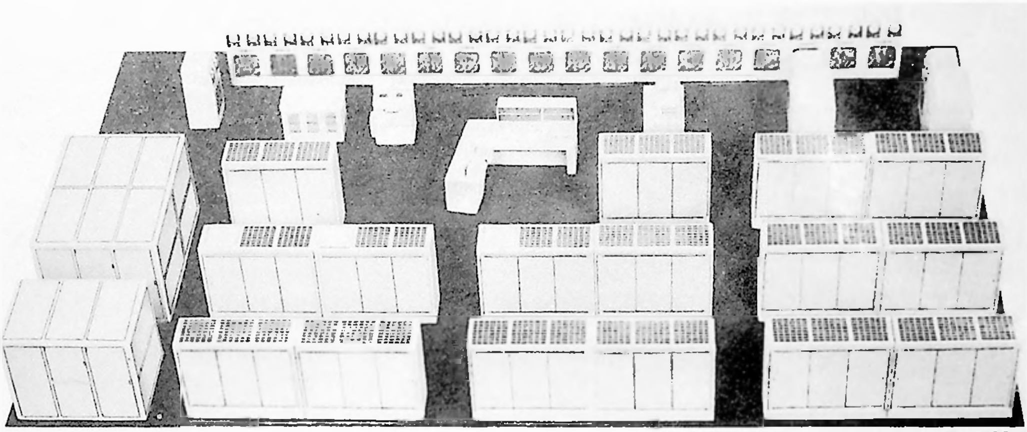
46. LEASE VERSUS PURCHASE

A decision on whether to lease or purchase a system involves many relative cost comparisons. Large-scale data processing systems rent for about $30, 000 monthly -- $360, 000 annually. Not all manufacturers have released sale prices, but large-scale systems (figs. 28, 29, 30, and 31) can be bought for some amount between $1, 250, 000 and $3, 000, 000. This means, other factors excluded, that from 3 to 5 years' rent would cover the purchase price. However, additional expense factors involved in ownership, such as maintenance personnel and parts replacement (included in lessee rental), must logically be added to the purchase price. The so-called medium-sized data processing systems (figs. 32 and 33), which rent monthly for an amount between $4, 000 and $12, 000, carry similar ratios and similar analysis requirements. Thus, a decision to purchase or lease involves important considerations and evaluation of many incremental cost factors which are difficult to reduce accurately to dollars and cents.



Courtesy of Remington Rand Division, Sperry Rand Corporation

Figure 28. Large-scale ADPS: UNIVAC II.



Courtesy of Remington Rand Division, Sperry Rand Corporation

Figure 29. Large-scale ADPS: UNIVAC 1105 (scientific and commercial).

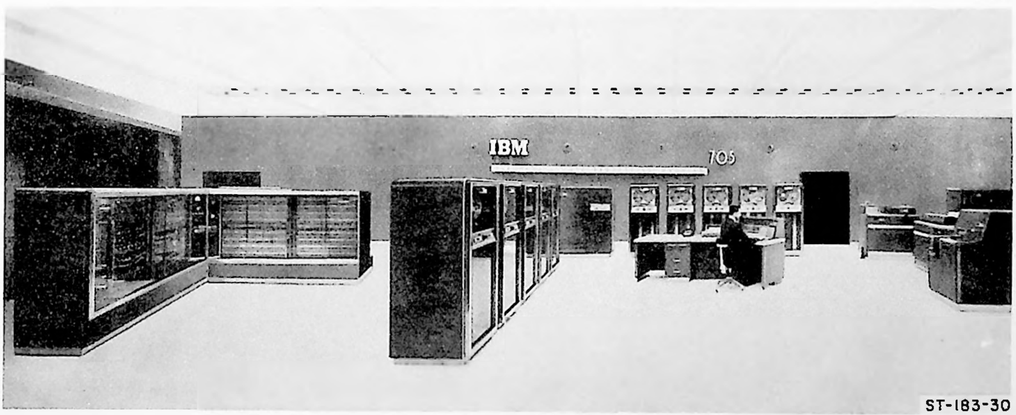


Figure 30. Large-scale ADPS: IBM 705.

Courtesy of International Business Machines Corporation

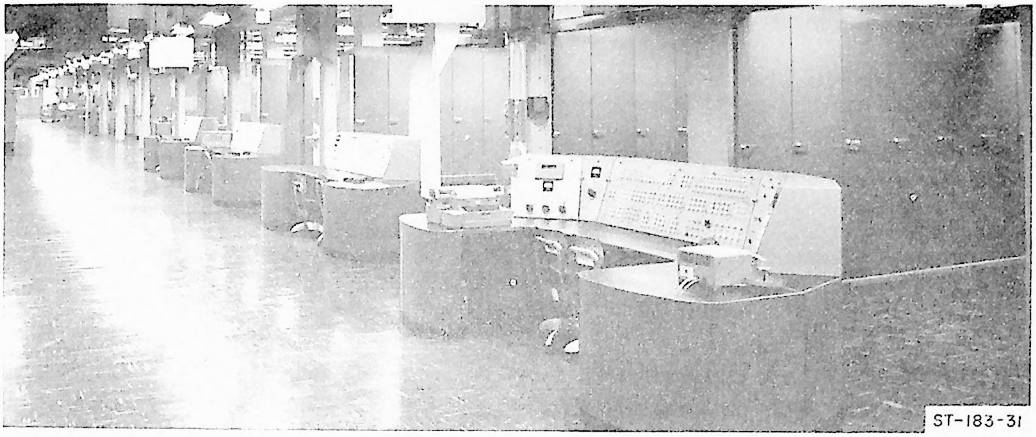


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Figure 31. Large-scale ADPS: RCA BIZMAC.

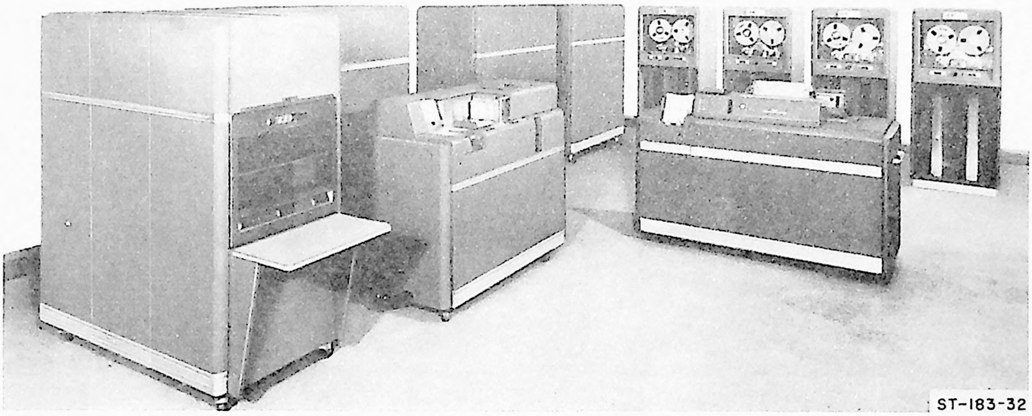

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Figure 32. Medium-sized ADPS: IBM 650.

Courtesy of International Business Machines Corporation

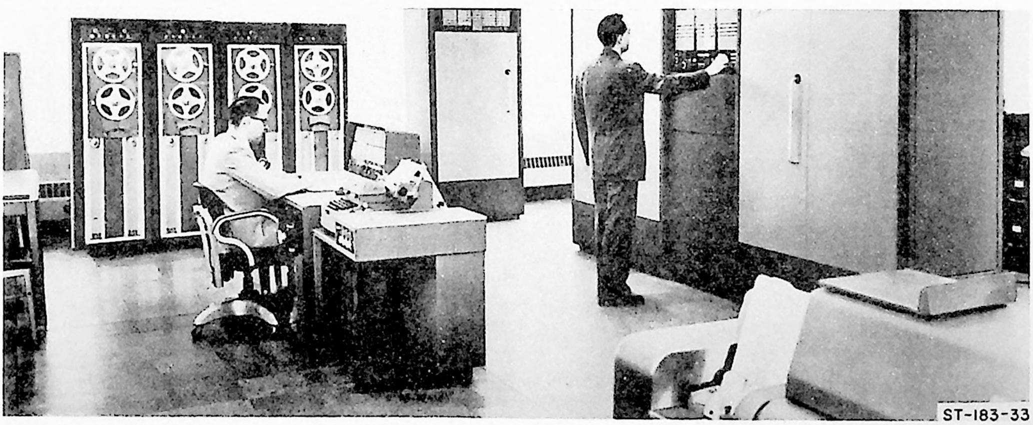

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Figure 33. Medium-sized ADPS: ElectroData.

Courtesy of ElectroData Division, Burroughs Corporation

a. Operation Costs of Purchased Systems. Operation and application (utilization) of ADPS are responsibilities of the owner or lessee. Maintenance of leased systems is the sole responsibility of the manufacturer. Once a system has been purchased, however, responsibility for its operation, application, and maintenance falls totally on the owner. The purchaser must train and maintain a qualified maintenance staff or employ the manufacturer's representatives on a service-contract basis. These service contracts, like those offered for other complex electronic systems, are usually quite expensive. Thus, the cost of an annual service contract is actually a part of the true purchase price. Within this area, the reliability and availability of maintenance personnel are important considerations, for machine down-time of any lengthy duration may paralyze the entire business operation.

b. Operation Costs of Leased Systems. Under the leasing system, the machines remain the property of the manufacturer, and the maintenance cost is included in the rental cost. Since the customer is actually renting the operating service on a shift basis, he is not required to pay for occasional lengthy down-time and usually depends on the manufacturer to shift the work to another machine until his own system is in working order. A further advantage of leased systems is that the lessee bears no cost of parts replacement. On the other hand, the lessee generally pays for his system use on a shift basis and, therefore, must pay more rent for two- or three-shift utilization.

c. Obsolescence. Technological advances in the field of ADPS have been many and rapid. For this reason, the obsolescence factor must be recognized in the decision of whether to purchase or lease. The highly competitive nature of the data processing machine industry has resulted in a steady stream of innovations to increase the scope, speed, and capabilities of ADPS. Obsolescence is a significant management consideration when anticipating a purchase; however, this factor is often overemphasized. The fact that a faster machine is available does not render the present system unsuitable or inferior for the job or jobs it is now doing. Having been properly planned for, it may remain for many years the most economical and feasible method of doing the job. It is only those staunch advocates of the management philosophy of utilization of the fastest method available who stress the obsolescence factor out of proportion. A final consideration in the area of obsolescence concerns the fact that technical developments can often be effected as modifications to existing equipment. Thus, an owner may install such a change when he feels that the added facility warrants the cost. The lessee may also rent the new feature after a similar judgment.

d. Current Versus Anticipated Work Loads. The very nature and complexity of an automatic data processing system necessitates careful analysis and fairly accurate projection of the work load for the system. Operations are usually started before all of the anticipated applications are ready for machine processing. This allows time to test anticipated programs as the command sees fit. Consequently, the ADPS should be installed to accommodate current as well as anticipated job processing. Applications of this sort should be taken into account initially in determining the suitability and size of a system for purchase. Thus, the long-range consideration of future applications is a significant element in the purchase of a system.

e. Trial Rental. The lease-with-option-to-purchase agreement offered by some manufacturers provides the lessee with a trial-rental period. If, after a year of leasing the system, the lessee chooses to purchase, a portion (usually about 40 percent) of his paid-in rental is applied to the purchase price.

47. INITIAL COSTS

There is a series of one-time costs or charges associated with ADPS study and installation. These costs are usually incurred during the project organization, evaluation, and installation of the system.

a. In many cases, an outside staff analysis team is called upon to help prepare the application and feasibility studies. Outside groups of this sort are costly to maintain. In addition, analysis personnel from within the investigating organization must be assigned to the project on a full-time basis and may require temporary replacement.

b. When determining and preparing a site, we must consider a number of factors. Large scale computers require an average of 5,500 square feet. (See figures 28 through 31.) The floor loading of this area must meet machine component requirements. We must provide on the premises for power supply, cable ducts, air conditioning, humidity control, maintenance staff and repair equipment space, and tape and card storage facilities. These are all initial expenditures which must be made before installing the system. The cost of ADPS site installation may range from $10,000 to $200,000, depending on the size of the system and the degree of elaborateness desired. (See also figures 32 and 33.)

c. Other costs which must be incurred before the system is functioning are for such supplies as paper, cards, and magnetic tape; for training operating and programming staffs; and for furniture and space for programming and maintenance staffs.

d. We must also identify, as an important consideration, the cost of conversion and parallel operations. In most instances, dual operations must be maintained to insure the effectiveness of the newly installed system.

48. AUXILIARY EQUIPMENT

A cost factor that is often overlooked is that of auxiliary supporting equipment. This type of equipment generally includes a battery of conventional machines used to prepare or rearrange input data for the data processor (computer). Equipment serving this purpose is included (by definition) in an ADPS and should therefore be included in any cost analysis.

49. ONE-TIME SAVINGS

Certain applications lend themselves to fairly accurate savings projections. If a revised inventory control system reduces a fifty-million-dollar inventory by five percent, the derived one-time savings might well justify the installation of the automatic data processing system.

50. INDIRECT MONETARY BENEFITS

a. It is difficult to evaluate the monetary benefits derived from such factors as speed and accuracy of statistical report preparation. In private industry, the value of up-to-date information may be fairly well judged by the analysis of records. This is included in the follow-up (before and after) study, which traces the effects of a change. In governmental and military activities, however, such comparisons and evaluations are not as readily prepared. Who, for instance, is capable of pricing savings in such areas as tactical army operations, personnel manipulation, and record keeping? The element of timeliness is, for the most part, too complex to value in dollars and cents.

b. Another factor for consideration is that ADPS not only accomplishes normal operations in a shorter time, but may also be applied in areas where the large volume and complexity of data formerly precluded its processing. The relative value of such anticipated applications is almost impossible to price in an economic feasibility study.

c. An advantage to be considered in this area is that ADPS most definitely increases the informational output of each worker. This is demonstrated by the volume of statistical information and projections which the system can produce. In many cases, this material was not previously prepared, or was prepared on a sampling basis only.

51. SUMMARY

The concept of cost analysis of ADPS carries with it many complex considerations. Although component costs remain stable, each anticipated installation must be studied and analyzed as an independent situation. A need exists for a justification standard to isolate the most critical factors to be considered. Such a guide would assist inventigating and analysis teams in the difficult project of economic justification.

Section III. PLANNING FOR AN ADPS APPLICATION

52. GENERAL

a. The generally accepted technique for determining and planning an ADPS application consists of five areas:

(1) Isolation and definition of specific functions which lend themselves to automatic data processing.

(2) Detailed analysis and procedural improvement of these functions.

(3) Interpretation of these functions into general automatic data processing machine techniques.

(4) Analysis of benefits to be accrued by utilizing an automatic data processing machine.

(5) Detailed interpretation and translation of functions into automatic data processing machine instructions.

b. AR 1-250, Automatic Data Processing Systems, further discusses these areas in outlining a procedure for proposals to use ADPS in the CONUS business-type operations of the Army. DA Pamphlets in the 1-250 series provide further instructions for conducting ADPS feasibility and engineering studies of busines-type operations, and a more comprehensive explanation of the ADPS concept.

c. A detailed procedure somewhat different from the CONUS business-type applications is being followed in analyzing the Army's combat-type operations for ADPS. The procedure in this case has been called systems analysis; it includes the specific sequence of studies, format of flow-charts, and format of the final report. The techniques and procedures used in analyzing combat type operations are described in the following documents:

(1) USAEPG-SIG-940-25, Preparation and Reporting Format of Systems Analysis Study.

(2) USASCS IS 85-027-1, System Analysis.

d. The information in this section does not follow either of the two approaches mentioned, but rather discusses principles common to both.

53. ESTABLISHING A TASK GROUP

a. The first step in studying the possibility of installing an ADPS is to establish a full-time task group. The mission assigned this group should define the limits of their initial investigations, indicate the need for continued progress reports to management, and include target dates for separate phases or the final report. The group should report directly to top level command or management. In some past cases, management extended the mission of the study group to include responsibility for installation and operation of the ADPS.

b. Generally, the group should be composed of persons currently involved with the operations of the organization being studied. Members of the committee must know specifically what is being done, what management feels should be done, and what management would like to do. Briefly then, this group requires diversity of knowledge, responsibility for operations, and ability to analyze problems and make decisions. Accordingly, personnel of the task group should be the second echelon supervisors of the operating areas affected. They should be thoroughly familiar with the operation being studied for possible ADPS application. In addition to personnel from the operating areas, a systems or management engineer should be assigned to the group. Desirable additions to the task group might come from an EAM (Electric Accounting Machine) systems group, professional consultants, or Department of the Army consultants established in the Office of the Chief Signal Officer.

c. Initially the task group must organize, establish objectives within defined limits, and determine procedures for accomplishment. In order to accomplish its mission the group may require specialized training. The objective of this initial training should be a basic understanding of how an ADPS operates, how it is applied to an operation, and the technique of studying an operation for the purpose of applying an ADPS. The ADPS Officers' Course offered by the U. S. Army Signal School, the ADP Systems Analysis Course offered by the Adjutant General's School, manufacturers' orientation courses, and study of available literature are recommended sources of training. A minimum of one month should be allocated to orientation of task group personnel.

d. In the interest of maintaining the morale of the entire working force of an installation at a high plane, it is strongly recommended that all personnel be kept advised of the task group's objectives and of the implications of introducing an ADPS into the organization. General orientation of the working force can be effectively accomplished through the medium of lectures, organization publications, and directives.

54. STUDY AND DOCUMENTATION OF PRESENT OPERATION

This survey, on a broad level initially, is designed to outline the various areas of data processing within the organization. After broad processing areas are established, the group begins to separate them according to their relative importance. The importance of data processing activities within the organization is also considered. At this point, it usually becomes evident that one or two of the processing jobs comprise a significant and important portion of the jobs being done. These so-called primary applications become the basis for the first detailed analysis. The following information is included in this study:

a. Detailed description of basic data to include the source, format, and volume.

b. Detailed description of files and records used to influence the details of processing, including the size of each file, the size of each record in the file, the kind of information in each record, key information in each record (such as stock number), arrangement of records which make up a file, and methods of file maintenance.

c. Detailed description of outputs to include format, volume, and distribution.

d. Detailed flow chart showing all the operations involved, from the creation of the source document through preparation of reports (output). Since this chart is designed to show operations, it might well be called an operational flow chart. It will be the basis for further analysis and procedural evaluation. For this reason it is recommended that organizational structure be superimposed upon the flow chart.

e. Discussion of time aspects, such as period of cyclic operations, need for random query, minimum time requirements for processing, and relative priorities.

f. Cost analysis of the present operation, including such elements as personnel, cost of supplies, and rental or depreciation of machine.

55. MANAGEMENT ENGINEERING

a. The management engineering study is used to evaluate present methods and procedures. If we adopt a questioning attitude at this point we can analyze and review the entire operation as now performed. We ask this kind of question:

(1) Can information channels be shortened, revised, or eliminated?

(2) Is all information now derived necessary or desirable?

(3) Are additional types of information desired?

b. The management engineering study will often point up unnecessary or obsolete practices, wasteful duplications, and costly delays under existing operations; it will be of benefit even if it is later determined that ADPS is not justified. Desirable system changes may be effected at this time. The changes may include operations, missions, responsibilities or requirements.

c. With the job areas outlined and the specific job or jobs broken down into detailed operational form, the next step is to begin action on determining the possibility of using ADPS to perform the job.

56. APPLICATION STUDY

Using the analysis information, the task group conducts a study known as an application study. This is actually an analysis of the jobs, as presented in detailed flow-chart form, for conversion to automatic data processing. The application study is a methods study designed to convert the present method of operation into the terminology, sequence, and operational form of ADPS. This study might indicate the need for, or advisability of, changing one or more of the major operational steps of the job. These recommended changes, which might appear anywhere from the origin of the source document to the preparation of the finished copy, are often required either to facilitate ADPS installation or to permit ADPS processing.

a. Analyzing the Job. We begin by taking the job description (as outlined above) and applying the elements of ADPS to it. Briefly, such a study involves analysis of the following areas:

(1) Basic source documents. Origin, format, type of information, volume, flow and frequency.

(2) Data conversion and input. Source document conversion and input speed.

(3) Data processing. Card sort versus tape sort, on-line printing versus off-line printing, characteristics of records, frequency of runs, types of runs, machine scheduling, and time phasing of runs.

(4) Storage of data. Volume of records, type of file maintenance (cards, tapes, internal, other), record area lengths, internal memory and register requirements, and tape or card requirements.

(5) Data conversion and output. Report format, anticipated or required off-line conversion operations, and volume output requirements.

b. General Application to ADPS. The goal of this work is to design the best possible system for accomplishing the job. A critical review of operations examines such potential improvements as multiple use of common source data, organization of files for speed of reference, and revision of procedural instructions to insure the least possible repetitive use and manipulation of identical documents. This type of analysis requires a general understanding of the capabilities and limitations of available automatic data processing equipment so that the system may be designed to produce the desired results.

c. Organizing Specifications. The information collected and analyzed prior to this phase of the study we now organize as a set of system operational specifications. The following items are included in the specifications:

(1) Input. A description of all known input including --

(a) Method or medium by which data will be received or developed.

(b) Format, message length, alphanumeric or other identifying characteristics.

(c) Daily volume, including cyclical peaks.

(d) Hourly rate at which equipment should receive data.

(2) Maintenance of information. A description of the information to be maintained, including --

(a) Volume of records.

(b) Method of file maintenance.

(c) Proposed record lengths.

(d) Alphanumeric requirements.

(e) Requirements for interrogation.

(3) Data Handling. A detailed description of each type of transaction or computation to permit a proper assessment of the problem. It is not necessarily desirable at this point to prescribe specifically how each transaction will be processed, because different types of equipment may require different procedural steps to accomplish the same results.

(4) Output. A description of output needs, including --

(a) Kind and distribution of output -- whether punched card, tape or printed copy.

(b) Daily volume by type of output.

(c) Required formats.

(d) Time after cutoff within which output data should be produced.

(e) Time cycle to accomplish each transaction.

(5) Other requirements.

(a) Data for equipment delivery and installation.

(b) Arrangements for maintenance of equipment.

(c) Requirements for communications services and compatibility with other equipments.

(d) Expandability to accomplish added workloads.

(e) Other requirements peculiar to the application.

d. Evaluating and Selecting Equipment. Selection of a specific system is based on a complex study and correlation of the job or jobs with available processing equipment. The study group seldom has the extensive knowledge and background required to decide which equipment can best do the job. The facilities of the Office of the Chief Signal Officer should be used for specialized technical assistance in preparing specifications and selecting ADPS and allied communication equipment. Analysis of equipment should develop equipment costs (including supporting conventional punched card equipment) and personnel requirements; it should also specify arrangements for training and programming assistance, including training to offset attritional losses. Evaluation and selection of equipment should be made in terms of a full analysis of the criteria (particularly time and cost) listed below:

(1) Capabilities of the machine to do the job.

(a) Acceptance of input documents and data.

(b) Sufficiency of storage and processing capacity.

(c) Adequacy of data handling.

(d) Production of output in required form.

(e) Adequacy of controls and accuracy of equipment.

(f) Adaptability to long range plans.

(2) Time taken to do the job.

(a) Hours of use in relationship to potential hours.

(b) Capability to achieve processing and interrogation cycles.

(c) Potential for expansion and mobilization needs.

(3) Acceptability.

(a) Availability.

(b) Adequacy of maintenance services.

(4) Advantages of use.

(a) Timeliness of data production.

(b) Production of data desired but previously not available.

(c) Economics.

(d) Other tangible or intangible benefits to be gained.

e. Application Studies in the Field. If the operation under study takes place in the army in the field, the material requirements will more than likely be met by military computing equipments. If it appears that the requirement cannot be met by contemplated or actual military equipment, a set of military characteristics (see sec III, par 8, AR 705-5, Research and Development of Material, 28 Dec 55) should be prepared as the normal means of initiating materiel development. The system operational specifications developed in accordance with c above are directly applicable as part of the statement of military characteristics.

57. EVALUATION OF PROPOSED ADPS APPLICATION

After the method of application has been specifically determined, a study should be undertaken to evaluate the proposed application. The purpose of this evaluation is to ascertain whether the expected benefits outweigh the expected costs of converting to and operating under the new system. The study will stand as justification for recommending an ADPS or for recommending retention of the present system instead of ADPS. The study aims at the answers to such questions as --

a. Is any automatic data processing system feasible from an operating standpoint? Do the volume, workload, and requirements warrant an ADPS?

b. Is the job economically feasible?

c. What components and what variable speeds are feasible for the job?

d. Is there a better system or procedure available to do the job?

e. What benefits other than cost can be expected, such as expandability and new processing activities, and how are these benefits valued?

58. INSTALLATION PLANNING

After the decision has been made to utilize ADPS, a series of concurrent activities begins. Depending on the size of the anticipated system, delivery date may range from 4 to 24 months from the date of order. During this time, we must make extensive and time-consuming preparations for program, personnel, and facilities.

a. Preparing for the installation of the ADPS involves considering and coordinating many factors. By the delivery date, we must have the site completely prepared, all staffs trained, major program applications completed and tested, and phase-over activities ready to begin. Coordinating these elements requires careful scheduling and close control over the entire preparation program.

b. Installing organizations carry on phase-over operations of varying durations. Past operations of this type have averaged approximately 6 months. During this period, parallel operations are usually maintained as a final check on the newly installed system.

c. Planning and analysis do not cease when system operation begins. Instead, it is wise to maintain a staff to continue study on --

(1) Present program revision and improvement.

(2) Analysis, preparation, and development of additional applications for system processing.

(3) Evaluation of new ADPS equipment and additional attachments to the existing system.

59. FLEXIBILITY

The element of flexibility in an automatic data processing system is an important consideration for management. However, the term flexible is at times misleading and cannot be validly applied to an automatic data processing system as a whole.

a. If a manufacturer publicizes the fact that his ADPS is highly flexible, he probably means that it is a general purpose system that is capable of processing various types of jobs. General purpose means that the ADPS will provide the programmer with the physical components, memory capacity, and internal program steps to guide him in his work with the system. In this case, the term versatile is more descriptive than flexible.

b. Certain systems are called special-purpose systems because they are designed and manufactured to do a specific job or a limited series of types of work. To change these systems, it may be necessary to revise and modify the circuitry. Systems of this sort are inflexible, since their construction and instruction capabilities will not permit their use on diverse types of jobs.

c. The term flexibility is also applied to the way physical components of the system can be used. Here, flexibility refers to the facility of ADPS in modifying the methods and speeds of input and output. This is the so-called building block principle. Use of 3 card readers instead of 1, 20 tape units instead of 10, and 2 or more printers on one system are examples of this concept. Data conversion on off-line equipment is another element of component flexibility. These peripheral operations save main frame (central processing unit) time by performing the most time-consuming operations on equipment that is not attached to the main system.

d. Inherent flexibility of the system relates mainly to the programming of the machine and the effective employment of the program instruction steps. An example of inherent flexibility is a system that can process a payroll, up-date the master record, and create checks and statements of earnings at the same time.

e. Another concept of flexibility involves the compatibility features of automatic data processing systems. Compatibility refers to the ability of a system to accept and process data prepared by another system. Such data, either output from another system or information transmitted over various communication systems, require no form or code modification. The ability or inability of a system to accept various types of input from diverse sources is a significant consideration. Many commercially available systems accept input information in different forms, but they seldom provide for compatibility between systems.

f. Note here that the concise and detailed nature of the program makes it somewhat inflexible in the sense of ready revision. If changes are to be made on a processing job, these revisions will, in many cases, require major changes in the entire program. The circumstance would require a close, detailed examination and rewrite of the program. In addition, any revision of a working program must be completely tested before it is introduced. Consequently, ADPS is not readily flexible when processing jobs require frequent and major program revisions.

g. Finally, the detailed nature of program writing is a challenge to the application flexibility of an ADPS. Most applications need detailed and lengthy analyses; and the resulting program can be no better than the human mind creating it.

Section IV. ADDITIONAL PLANNING CONSIDERATIONS

60. MOBILIZATION ASPECTS OF ADPS

The ADPS has some distinct advantages in improving mobilization capabilities, but it also has disadvantages. The advantages stem from expandability and standardization of operational systems. The disadvantages are similar to those experienced in introducing complex electronic machinery on the battlefield. However, we can develop machine procedures (programs) for desired operations on the basis of a type field army. Such procedures should achieve some degree of standardization in support operations and facilitate the activation of new units.

a. There is considerable contrast between the ease with which the ADPS can handle an increased workload and the difficulty experienced in expanding an organization to accomplish the clerical work manually. This feature of an ADPS is measurable; further, it has a known limit, resulting from its size and, ultimately, its speed. For example, if a particular installation processes all data input in an 8-hour period each day, the basic system can tolerate an immediate trebled (three-shift) increase of data input. We could probably increase this further by adding auxiliary equipment and adopting minor procedure changes. And we could immediately double the over-all capacity by installing a second similar ADPS, using the same procedures and machine program that were established for the first ADPS.

b. By complete mechanization of personnel records, we could improve the methods of call-up and assignment of critical personnel.

c. Use of ADPS in the Army's logistic support system could provide accurate data for both accounting and procurement. Such data would greatly assist in an orderly, logistical build-up to support mobilization.

d. Dependance of ADPS on supporting communications can be viewed as somewhat of a problem area, if not as a definite disadvantage. OCSigO has an active development program to provide a universal communication system based on the latest advances in digital techniques. The proposed communication system could, in addition to permitting the transmission of all normal means of electrical communications, provide for on-line exchange of data between computers and remote input-output devices. This is the new concept of data processing communication -- complete integration of an electronic data processing machine with an operational system through electrical communication.

e. The complexity of ADPS presents a requirement for highly qualified personnel. We can partially overcome this requirement by using previously prepared machine programs, but there will still be a shortage of supervisory, operational, and maintenance personnel. Through the establishment of military occupational specialties we are solving the problem of selecting and training enough personnel to man the anticipated large number of mobilization day (M-day) automatic data processing systems. Such trained personnel could be used at either major fixed installations or mobile field army installations.

f. Centralization of data flow, storage facilities, and processing points means a high degree of vulnerability. This problem can be met by establishing alternate machine sites, with trained personnel to insure continuous machine operation. Such a plan has already been given serious consideration by both the Deputy Chief of Staff, Logistics (DCSLOG) and the Deputy Chief of Staff, Personnel (DCSPERS), as well as the Assistant Chief of Staff, Intelligence (ACSI). This plan has been so aggressively pursued that each fixed-installation-type system in the Army today has an alternate plan for continuous operation, requiring both an up-dated machine program and up-dated master files at alternate sites, with plans and facilities to reroute supporting communications. Today, this is not accomplished automatically. In the future, as programs are developed and modified, they will be stored at the alternate sites, together with master files of data. The personnel operating the alternate machine, which may also have its own daily work load to perform, will therefore be prepared to take on the additional emergency tasks.

61. DECENTRALIZATION OF ADPS

One of the basic concepts of military tactics provides for decentralization of military command, because the commander on the ground is in the best position to determine the situation confronting his forces and to take positive action to insure accomplishment of his mission. The same principle may apply to the use of ADPS. The more complicated ADPS equipment may be located farther to the rear under the command of a higher echelon, but the subordinate commander must be given the right to use this machine through his communication system as though it were a part of his command. The practice will be to decentralize ADPS throughout the various Army commands, where feasible and practicable.

62. CENTRALIZATION OF ADPS

Management of an organization having wide geographical distribution creates many problems in data processing. Information and data in a widely dispersed organization usually pass through a number of interim and summary accumulation steps before they reach the headquarters. Thus, detailed information is lost in summaries and is delayed en route to the headquarters. Top management personnel, therefore, must work with delayed summaries accumulated throughout the field and forwarded to the top.

a. The advent of high-speed automatic data processing equipment has opened many new avenues of data processing procedures. Improved communication and data transmission facilities, in addition to rapid data processing, have made it easier to centralize record keeping and statistical analysis. For these reasons, management is now able to review processed data that has been prepared accurately and quickly in complete and detailed form. Having such information quickly available provides for closer control and more effective planning. Preparation of information at a central location also allows for timely dissemination of correlated information back to the local areas. Centralized processing, however, does not necessarily mean centralized control.

b. The degree of data-processing centralization which management needs will vary with the type of organization, its requirements, and its goals. In instances where a headquarters needs the details as well as the synthesis, ADPS (to include data transmission devices) can contribute significantly to the centralization of a data processing activity.

63. IMPACT OF ADPS ON MANAGEMENT

Electronic machinery will never replace management. Like the adding machine, the desk calculator, and the punched-card system, ADPS is a tool to assist management in the functions of planning, organizing, and control. Because of its robot-like operation, the electronic machine can only reflect the intelligence of the person who designs its program of operations. It may be faster and more accurate in performing its work, but it has no creative ability; that must be supplied by the programmer. We can utilize ADPS efficiently, therefore, only after we have established a well organized, adequately staffed, and properly coordinated program.

CHAPTER 3

COMMUNICATIONS AND ADPS

64. REQUIREMENTS FOR COMMUNICATIONS

The element of timeliness is of extreme importance in military operations. Accurate and up-to-date information is essential if military management is to operate efficiently. In the past, we have found it extremely difficult to accumulate information from, and disseminate information to, widely dispersed service installations. We had no central installation to handle and correlate large volumes of data, and only limited communication facilities for the handling of this traffic. Integration of electronic data processing machines with modern communications will give us the flexibility, accuracy, and speed of transmission required in data processing. It will also provide a central location for the accumulation of this data.

a. The high speed and versatility of modern electronic data processing have facilitated the preparation of vital data. To utilize these high-speed processing devices effectively, however, current information must be gathered and forwarded quickly and accurately to the processing center. This means that we must design and establish responsive communication systems to provide information channels for centralized processing, thereby eliminating consolidation and summary at interim echelons. By integrating electronic data processing machines with effective communication facilities, we can handle, in a matter of days or hours, information that is now delayed weeks and months on its way to and from military units. This current information, prepared and presented in orderly form, will assist the command in more promptly recognizing, isolating, analyzing, and acting upon specific areas of decision.

b. Direct integration of an electronic computer with communication facilities demands transmission accuracy. The human mind can reconstruct a mutilated word or recognize an unrealistic fact, but a mechancial processing unit cannot. Therefore, the limited judgment of a computer requires transmitted data that is carefully prepared and handled. ADPS is most effective when the speed of data transmission is increased without sacrificing accuracy.

c. A further requirement for efficient data flow is a transmission device that will deliver information in a code form compatible with ADPS. This type of on-line or integrated data processing would eliminate time-consuming and error-producing copying of source information prior to processing.

65. USE OF COMMUNICATIONS

The principles of integrated data processing communication can be applied to many Army record-keeping requirements. In terms of specific results, this might mean a supply system that can interpret and convert a shortage created by a supply requisition into an immediate procurement or cross-shipment order; or a sensitive personnel system capable of reporting daily strength, replacement flow, and requirements. In the hypothetical case given below, a responsive supply system is used to demonstrate these advanced concepts.

a. Let's assume that a post supply office wishes to submit an urgent requisition to a supply depot several hundred miles away. If the post supply office is linked to the depot data processing installation by means of conventional teletypewriter communication facilities, it is possible to expedite such urgent requests.

b. At the supply office, the requisition is prepared on a typewriting device that also produces a punched-paper tape as an automatic by-product of normal typing operations. This tape is in a code that is compatible with the teletypewriter machine. After typing the requisition, the typist verifies the printed copy to insure accuracy. The paper tape is then transmitted to the supply depot.

c. The requisition arrives at the depot in punched-paper-tape form. We may use tape in this form as direct input to certain data processing systems, or we may convert it to another medium, such as punched cards or magnetic tape, depending on the input requirements of the ADPS installed at the depot. Introducing this information into the ADPS effects the following program-controlled operations. It --

(1) Up-dates the depot master stock record to reflect the change.

(2) Examines the on-hand balance to determine if the minimum reorder level has been reached.

(3) Produces, if needed, a notification to reorder. The system, if so programmed, may produce a finished replenishment order, including a predetermined standard reorder quantity.

(4) Prepares a back order document, if necessary.

(5) Prepares shipping tickets and related documents.

(6) Accumulates any desired accounting and statistical information.

(7) Produces a paper tape or other medium convertible to tape, indicating the action taken on the requisition.

d. The paper tape, or other message medium converted to tape, is then transmitted to the originating office as an acknowledgement of the order and notification of action taken.

e. In this manner, we can accumulate data at the point of origin as a by-product of normal typing operations and can forward it directly to the data processing center. Devices other than conventional teletypewriters, such as punch-card transceivers, may also be used in such an operation. In the latter case, punch cards are created as a by-product of normal typing and electrically transmitted by the International Business Machine (IBM) Card Transceiver.

f. After high-speed processing, various notices and documents of action can be rapidly distributed, thereby completing the process in a matter of hours. The savings derived from such mechanization include a significant reduction in time for a processing cycle and an important reduction in the clerical operations of recording, interpreting, and copying. Advanced systems under development will make this procedure fully automatic, thereby making the operation complete and uninterrupted from acceptance of the information to receipt of action initiated.

g. In practice, the teletypewriter has received only limited use as a data transmission device integral to ADPS. Although satisfactory in most respects, its major disadvantage is that errors made during transmission cannot be detected automatically.

66. ERROR DETECTION

The importance of error-free, long-distance data transmission has been reflected in the development of several self-checking transmission devices. The error-detecting facilities of these devices are based on the transmission code. For example, if individual characters are represented by a series of up to seven electric pulses, six may be used to represent actual numbers and letters, and the seventh may be reserved for checking purposes. Any one of 64 characters may be represented by a combination of the presence or absence of six pulses in a series, and the presence or absence of the seventh pulse provides an inherent checking feature. In this case, the seventh pulse is used or not used to make the total number of pulses, representing any character, odd. Any even number of pulses in the character representation automatically adds the seventh pulse to maintain the odd condition. At the receiving end, each

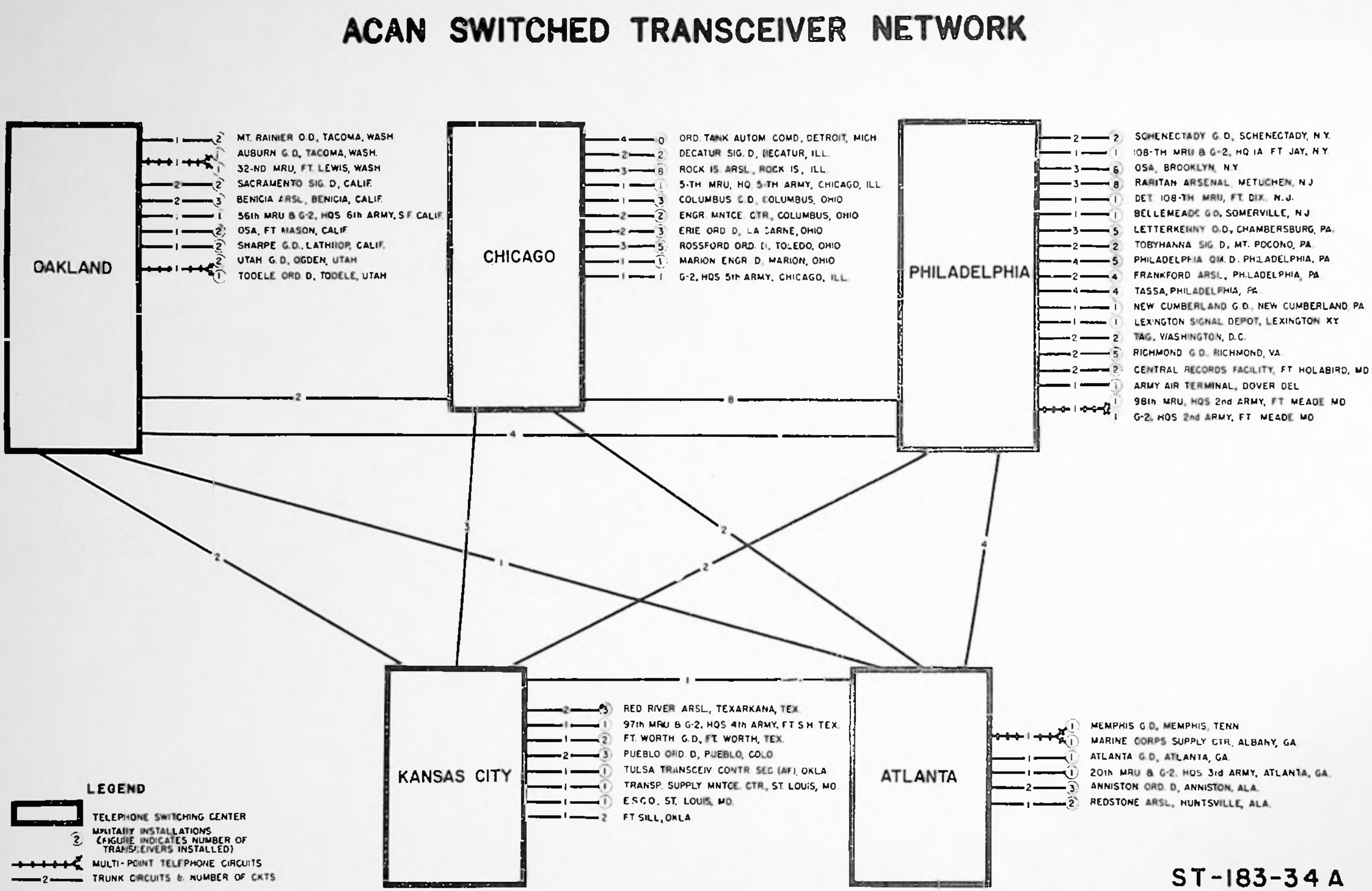

Figure 34a. Army data transmission system.

U. S. ARMY
OVERSEAS DATA COMMUNICATIONS FACILITIES
1-SEPT 1957

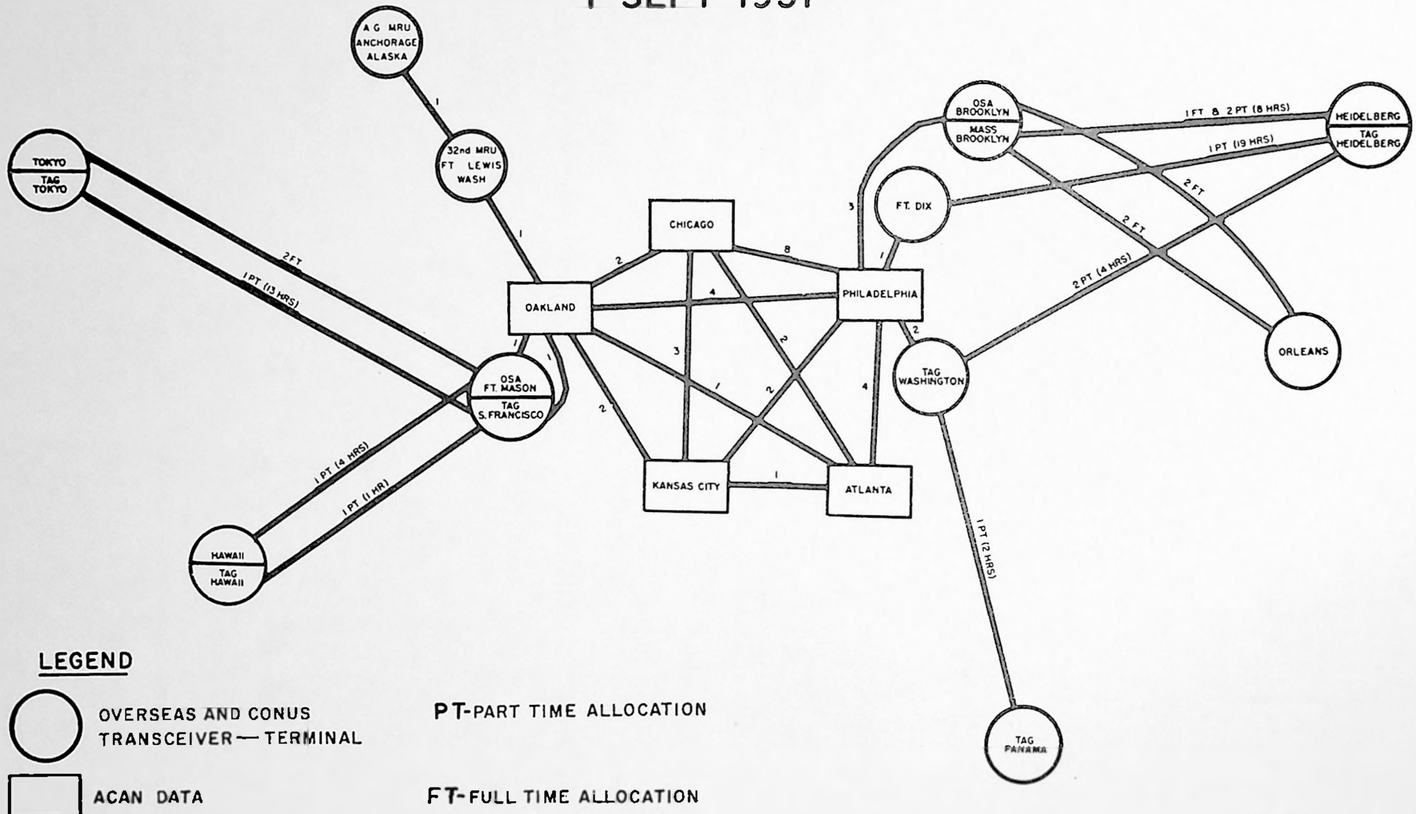

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Figure 34b. Army data transmission system.

character is automatically checked through electric circuitry to insure an odd number of pulses. When an error is detected, the transmission is repeated or the operation is stopped and the operator signaled. This checking method is neither universal nor infallible, but systems in which it is incorporated are able to detect and isolate most error conditions.

67. DATA TRANSMISSION DEVICE

a. Almost of all of today's data transmission devices create, or can be adapted to create, a medium which can either be used as direct input to an ADPS or be readily converted to ADPS compatibility. One device transmits information from punched cards and recreates the card at the receiving end. Another machine permits paper-tape to paper-tape transmission, while still another utilizes magnetic tape at both ends of the circuit.

b. The speed of a data transmission device is limited first by internal design and then by the type circuit over which it is designed to operate. Depending on the number of units and type of channels (telephone, telegraph, television, etc.) employed, speeds of from 240 to more than 90,000 characters per minute are possible. However, cost becomes a limiting factor, because increased speeds require more costly circuits.

68. DATA TRANSMISSION SWITCHING SYSTEMS

The pressing demand for improved communication facilities has forced us to study and develop new methods of controlling and coordinating data transmission. We have established centrally located data transmission switching facilities in an attempt to solve some of the economic and circuit utilization problems previously encountered in long-distance data communications. Such switching centers, operating on principles similar to those used in effecting long-distance telephone calls, provide the following benefits and economies:

a. Maximum flexibility in operation.

b. Service to surrounding installations on a subscriber basis, thereby eliminating duplication of circuit rental and associated costs.

c. Service to smaller installations, where previously the volume did not justify autonomous long-distance circuits.

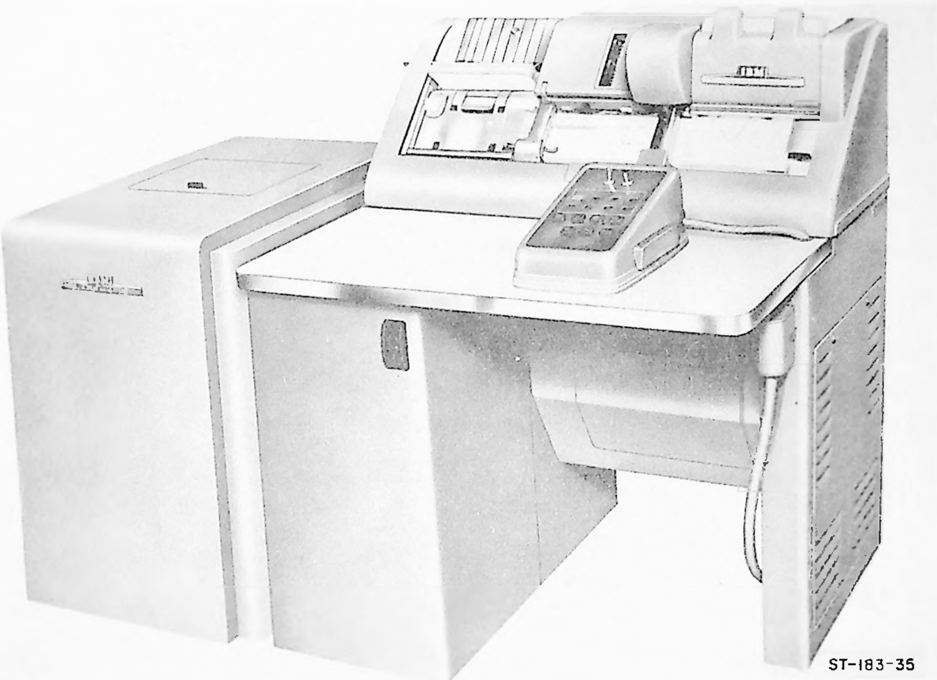
d. Provision for the best scheduling and coordination of transmission so as to use existing circuits effectively.

69. ARMY DATA TRANSMISSION SYSTEMS

a. The initial Army data transmission switching system became operational in November 1956. This system is being used to transmit logistical data between various CONUS military installations. Five major switching centers, strategically located on the basis of transmission volume and geographic routing, comprise the first network. Additional switching centers will be added to the system as the need arises.

b. In addition to the existing switched network in CONUS, other circuits using strategic radio systems have been provided to oversea theaters (figs. 34a and 34b). These circuits are currently supporting data transmission for supply and personnel operations.

c. Actual transmission of data is from punch cards through the medium of IBM data transceivers (fig. 35). These self-checking units transmit and receive 80-column punch cards.



Courtesy of International Business Machines Corporation

Figure 35. Card-to-card transceiver.

70. FUTURE PLANS

Future plans for U. S. Army data transmission anticipate a world-wide universal digital communication system. The short title of this system is UNICOM, for Universal Integrated Communication System. Flexibility of data flow will allow for rapid exchange of information to and from any Army installation on a world-wide basis. Some of the more significant features of such a system will be:

a. Error Detecting Facilities. The accuracy of every transmitted character will be assured by means of extensive self-checking features.

b. Error Correction. Devices, procedures, and methods will be established to correct detected errors.

c. Optimum Transmission Speed. The supporting communication system will be developed to provide various rates of data transmission. The major communication requirements fall into two categories: data collection and dissemination, and data transfer or interchange.

(1) Data collection and dissemination can be handled by improved transmission devices, which will handle approximately 1,000 six-character words per minute. This speed can be carried by a telephone-type channel.

(2) Data transfer or interchange necessitates movement of tremendous quantities of information and, therefore, may justify higher transmission rates. This requirement stems from computers "talking" to computers. In all probability, this will be accomplished by transmission devices containing magnetic storage equipment (tapes, cores, and drums). Transmission at these rates may require a special communication channel, such as the type employed for television.

d. Automatic Switching. Automatic switching techniques now in use for routing teletypewriter messages will be applied to future data transmission systems. Such facilities will, among other things, alleviate routing blocks and eliminate human intervention in determining message destination.

e. Encryption Facilities. Automatic encryption and decryption devices will speed up necessary coding and decoding operations.

f. Flexibility. Complete flexibility is necessary in the interchange of data between different types of data transmission devices. For example, it may be desirable to originate information at a low echelon on paper tape and transmit this information via paper tape to the next echelon where it may be received on magnetic tape. Figure 36 illustrates this principle. The card reader, paper-tape, computer, and magnetic tape devices shown in figure 36 are digital data devices. Since these digital data devices transmit numbers and alphabetic characters, the code (as well as the rate) used in transmission may be standardized, thereby making the interchange of data between these various devices technically feasible. The other devices, however, are basically analog devices which may be converted to the standardized digital transmission rate for transmission purposes.

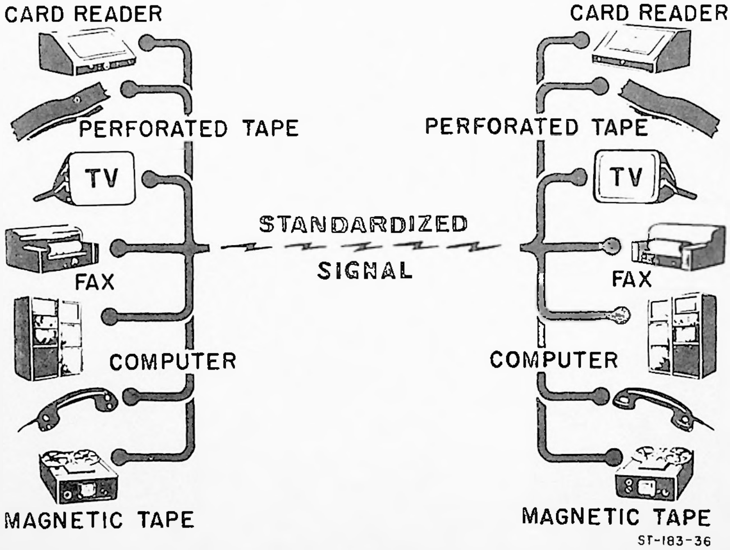


Figure 36. Flexibility through standardized code and transmission rate.

71. SUMMARY

The flow of information from posts, camps, stations, and military offices will no longer be impeded along the chain of command. Information of an important nature will be expedited to its destination in the least possible time, devoid, for the most part, of repetitious copy and multiform endorsements. Closer control of this type of information will make for more efficient planning and, therefore, more productive and realistic action. The importance of effective communications is well recognized by military management. By implementing ADPS with extensive and effective information flow channels, we can centralize data processing operations. Centralization of processing by means of extended communications will not only provide for fast and accurate compilation of data, but will also facilitate closer control by projecting the use of ADPS down to the lowest echelons.

CHAPTER 4

APPLICATIONS OF ADPS

Section I. GENERAL

72. INTRODUCTION

Even though automatic data processing is still virtually in its infancy, it has found valuable application in various fields. Industry is using it with great success to process data in such matters as inventory, sales, production, airline reservations, billing, payroll, and accounting. Some of these applications have been, or are being, adapted to government activities.

73. SELECTED APPLICATIONS

This chapter describes various ADPS applications in government and industry. These applications have been selected as representative of the flexible aspects of ADPS. Each has provided management with a solution to one or more data processing problems. In most cases, these are the primary applications; however, economical use of the systems usually includes a series of related and diverse processing jobs.

Section II. Project MASS

74. PURPOSE

The United States Army has undertaken the design and installation of a highly responsive supply system (fig. 37) that can provide continuous and efficient supply support to extremely mobile combat units. The undertaking, designated Project MASS (Modern Army Supply System), is a program sponsored by the Deputy Chief of Staff for Logistics. The basic theory of Project MASS evolved from extensive research in the field of supply and tactical strategy. Basically, a modern Army supply system must be highly responsive to combat needs and flexible enough to accommodate mobility and permit dispersion. In addition, the most economical levels of each supply item must be maintained on an established usage basis.

75. STREAMLINING THE ARMY SUPPLY SYSTEM

Paper work comprises approximately one-half of the time spent in supply operations. In streamlining the supply system, ways of reducing paper work offer a fertile field for investigation. This paper block, which includes indorsements, consolidations, extractions, and reviews of requisitions, has been reduced, in the past, by moving large stockpiles to oversea areas. Such a solution, however, not only fosters uneconomical inventory levels, but also creates an attractive and immobile target. Introduction of data processing, communications, selective item stockage, and premium transportation facilities provides the potential for streamlining the modern Army supply system.

76. REQUISITIONING

The concepts of Project MASS comprise the entire supply function from the request through the requisition to the delivery of the order.

a. The responsible supply officer of the combat unit originates orders for materiel on a simplified order form. Accuracy of order preparation is a necessity in this operation, since requisitions generally will not be subject to further review and indorsement.

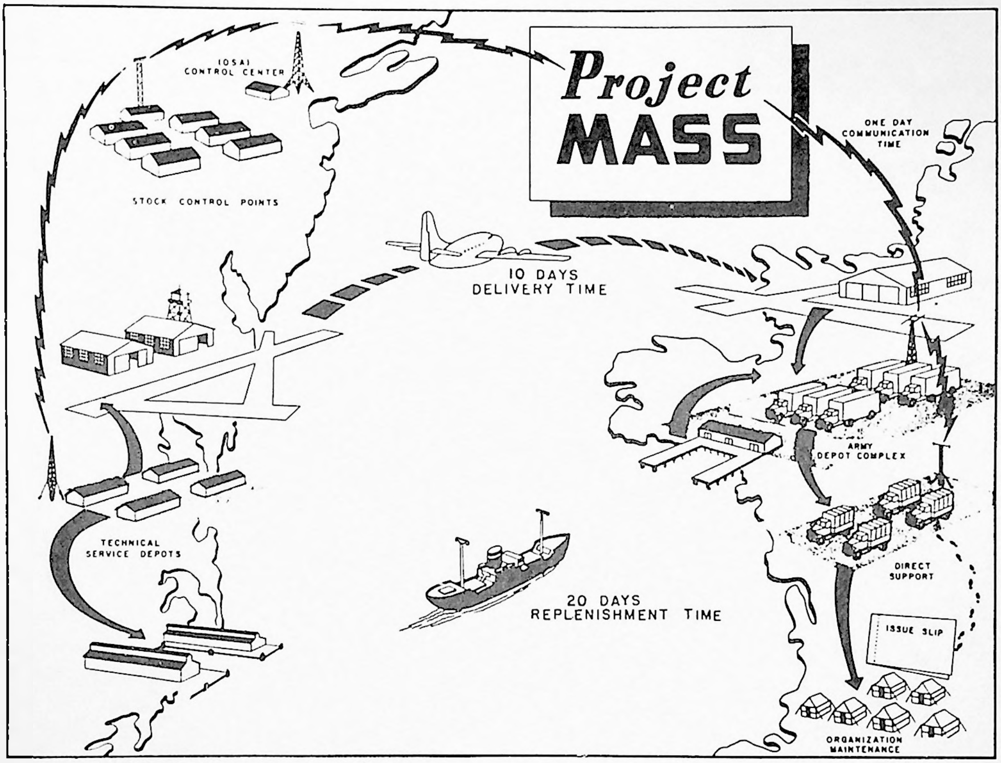


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Figure 37. Modern Army Supply System.

b. As requisitions must move from consumer to supplier by the most rapid means, the data processing-communications system must be automatic from the order point to the supply action location. Integration of modern electronic machinery for selecting, extracting, and inventory recording will facilitate order processing.

c. Materiel will be transported by all available means, depending on the bulk of the shipment and the priority of the requisition.

77. STORAGE

The desire to increase mobility, in the future, will limit outlying stock accumulations to high-turnover items; we will reserve bulk warehousing for CONUS supply installations. Through the application of field stock control system (which was tested and proved successful in Korea and which was later applied to CONUS supply operations) we can reduce the number of stocked items in a field army to a fraction of the level presently authorized without reducing combat effectiveness. We can do this by establishing a selected stockage list, consisting primarily of high-turnover items. Since 85 percent of demand consists of repetitive high-usage items, we can meet the major portion of repetitive demand by selectively stocking the high-usage items and establishing a rapid and efficient method of moving nonstocked items from CONUS supply depots.

78. PHASES

a. Project MASS is divided into two phases. Phase I covers the design, installation, and operation of a large-scale test of MASS in connection with the supply of repair parts to the Seventh Army, a major oversea command.

b. Phase II consists of a series of analyses of the test program, and the application of these results to the development of a modern supply system embracing all items of supply.

79. INITIATION

Project MASS began operations in July 1956, utilizing existing punch-card accounting and communication equipment. Newly developed data processing and communication equipment will be added as the test progresses and the criteria for suitable systems are established.

a. The following procedure is now in operation:

(1) Organizational maintenance personnel prepare a single-line item requisition (variable quantity of one item) on a newly designed control form, and hand carry it to the direct support unit.

(2) If the item is available, the request is filled from the selected stockage authorized for that direct support unit.

(3) If the desired item is not available, the direct support unit creates a single-line item requisition on a punched-card form that is compatible with the IBM transceiver data transmission device. Cards are also created in instances where withdrawals from stock cause balances to dip below minimum levels.

(4) Requisitions are transmitted daily to the Seventh Army stock control center.

b. The following operations are performed at the Seventh Army stock control point:

(1) Requisitions received from direct support are matched against the Army selected stockage list.

(2) Requisitions for items carried in stock and available at the various technical service depots are sent via transceivers to the depots. The possibility of local procurement is also determined at this point.

(3) Reorder requisitions are initiated to maintain proper levels of the Army selected stockage list and are electrically transmitted to CONUS back-up depots via the Oversea Supply Agency (OSA) in Brooklyn, New York.

(4) Requisitions for non-stocked items are also electrically transmitted to CONUS.

(5) Data are collected to assist in the analyses of the test system.

80. PRESENT OPERATIONS

a. Electrical accounting machines and a medium-sized digital computer (IBM 650) are currently being used to process data at the Seventh Army Stock Control Center.

b. The materiel movement function includes a balanced land, sea, and air transport system. Shipment of items that require special handling is effected by air, since the complete cycle is established as a 10-day period between the time of requisitioning and the time of delivery to the army. A transportation system has been established within the army area to distribute the supplies in much the same manner as the parcel post delivery system. The remaining supplies, which constitute the replenishment items for the army selected stockage list, are being shipped by surface means. A resupply cycle of 30 days has been established for these items.

c. About 10,000 requisitions in punched-card form are being received daily at the army control center (ACC) from the direct support units. Of this total, about 8,800 are forwarded to Seventh Army depots for supply action. The remaining 1,200 requisitions are being transmitted to CONUS via transceiver facilities as special requisitions for air delivery. In addition to the 1,200 special requisitions, approximately 2,000 requisitions are being transmitted daily to CONUS for replenishment of depot stock. In CONUS, the punched-card requisitions are received in the Oversea Supply Agency, batched by technical service item categories, and transmitted to designated technical service depots via the switched data network previously described.

81. SUMMARY

a. Project MASS includes certain features and facilities not previously available in army supply systems. Each requisition is handled as a separate message over a self-checking communication system from the direct support level to the supply action point. The stockage lists of the army have been scientifically designed to offer maximum service with minimum stockage. Through the use of modern machine methods, each requisition can be given individual attention and special handling service.

b. Measurement of all important variables will continue throughout the system test. These variables include the supply procedures, the flow of information, and the flow of materiel. Analysis of these data, coupled with predicted consumption rates of materiel in modern warfare, should provide sufficient basic information to engineer a successful modern army supply system. This modern army supply system will become an integral part of a long-range plan and will provide an automatic reporting means for logistical and administrative support.

Section III. AUTOMATIC AIRLINE RESERVATION SYSTEM

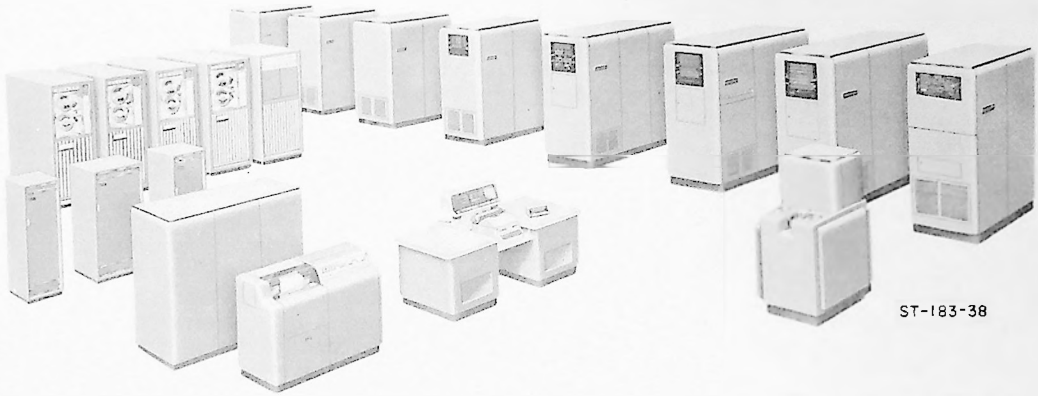
82. INTRODUCTION

This application represents a type of ADPS utilization which appears to hold particular military interest in that a centralized data processor is interrogated from remotely located input-output devices.

83. THE PROBLEM

a. The large number of persons availing themselves of air travel and the heavy traffic schedules have created many problems in the processing of airline reservations. Present methods of handling reservations involve time-consuming and confused communications, which are both costly to the company and frustrating to the passengers.

b. Reservation record keeping involves the maintenance of one master record for every individual flight on a schedule. This master record must be available to all reservation clerks in various offices along the flight route, so that they may determine the availability of aircraft space and reduce this amount of space when seats are sold. The problem is further complicated by the frequency of flights, the distance between reservation offices, and the need to maintain an up-to-the-minute flight status record.



Courtesy of Remington Rand Division, Sperry Rand Corporation

Figure 38. Univac File Computer Model 1.

84. PROCESSING OPERATION

As an answer to this problem, Northwest Orient Airlines, in collaboration with the Sperry Rand Corporation, has designed a specialized automatic data processing system that utilizes the Univac File-Computer to make the reservation record-keeping process fully automatic (fig. 38). The master computer, which houses the magnetic drum memory units, is located in Minneapolis, Minnesota. These units, expandable up to 1, 800, 000 characters, store all data concerning scheduled flights. Nineteen input-output inquiry stations, called agent sets, were established for the initial installations. These agent sets are located in Minneapolis, St Paul, and Chicago (fig. 39). Nine additional sets were included in the system shortly after its inception, and Milwaukee, Detroit, and Seattle were added at a later date. Sets close to Minneapolis are linked directly to the central computer and drum storage unit, while outlying agent sets utilize telephone or telegraph lines.

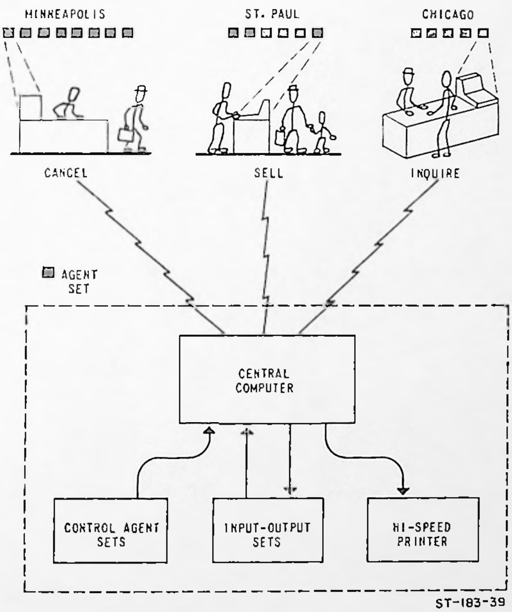


Figure 39. Northwest Airlines Reservation System.

85. REMOTE INPUT-OUTPUT DEVICE (AGENT SET)

a. The agent set (fig. 40) is a specially designed counter-top device which displays flight status and related information in visual (lamp) form. The ticket agent uses a keyboard to make an availability inquiry, and to record a sale or cancellation by keying the information into the system set.

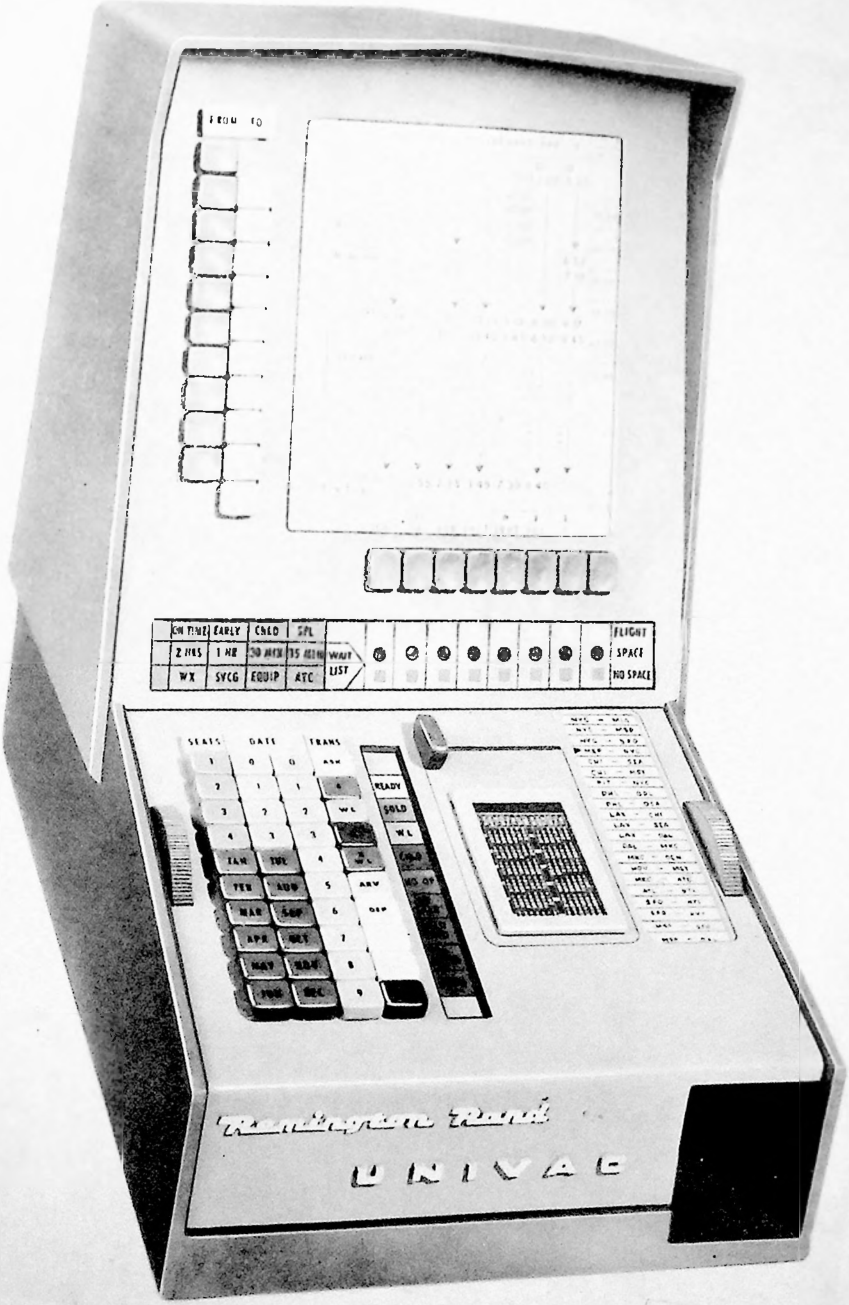


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Figure 40. Ticket agent set.

b. Flight schedules that are stored on photographic slides are housed in a slide cartridge. By selecting the desired slide schedule, the contact to the proper program and the specific record in the memory unit is effected. By keying in the flight in question and the type of information or operations desired, the agent set can contact the master unit and produce an answer or perform an operation in a few seconds. Information on such matters as departure and arrival schedules, fare rates, type of plane, round trip, tariffs, and meal service is readily available. Suppose, for example, that you ask a ticket agent in Seattle for information and an air reservation to Chicago on a particular date. The agent refers to his agent set and selects the proper schedule slide. As each slide can accommmodate up to eight flights, comparative information may be displayed. The agent tells you the time and space available, and you reserve a seat on a specific flight. The agent then keys in the sell transaction, and the number of seats available on that particular flight is reduced in the master record. In a like manner, cancellations are keyed in to increase the space-available balance.

86. LOCAL OUTPUT EQUIPMENT

Reports and statistical analyses may be prepared from the information in the memory drum by using supervisor-controlled equipment at the central computer location. Information may be secured from the computer on an electric typewriter, a card-punching unit, or a high-speed printer. This readout equipment can also maintain a perpetual transaction record of interrogations, sales, cancellations and balances.

87. SUMMARY

Use of an automatic data processing system for report and statistical analyses demonstrates the system's versatility. In the case just described, a master record is maintained in one central location, while status inquiries and revisions can be made from outlying stations. Such facilities eliminate tedious record keeping and excessive communications, and provide for up-to-the-minute accurate processing.

Section IV. MILITARY STOCK CONTROL

88. GENERAL

The United States Army Signal Supply Agency (USASSA) has initiated a program to accomplish its supply control and management functions by establishing a centralized stock control point and using an IBM Type 705 Data Processing Machine. The central stock control point is located in Philadelphia and is linked to subsidiary depots through the data transceiver network (see 69 above) to direct the record-keeping and coordinating operations.

89. STOCK CONTROL PROBLEM

Stock control of any nature requires extensive data processing operations. When supply management involves an inventory of approximately 150, 000 communication and photographic items, classified in 40 different accounting categories and stocked in four separate depots, the control function becomes quite complex.

90. STOCK MANAGEMENT

Closely controlled centralized stock management, using high-speed electronic data processing, is an innovation among the methods of army stock maintenance. It provides closer stock control, expeditious handling of requisitions, more accurate and up-to-date stock balance reports, rapid reflection of shortage conditions, and a system of economical procurement and distribution.

a. To institute an effective supply management system, USASSA selected an ADPS to --

(1) Record all changes on a master inventory listing.

(2) Process requisitions not filled by Signal Corps depots because of non-availability of stocks, and to select substitute items when available.

(3) Review inventory levels with respect to requirements in order to initiate central procurement.

(4) Maintain supply information, such as unit of measure, supply control point, and repair status.

(5) Process requisitions, as an initial source of supply, for certain types of consignees whose original requisitions do not pass directly to the depots.

(6) Determine the requirements for all communication and photographic spare parts, and for certain secondary items.

b. The primary mission of the USASSA system is to maintain proper balance between resources and requirements through inventory review. The machine program is very complex and consists of approximately 20, 000 program steps.

91. DAILY OPERATIONS

a. The Philadelphia installation is a control point of the USASSA data processing system. It is likewise a coordinating center of the supply system. The remainder of this section will be concerned with a review of the major operations of this supply agency and the framework within which it operates.

b. Each day, USASSA receives a number of communications on which it must act. These communications, or transactions, may include any type of stock management operation, such as requisitions for unfilled orders, shortage reports, notification of shipment, status or classification changes, purchase requests, or other miscellaneous stock transactions.

c. Transactions are received on punch cards via transceivers from U. S. Army Signal Depots in Lexington, Kentucky; Sacramento, California; Decatur, Illinois; and Tobyhanna, Pennsylvania. Transactions are also received from other sources, such as the various technical services and governmental agencies.

92. DAILY REQUISITION PROCESSING AND INVENTORY REVIEW

a. The daily job of requisition processing and inventory review is designed to --

(1) Maintain up-to-date information on all active items of supply on a current basis.

(2) Review each item whenever there is a change in the status of the item. This review is used to determine whether the balance between requirements and supply has changed sufficiently toward stock management.

(3) Process requisitions originating at supply agencies or transmitted there by depots.

b. The job is facilitated by storing all information necessary for inventory management (catalog information, on-order information, back-order information, on-hand balance information by reservation account and depot, requirements, etc.) on reels of magnetic tape. The various daily transactions are recorded on punch cards and are converted to magnetic tape so that the ADPS may perform the processing by using the most rapid input medium.

93. APPLICATION TO ADPS

a. The first major task of the requisition processing and inventory review job performed by the ADPS is that of file maintenance, which includes the recording of all information pertinent to each item of supply in its appropriate record location. The ADPS accomplishes file maintenance by effecting changes in depot inventories, substitute items, requirements, and sundry catalog data; by recording obligations against inventories created by the issuance of shipping orders; by recording, as unprocessed requisitions or as back orders, requisitions which have not been filled because of insufficient stock; and by recording the current status of any replenishment action that has been taken. Replenishment actions are retained pending the development of procurement data and are released when those data are received. All other essential data are recorded to keep the master subsidiary files up to date. New transactions are processed against current inventory files.

b. On completion of file maintenance, the next task is the processing of incoming requisitions. This operation includes the processing of shortage reports, requisitions, and requisition extracts for given stock numbers arranged in a priority sequence. Requisition processing involves:

(1) Determining the best available stocks with respect to the requisition.

(2) Preparing shipping orders on available items, and applying file maintenance transactions to up-date obligations records.

(3) Listing unprocessed requisitions for items not available.

(4) Preparing a cost statement, indicating the disposition of each line item requested.

c. The machine automatically performs a management inventory review of the appropriate items whenever a change in requirements, substitutes, lead time, or inventories has taken place. It also indicates requisitions that have not been filled because of insufficient inventories in the system. In this review the machine determines whether, as a result of the changes, the item has reached its authorized replenishment level or has gone into an excess position.

d. If items require replenishment, the system first determines whether there are any serviceable or unserviceable excesses which have not been disposed of by salvage. It then determines whether there are any repairable inventories in the system. If any of these situations exist, the machine initiates replenishment action. If there are no items available in excesses or in repairable inventories, or if the quantities available in such inventories are not sufficient to cover the quantity required for replenishment, the machine determines the normal source for replenishment. This source may be assembly, fabrication, central procurement, or cannibalization. If the normal source of replenishment is other than central procurement, the machine prepares a recommended replenishment action, indicating the normal source.

(1) If the normal source of replenishment is central procurement, the machine examines the characteristics of the item, the magnitude of the quantity to be procured, and the estimated value of the procurement. The machine then selects a distribution pattern based on these factors and determines what portions of the total quantity will be delivered to each depot in the supply system. Following this, the system determines when the first delivery should be made, over what period of time incremental quantities should be delivered, and what the monthly movements should be.

(2) If it is determined that open procurement for an item has gone into an excess position, the machine establishes the portion of the procurement that is excessive and initiates the cut-back action.

(3) For all actions recommended, the machine prepares a complete list of the data on which it bases its decision. These backup data provide the stock manager with the information required to either approve or disapprove the machine's recommended action. If the stock manager disapproves a recommendation, he must furnish the machine with file maintenance transactions to change the data on which the machine's decision was made.

(4) Based on these recommendations for management action, the machine generates its own file maintenance transaction to record the recommended replenishment action as resources against which future requirements may be processed.

94. NONAVAILABILITY LISTINGS

The machine prepares a listing of unprocessed requisitions for items not available to provide a complete record of all potential substitutes for the unfilled requisition line items. It also prepares a list of all available, due-in, and requirements data stored on magnetic tape for each stock number which appears on the unprocessed list. These lists are reviewed manually, and disposition instructions are furnished in punch-card form. This disposition may result in the preparation of shipping orders; notices of delay to the requisition source with an indication of what action will be taken, and when the item is expected to be available; or placement of the items on back order. From the time an item is recorded as a back order, the machine subsequently searches for available inventories either on the items placed on back order or on substitutes for them. When such availability information enters the system, the machine automatically prepares shipping orders and releases the back order.

95. COST STATEMENTS

For each reimbursable requisition processed, the machine prepares a funds (cost) statement. The values of items which cannot be supplied are retained on a magnetic tape file until such time as action is taken on the unprocessed requisitions. As subsequent action is taken on these suspended items, modified statements reflecting adjustment to individual disposition totals are prepared. These cost statements may serve as the basis for fiscal entries, for billing, or for the return of unused funds to the requisition source. They may also serve as requests for additional funds.

96. SUMMARY

a. Stock control and management, as performed by USASSA, is a momentous data processing task. The complex ADPS program that guides the processing is the result of many years of study and analysis of stock control problems. This application is a further demonstration of the versatility and capability of high-speed automatic data processing systems. Manual performance of such a control function would soon bury USASSA under a mountain of unprocessed transactions.

b. The benefits derived from such an application are many and varied. Most significant is the fact that we can maintain up-to-date records and process current transactions against these records in a minimum of time and with a minimum of routine clerical handling. Furthermore, by effecting closer control we can maintain stock balances at the most economical level, thereby avoiding costly duplications of inventory items.

Section V. CENTRALIZED DATA PROCESSING BY SYLVANIA ELECTRIC PRODUCTS COMPANY

97. GENERAL

Management of any organization producing widely diversified products in many localities is faced with data processing problems. The Sylvania Electric Products Company is such an organization, employing 27,500 people in 71 production locations scattered throughout 61 cities and towns in 20 states. To cope with the almost impossible task of gathering and analyzing all required information from its widely spread installations, Sylvania initially delegated many operating management functions to the individual plants and divisions. Although such delegation of functions facilitated effective local control, it created new problems in accumulating and forwarding the information necessary for top-level (centralized) management. The problem was further complicated by the fact that Sylvania has experienced an exceptionally rapid expansion in plant and laboratory operations, enlarged distribution, and continually broadening markets. Particularly affected were top level management's efforts to keep up-to-date on such matters as inventory, sales, production, billing, and other activities.

a. To solve these problems, Sylvania decided to centralize the data processing functions of gathering, recording, computing and classifying such information in Camillus, New York. Sylvania's data processing system is shown in figure 41. This centralization was implemented to --

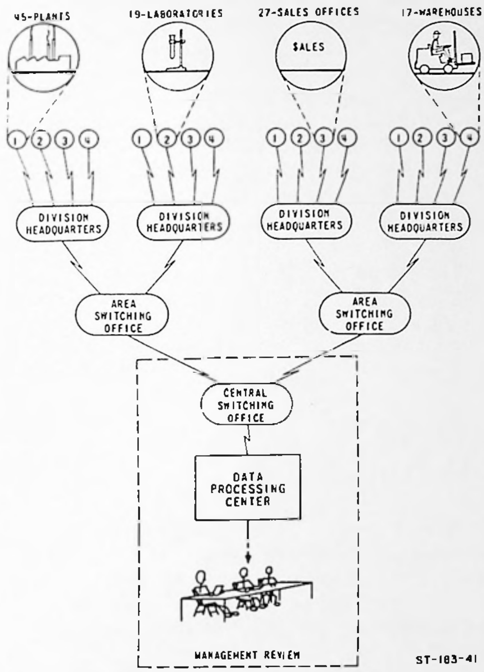


Figure 41. Sylvania's integrated data processing system.

(1) Speed up normal data processing operations.

(2) Achieve closer liaison with outlying plants, laboratories, warehouses, etc.

(3) Provide top management with accurate and up-to-date information.

(4) Decrease the overhead costs of clerical personnel.

b. The Sylvania system includes an 18,000-mile private-wire network, connecting 71 facilities to one data processing center. Data flow is by means of 5-channel, punched-paper tape over leased Western Union lines. This extensive communication network, coordinated by three automatic switching centers, supports a Sperry Rand Univac which, within four years, will constitute the nerve center of Sylvania's nationwide framework.

98. INITIAL OPERATIONS

On the first day of operation in March 1956, communication circuitry carried 5,000 normal administrative messages from the 45 plants, 19 laboratories, 27 sales offices, 17 warehouses, and 10 division headquarters to Camillus. First to be processed was the payroll of the plant at Seneca Falls, New York. In this operation, payroll information was transmitted to Camillus via Western Union telegraph lines. It was received in punched-paper-tape form. Information on the paper tape was transferred to cards, and then to magnetic tape. A paper-to-magnetic tape converter was installed to eliminate this interim step. A high-speed printer prepares all checks and the central computer updates and maintains the master record. Payroll processing includes wage payments to all of Sylvania's employees, plus the preparation of required statistical data on labor distribution, cost accounting, and other necessary accumulations.

99. FUTURE OPERATIONS

In the future the Sylvania Company looks forward to certain definite results accruing from its data processing system.

a. Daily action reports are received from 17 warehouses for preparation of a weekly total and individual inventory listing. This processing eliminates the delayed accumulation of information. It also greatly facilitates the establishment of divisional requirements and the presentation of a company-wide picture.

b. The data processing center has emerged as the sole facility for complete accounting and statistical services for all operating divisions. The statistical reports now used by the division management are prepared at the data processing center and are available on the 3rd or 4th of the month, as opposed to previous delivery on the 15th. Conversion of one complete division provided experience for later conversions.

100. SUMMARY

The Sylvania program points up many concepts applicable to U. S. Army data processing operations. The geographical distribution of the two organizations is similar, and the need for accurate and up-to-date information is imperative for both. The Sylvania Company data processing center operates on a service-bureau basis; that is, it operates for all divisions, but each division operates independently of every other division. Because the divisions do not warrant separate computer installations, the central unit operates for all. This basic concept may be applied to the diversified units of the Army.

Section VI. TAGO AUTOMATIC DATA PROCESSING SYSTEM

101. GENERAL

In March 1955, The Adjutant General's Office (TAGO) initiated a comprehensive study in an attempt to determine how Army personnel administration and record keeping could be improved with regard to providing more effective and timely management information. This research, conducted by a seven-man TAGO committee, resulted in the installation of an ADPS consisting of a large scale computer and a supporting transceiver communication network. The immediate aim of this installation was to improve operations accomplished at D/A level rather than inaugurate a far-reaching long-range system that would have a similar effect in field operations. More specifically, the desired objectives were:

a. Timeliness. Management personnel, the users of information and reports compiled at D/A level, stated that distinct advantages would accrue in the form of bases for more sound decisions if the required personnel and strength information could be made available more rapidly than was currently possible.

b. Accuracy. Employment of internal data type checks would insure a high degree of accuracy in the massive volume of data to be processed by the system.

c. Increased Detail. ADPS capabilities would facilitate the gathering and processing of certain types of information heretofore inaccessible or available only at prohibitive costs.

d. Economy of Operations. In addition to the above benefits, it was anticipated that certain economies of operation would result from ADPS installation.

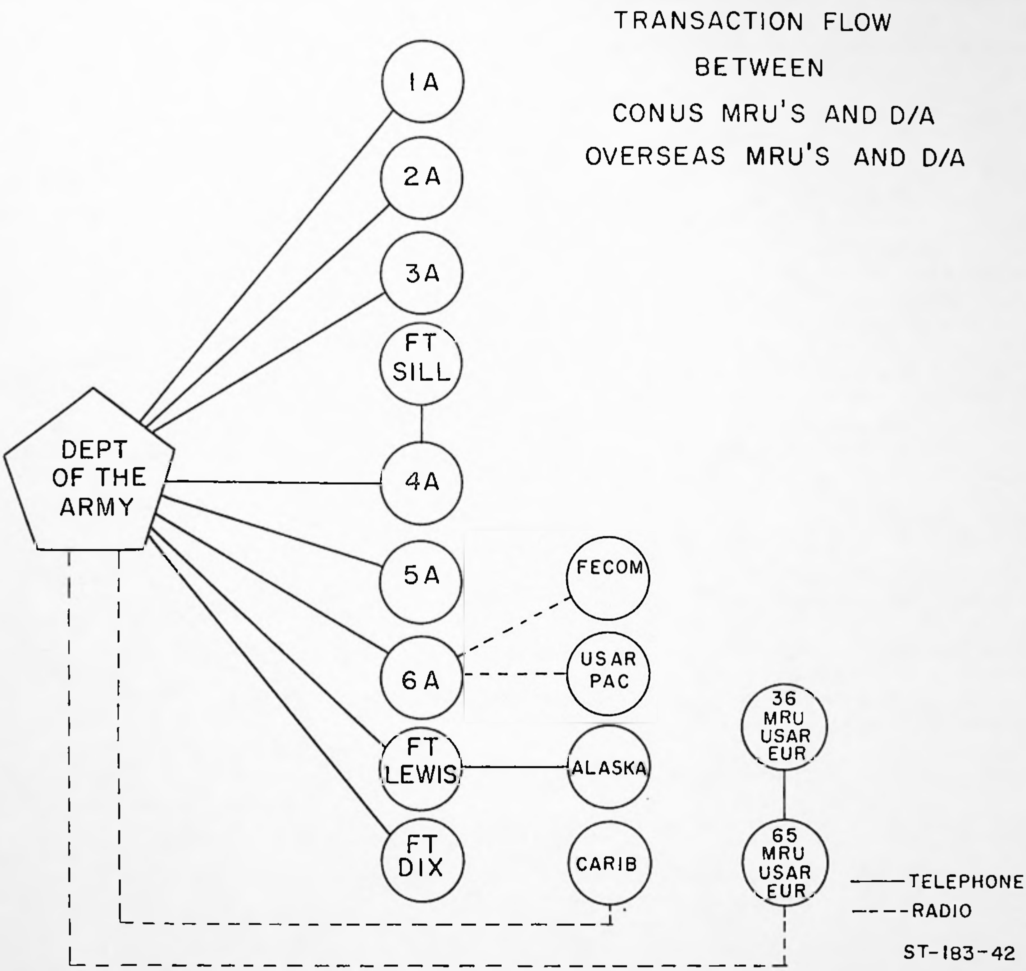


Figure 42. Transaction flow.

102. COMMUNICATION FACILITIES

The TAG ADPS installation is presently supported by a widely dispersed transceiver network. (See figure 42.) These transceivers transmit information to the Department of the Army from CONUS and major oversea command locations. Use of such transmission devices provides rapid and orderly accumulation of data from distant points and facilitates up-to-date record keeping which, in the past, was sometimes as much as four months in arrears of specific action. The transceiver network is also employed in transmitting error messages from the Department of the Army to the field. It further provides an effective communication coordination network between the various field installations in connection with reassignment of personnel (fig. 43). It is anticipated that this network will be employed in the future to carry certain types of information back to the field locations.

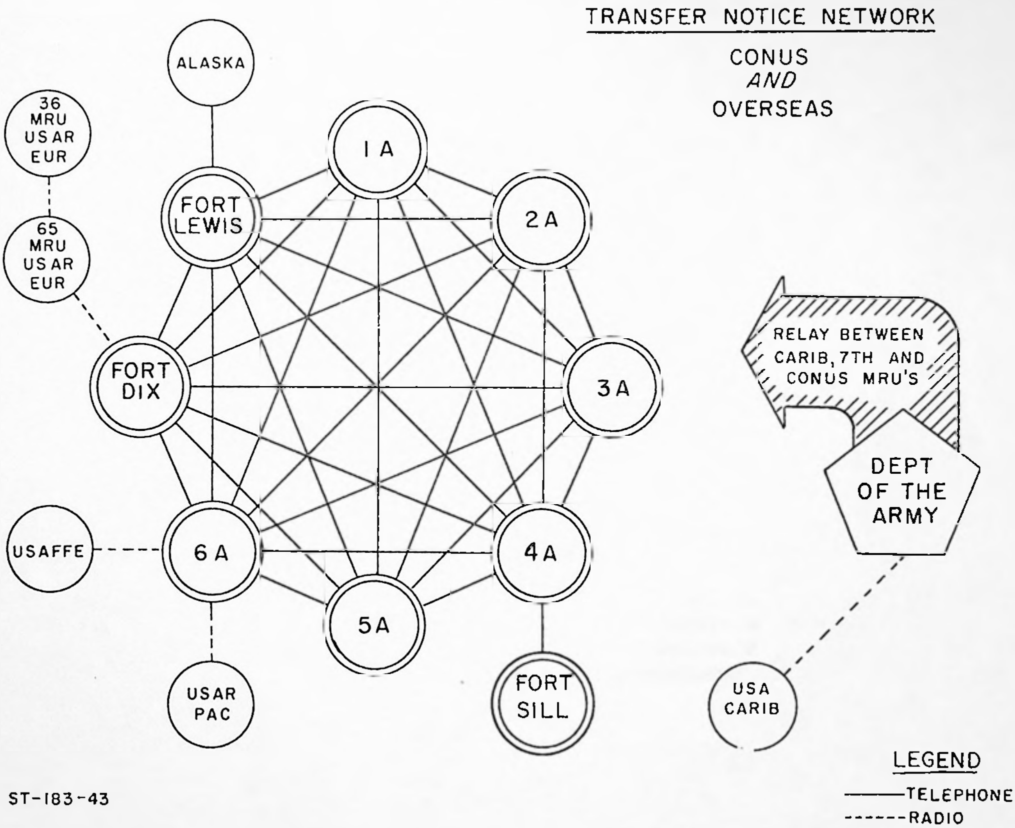


Figure 43. Transfer notice network.

103. MASTER FILE

The Office of The Adjutant General in Washington, D. C., maintains a master personnel record file of every commissioned and warrant officer, male and female, on active duty with the Army. Each personnel record is recorded on the master file in 395 characters. These sequenced records (approximately 110, 000) are maintained in an 11-reel magnetic tape file which is updated and rewritten every workday.

104. THE SYSTEM FLOW

a. Document Origination. Punch cards may be prepared at both Department of the Army level and CONUS army and major oversea command level, depending upon the type of action. The transactions prepared at CONUS army and major oversea commands are forwarded via transceiver to the Washington, D. C., computing center. After a minimum of EAM preparation the daily activity of transaction records (approximately 4, 500 cards) are converted to magnetic tape.

b. Input. All transaction input to the system is in the form of magnetic tape, created on off-line card-to-tape conversion equipment. This facilitates more rapid input.

c. Processing.

(1) Prior to the major daily updating run, the transaction file is sequence-sorted and edited for accuracy of coded data. The transaction file is then run against the master file under the direction of a 2,500-instruction program. If the transaction record represents an addition to the Army, a new master record is placed on tape in its proper sequence. If the transaction signals a retirement, a discharge, or a relief from active duty, the obsolete master record is deleted from the master file. When transactions represent a change in assignment, actual or projected, or a change in personnel status or statistical data, the master record is updated accordingly. There are more than 70 different types of transactions that might affect a master record.

(2) During the updating cycle, which requires about 1.9 hours per day, many checks between the transaction data and master record data are performed to assure accuracy. For example, the chronology of reassignment actions is checked for processing sequence; a record selected for corrective action is so noted on the master record in order to preclude processing, pending the return of corrected data; and promotions are checked to insure that the progression is to the next higher grade only. Controls in the daily updating are centered around balancing previous and current record counts and "hash" totals. Also included in the program is a check point and restart routine which permits the recall of memory as it was immediately following the last or any previous balanced check point. This is an effective method of recreating a particular sequence without rerunning the entire file in the event of an error or a damaged tape.

(3) More than 60 programs have been written and tested for the performance of other jobs, such as statistical analyses and various reports and summaries.

d. Output.

(1) Daily. In addition to the new master record file, the updating program produces a subsidiary tape consisting of accession and separation statistical records, locator records based on new assignments, command strength summary cards, and identified error conditions. This output totals approximately 2,000 records per day which are handled by EAM equipment after a tape-to-card conversion.

(2) Periodic. About 120 different reports are prepared from the system on a recurring base. These reports are summary tabulations for strength purposes and individual name listings for management and statistical purposes. They include:

(a) Summaries of officer strength.

(b) Officer inventory and projection reports.

(c) Summaries of enlisted strength.

(d) Personnel statistical reports by branch, grade, component, etc.

(e) Unit strength reports.

(f) Officer qualification reports (MOS, education category, etc.).

(g) Officer efficiency index reports.

(3) Special requests. In addition to the above reports, an average of 10 to 15 special request reports are prepared during a normal month. In order to accomplish these special requests with a minimum of programming, a flexible extract program has been developed.

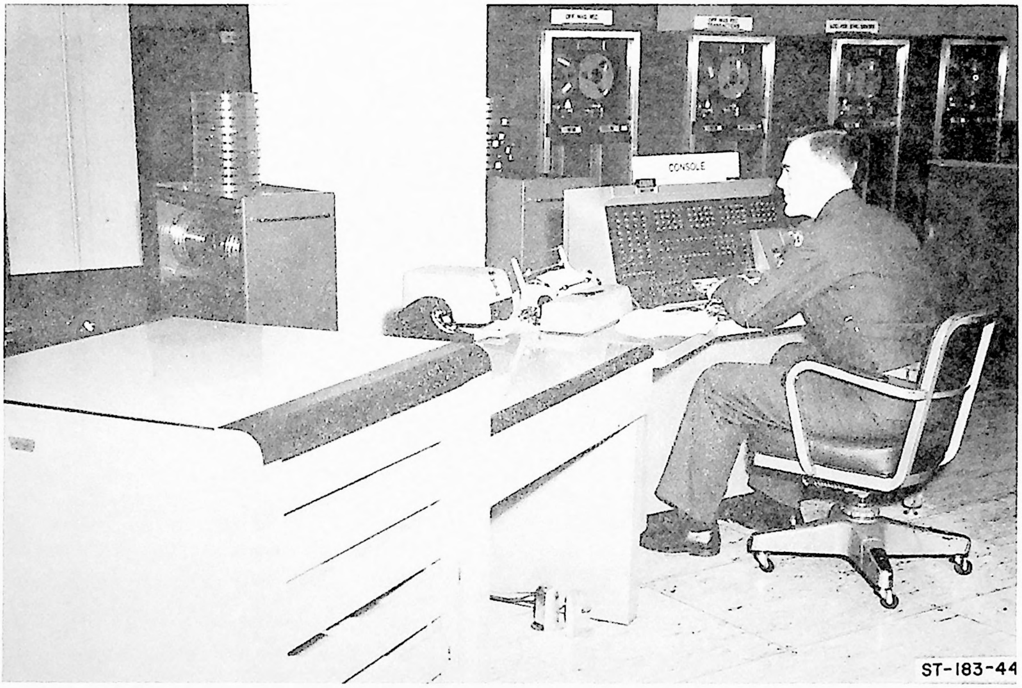


Figure 44. Personnel management by ADPS.

105. EQUIPMENT

The IBM Type 705 data processing system (fig. 44), installed in March 1957, consists of the following component equipment: a card reader, 12 magnetic tape units, a central processing unit, a card punch unit, a printer, and a tape data selector with printer and punch unit. The monthly rental for single-shift operation is approximately $32, 000, which is increased on a use-incremental basis by second-shift operations.

106. INSTALLATION ORGANIZATION

a. System Engineering Section. This high-level group is responsible for the over-all planning of the installation and for systems analyses in connection with the statistical and accounting system of the army.

b. Programming Section. The programming section is divided into four units as follows:

(1) Strength Unit. This unit is responsible for subject matter programming.

(2) Processing Unit. This unit is responsible for programming all requirements in connection with updating the master record tape file.

(3) Officer Qualification Unit. This unit is responsible for all programming in connection with qualification type reports.

(4) Research Unit. This unit is responsible for the preparation of special programs and provides specialized assistance to other programming units.

c. ADP Operation Section. These personnel are responsible for the two-shift operation of the ADP equipment in the processing center.

d. Control Group. The control group is responsible for such areas as systems scheduling, machine utilization and cost data, and other similar considerations pertaining to the orderly completion of the required operations.

107. FUTURE PLANS

The future plans for the TAGO ADPS installation include a modified processing system for enlisted personnel with a view to economy in the operation of the enlisted distribution system. In addition, the ADPS installation will maintain data for and prepare the Army Troop Program, extend the master officers' record to include additional items of information, and modify the daily updating base to a less frequent base.

Section VII. CENSUS BUREAU

108. INTRODUCTION

Every ten years the U. S. Government, through the Census Bureau, is required by law to make a complete inventory of the nation's population, homes, and farms. The Government also inventories the status of the nation's agriculture, foreign and domestic trade, and governmental and industrial resources.

a. The scope and magnitude of such fact-gathering problems are tremendous. Millions of schedules and hundreds of millions of punch-card records must be developed and processed in such a manner that each person and resource is properly classified within the appropriate category.

b. The census is physically taken on both a de jure (legal residence) and a de facto (where actually residing) basis by an army of some 200,000 enumerators. Census takers visit every home, institution, and farm in the country to develop detailed inventory information on population and housing. The results of this massive fact-gathering operation must be controlled, screened, correlated, edited, and processed into a practical format.

c. In the past, the processing phase alone required the use of 10,000 people and a large number of punch-card machines working around the clock for approximately two years. It is anticipated that use of centralized ADPS in the future will result in significant reductions in the number of personnel involved and the amount of time required.

109. PLANNING FOR THE FUTURE

a. As far back as 1950, the Census Bureau sought a more efficient and economical method of census processing. Automatic data processing systems appeared to present a reliable and practical processing tool. Accordingly, the Census Bureau purchased its first general business-type electronic computer (Sperry Rand's Univac 1) to test its value in the processing of census data. This test of electronic techniques proved so successful that a second ADPS was added for further testing.

b. The Census Bureau has now developed and approved an entirely new processing approach to handle the data-reduction task expected in the 1960 census. The backbone of this approach is an ADPS which will be much more effective than those used in the tests. This system will replace the present two computers with components having greater memory capacities and faster operating speeds than the present equipment. Assembly and preparation of the raw data (schedules) for the computers will also be improved, because of the successful development and testing of document-sensing electronic equipment.

110. THE 1960 CENSUS

The plan for the 1960 census provides for the utilization of automatic data processing techniques within the framework of the following procedure:

a. Collection of the raw census data by orthodox methods, using enumerators and preliminary screen processes similar to those used in the 1950 census. This will develop all required data on specially designed schedules that are suitable for automatic processing. Such data will be controlled by enumeration on a geographical district basis.

b. Recording of all data reported on enumeration schedules, after screening and verification, on 16-mm microfilm rolls at field level (districts).

c. Processing of prepared microfilm schedules by a sensing device known as Fosdic (film optical sensing device, input to computers). This device will convert the enumeration data directly into binary form on magnetic tape that is compatible with the computer.

d. Subsequent processing of the prepared magnetic tape (containing raw census data) by an advanced ADPS that will edit, reject, tally, sort, correlate, consolidate, and prepare the various reports and tables required of the 1960 population and housing censuses.

111. ADPS ADVANTAGES OF CENSUS COMPUTATIONS

The Census Bureau has estimated that, through the use of ADPS, it will --

a. Produce the final population and housing census results for release within one year. This will effect a 50 percent reduction in the time normally required to publish final results, and is expected to improve the accuracy of the census results.

b. Save a total of $8 million in census-processing cost by eliminating the need for --

(1) 4,500 extra key-punch operators and their supervisors.

(2) Punching, verifying, and processing some 400 million punch cards.

(3) 4,000 additional key-punch machines.

c. Provide the facilities for efficient processing of various other associated census reports and documents.

112. SUMMARY

The extensive compilations and cross-classifications encountered in the work of the Census Bureau have their counterparts in the work of the Army. However, where the Census Bureau faces this project only every ten years, the U. S. Army faces a somewhat reduced, but similar, problem every day, week, and month.

Section VIII. PAYROLL AND ACCOUNTING

113. GENERAL

Payroll, labor distribution, and associated financial accounting operations were some of the first jobs studied, programmed, and processed on electronic data processing machines. Payroll preparation is essentially a file-maintenance operation. It involves updating cumulative earning records; computing gross pay and deductions; and preparing such documents as paychecks, statements of earnings, labor distribution summaries, and cost accounting reports.

114. PROCESS

Most electronic data processing machines are readily adaptable to payroll jobs, since records are easily maintained in a predetermined sequence on reels of magnetic tape. Such storage allows for the recording of all pertinent data and the processing of each record with considerable speed and accuracy. At the end of each pay period, activity data can be accumulated in the form of punched cards, punched-paper tape, or some other input method, to be processed against the master file. Thus, payroll adjustments, deductions, personnel changes, work-order tickets, in-out tickets, and clock cards can be introduced into the system and, under the direction of the stored program, be distributed to the proper areas.

115. FINANCIAL DATA OPERATIONS

While the ADPS is accomplishing payroll accounting operations, it can also perform other related financial accounting operations, such as dependents' allotments, rank revision, temporary duty (TDY) allowances, and clothing allotments.

a. Storage of all essential data within a given record makes possible the accumulation of any desired statistical reports with relative ease. As all information is available in one file, a specialized program routine can be designed to isolate and correlate any facts of the records.

b. Payroll accounting always has been a problem to the Army because of changes in rank and geographical location of personnel. The speed of data preparation attained through ADPS utilization allows for a more accurate and up-to-date reflection of existing conditions. This principle is particularly well demonstrated by a payroll application of one industrial firm employing 40, 000 hourly workers. Information accumulated throughout the plants is received at the data processing center by noon of each Monday. By the following Wednesday morning the following operations are completed and documents are prepared and ready for distribution:

(1) Payroll register.

(2) Checks and earnings statements.

(3) Payroll cards for check reconciliation.

(4) Clock cards.

(5) List of bond purchases.

(6) Department total cards.

(7) Payroll distribution cards (or reports).

(8) Miscellaneous reports and registers.

c. The whole application requires only 3-1/2 hours in the central processing unit, leaving ample processing time for such applications as daily billing, accounts receivable, and inventory control.

116. FUTURE APPLICATION

U. S. Army payroll accounting is currently performed by conventional punch-card equipment and manual methods. Payments to service personnel and their dependents are made once each month, and payments of a specialized nature often take from two weeks to two months. It is not difficult to foresee the application of ADPS to Army payroll accounting in the near future. Studies are already under way to determine the most efficient manner in which to handle payments to military and civilian personnel.

CHAPTER 5

PROPOSED ARMY UTILIZATION OF ADPS

Section I. GENERAL

117. PRESENT APPLICATIONS

To date, major efforts in the use of ADPS within the Department of the Army have concentrated on high-volume data processing operations such as those described in the preceding chapter. These efforts are exemplified by existing or planned ADPS installations in USASSA, TAGO, and several large technical service depots. Comparatively little, however, has been done with respect to other important data processing areas.

118. FUTURE APPLICATIONS

Long-range plans for military applications envision the extension of automatic data processing facilities throughout the various echelons of CONUS and the Army in the field.

a. Until very recently, little consideration has been given to utilizing ADPS at posts, camps, and stations. These installations, however, are the originating points for virtually all information and are burdened with heavy logistical and reporting activities and responsibilities.

b. Tactical employment of automatic data processing techniques is a necessity if we are to provide the future battlefield commander with the degree of command control required to operate effectively in the pentomic environment of maximum striking power combined with high mobility and maximum dispersal.

Section II. CONUS UTILIZATION

119. POST USE

The results of a recent investigation of data processing activities at two representative CONUS posts indicate strongly that integration of ADPS at the Class I installation level is both feasible and highly desirable. From analyses and studies made at Fort George G. Meade, Maryland, and Fort Jackson, South Carolina, the investigating task force under the direction of the Comptroller of the Army concluded, in part, that --

a. An engineering study of the application of an automatic data processing system to a Class I installation is justified on the basis of indicated economy, speed, and flexibility of operation.

b. The engineering study should be based on the valid requirements of the Class I installation and higher authority, unrestricted by current methods and procedures. This engineering study should include:

(1) Design of an integrated data processing system to utilize fully the potentialities of ADPS equipment.

(2) Specifications for equipment.

(3) Programming for operation.

c. The major potential of an ADPS at a Class I installation is in the following activities:

(1) Item accounting.

(2) Financial inventory accounting.

(3) Miscellaneous logistical services.

(4) Repairs and utilities (R & U) cost accounting.

(5) Stock fund accounting.

(6) Army command management system.

(7) Civilian payroll.

(8) Financial accounting.

(9) Military personnel strength summaries.

(10) Operations accounting and reporting.

(11) Civilian personnel management.

d. In the interest of a completely integrated Army system, it might be advisable to mechanize small installations even though the cost would be in excess of the current cost of manual operation.

e. The high cost of ADPS equipment requires a service-center type of operation to justify installation and to make effective use of equipment.

f. In addition to the major applications of ADPS equipment, there are a substantial number of other possible applications which lend themselves to automation as a secondary phase for conversion, with little or no additional cost.

120. JUSTIFICATION FOR ADPS AT POSTS

a. Although the missions of various posts, camps, and stations differ, the major data processing activities are, for the most part, similar in nature. This fact is validated in the cases of Fort Meade and Fort Jackson, and is further substantiated by a preliminary study made at Fort Monmouth, New Jersey (a Class III installation).

b. At Fort Jackson and Fort Meade, it was determined that ADPS can be justified on the basis of present workloads. Smaller posts, camps, and stations, however, may not have sufficient workloads to warrant installing machines at each location. In such cases, it may be possible to establish an ADPS service (on a subscriber basis) to serve two or more of these smaller posts. These posts would utilize high-speed data-transmission circuits as interconnection links. In this manner the advantages of ADPS could be made available to every post, camp, and station in an economical and efficient manner.

121. PROJECTION OF THE SYSTEM

Assuming inevitable adoption of ADPS at post level, the next step is the projection of automatic data processing throughout the CONUS army organization. Following installation of ADPS in posts, camps, and stations, automatic data processing facilities will be accessible at almost every level of the Army (fig. 45). The next important step is to integrate independent systems which are interdependent and interrelated. The coordinating medium would be the U. S. Army data transmission network described in chapter 3. With complete integration, the Army's data processing might be accomplished as follows:

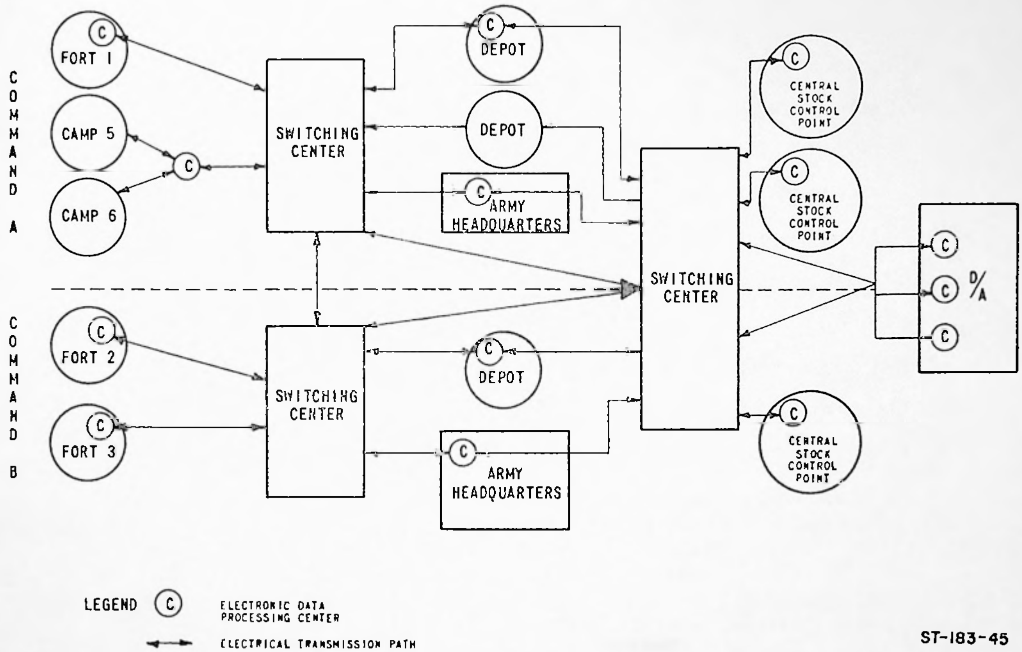


Figure 45. Concept of an integrated data processing system.

a. Activities at posts, camps, or stations would originate data in documentary form and forward it to the processing center. In order to project mechanization down to the lower levels, we would use remote input-output units to initiate and transmit data. These devices would produce and transmit paper tape, punch cards, or other media which we could introduce directly into the system at the ADPS site.

b. If the service center is not located on the post served, we would prepare and collect the punch cards or tape at one location on the post for transmission to the service center. If it is located on the post, we would forward data directly to the service center. In any case, the center would --

(1) Accomplish the necessary processing.

(2) Notify the originating office (through established facilities) of results and any further necessary action.

(3) Automatically prepare and accumulate or forward data for use by higher headquarters. Such information could be accumulated in the form of punch cards or magnetic tape for a prescribed time period, depending on the established requirements of the system.

c. The procedure at the Army headquarters would be similar to post procedure. The ADPS would process desired information for headquarters use, while concurrently producing data for use at Department of the Army level. Here again, the data transmission network would serve as the means to forward data quickly and accurately.

d. Finally, at DA level, timely data would be received and processed by ADPS to provide management reports and analyses reflecting current operations of all echelons of CONUS. Feedback information would be channeled down through the Army chain of command as desired and needed.

122. SUMMARY

a. Integration of ADPS throughout CONUS will effect significant economies and efficiencies in data processing. The high speed of data transmission and processing will facilitate coordination that never before was possible within and between various Army levels. Economies derived from optimum stock management will more than pay for the data processing installations. Coordination of many activities and record-keeping functions, such as personnel reporting and manipulation, financial accounting, etc., will make available more accurate and current information for command action.

b. Installation of ADPS will also have the effect of simplifying and standardizing procedures that are used in accumulating and processing data. Much of the repetitive copying and complex paper form procedure will be eliminated by ADPS networks. This will not only provide us with an effective information flow, but will also allow us to apply work simplification techniques throughout CONUS.

c. The capabilities and flexibility of ADPS will be invaluable in the event of a national emergency. Integration of ADPS throughout the Army provides an almost unlimited potential for drawing different and localized organizational units into closer harmony.

Section III. EMPLOYMENT WITHIN THE FIELD ARMY

123. GENERAL

Planning for the tactical utilization of automatic data processing techniques should include considerably more effort than is normally given to the development of military characteristics for a new item of equipment. The electronic computer, heart of an ADPS, has an information-handling capability which, in all probability, has never been considered possible by the military commander or staff officer. To take full advantage of the inherent flexibility and capability of the electronic computer, we must thoroughly analyze our methods of supporting combat operations, including the activities of the commander and his staff. Officers well qualified in the subject field being studied should conduct a detailed system analysis as the first phase in the preparation of a statement of military characteristics which will lead to the eventual development of appropriate hardware.

124. ADPS IN SUPPORT OF THE COMBAT MISSION

A review of informational, statistical, and historical data pertaining to ADPS may stimulate thinking as to how these devices could be employed in solving day-to-day problems encountered in the tactical echelons of the Army. These problems concern the infinite number of detailed operations involved in controlling, transporting, quartering, feeding, and supplying troops in military operations. Study of the massive base build-up of supplies and personnel of World War II and Korea reveals that we must drastically modify combat-support operations in the future. In fact, the latest tactical concepts of the army -- with emphasis on augmented fire power, mobility, new weapons systems, technological means of acquiring combat intelligence, and increased control through advanced communication techniques -- demand that we establish an efficient and flexible combat-support system. An integrated automatic data processing system will, with other techniques, provide timeliness, complete control, and speed of service to substitute for the unusually large manpower and materiel resources that have been characteristic of previous combat-support operations. An ADPS will further provide additional command controls which have never before been possible. More specifically, it is anticipated that employment of an integrated data processing system in tactical operations will attain the following objectives:

a. Improve methods of coordinating administrative, logistical, and operational activities of widely dispersed and highly mobile field elements.

b. Reduce the time that a commander and his staff must spend on administrative matters.

c. Reduce daily maintenance and built-up tonnage in the physical areas of the combat elements of the field army.

d. Reduce the clerical and administrative workload, thereby releasing personnel for more important duties.

125. GENERAL APPLICATIONS IN TACTICAL COMMANDS

a. A program directed by Combat Developments, CONARC, is presently concentrated on accomplishing the above objectives. It is reasonable to expect that the Army will have a completely integrated data processing system by 1965, with interim capability in specific areas as early as 1960. Components of the system will be designed and engineered for employment throughout tactical commands and theaters of operations to meet the extensive data processing requirements of a modern army.

b. When we consider the application of ADPS in the tactical commands, we must remember that use of ADPS is progressing in line with a series of technological advances and developments of equipment. Not too much effort has been expended toward developing specialized ADPS equipment for field army use. Integration of data transmission into military communication networks is just beginning to gain momentum. With these facts in mind, preliminary studies have been undertaken to establish the areas and extent of ADPS application in the field. Certain operations indicate potential fields to be covered. These areas have been broken into more specific subjects and allocated to various Army activities for detailed analysis as part of the combat development study previously mentioned.

126. SPECIFIC APPLICATIONS IN TACTICAL COMMANDS

a. Personnel Applications:

(1) Daily and periodic strength reports.

(2) Replacement information, including estimates of losses anticipated.

(3) Prisoner of war records and reports.

(4) Burial and graves registration activities and records.

(5) Civil affairs activities.

b. Intelligence:

(1) Intelligence summaries and special reports.

(2) Dissemination of essential elements of information.

(3) Records and inventories of maps, photomaps, photographs, interpreted documents, and similar material.

(4) Analysis of enemy cryptosystems.

(5) Target acquisition.

c. Operations Activities:

(1) Maintenance of up-dated troop lists and TOE's, and their assignments and attachments.

(2) War game courses of action available to the command.

(3) Data on enemy capabilities and limitations.

(4) Conduct of feasibility analysis to determine if personnel and supplies are available to launch and support an operation for a given period of time.

(5) Bomb damage estimates, reports, and assessments.

(6) Display of G2-G3 information in a tactical support center.

d. Logistical Applications:

(1) Supply actions, stock management, and inventory control.

(2) Evacuation and hospitalization.

(3) Transportation and services requirements and plans.

(4) Logistical estimates of the situation.

(5) Determination of supply requirements.

e. Air Operations and Activities:

(1) Summarizing requests for air strike, air photo, and air reconnaissance missions.

(2) Air navigation and control.

(3) Weather data reporting, evaluation, and dissemination.

(4) Aircraft loading and operation phasing.

f. Communications:

(1) Traffic analysis and equipment utilization.

(2) Radio frequency allocation and utilization.

(3) Electronic countermeasures operations.

g. Fire Support Coordination:

(1) Designation of the most efficient support weapon for given targets.

(2) Field artillery fire control.

(3) Computations and summarizations of ammunition expended for fire support.

h. Management Programs:

(1) Payroll operations for military and civilian personnel.

(2) Accounting of funds between headquarters, including transfers, advances, and partial payments.

(3) Records and reporting of participation in foreign aid programs.

127. ENVIRONMENTAL REQUIREMENTS FOR TACTICAL ADPS

Satisfactory ADPS equipment needed to accomplish the tasks described above in a tactical environment is not yet available; however, the Army does have an established research and development program to provide the required equipment. Environmental conditions demand that the various items developed have the following basic characteristics:

a. Complete mobility.

b. Rugged construction and reliable operation.

c. Temperature and humidity control requirements drastically reduced or eliminated.

d. Associated data transmission equipment compatible with military and commerical communication systems.

e. Form of data compatible with encryption facilities.

f. Miniaturization for increased mobility and minimum power requirements.

128. MAJOR COMPONENTS OF TACTICAL ADPS

Several packages of automatic data processing equipment are under development for the Army in the field. They may be grouped into five functional classes: processing, storage, control, input-output, and data transmission. Each has its own element of control and is therefore capable of independent operations. Several packages may also be integrated into a large data-processing system. Similar design techniques are being used throughout for maximum ease of maintenance and operational flexibility. For example, the order codes of all processing units are similar, so that programs written for one unit may be run on another with the least possible modification. The word length and word structure are identical throughout. Many of the plug-in units and modules (groups of plug-in units) are directly interchangeable. Design considerations call for ruggedization of all equipment to meet field conditions. Each component must be capable of operating at temperatures ranging from 25°F to 132°F, and at relative humidities up to 97 percent. Dust conditions such as those found in desert areas must not affect operation. Each must pass the standard road test given to all mobile equipment. Each package will be mobile and will include necessary communication terminal equipment so that data can be transferred between it and any other device. More detailed information on these items is available at the Office of the Chief Signal Officer, Department of the Army.

129. MOBIDIC

a. General Characteristics. The MOBIDIC is a high speed, large scale, general purpose, transistorized digital computer housed in an air-conditioned XM450 van. Input-output devices for the MOBIDIC are magnetic tape, punched paper tape, electric typewriter, and page printer. A unique feature of the MOBIDIC is that data in real time may be introduced directly from an outside source through a special device called a real time register. This means that continually changing data, such as air traffic, aircraft warning, weather conditions, and fire control data, can be kept up-to-date by automatic methods. An artist's conception of MOBIDIC is shown in figure 46.

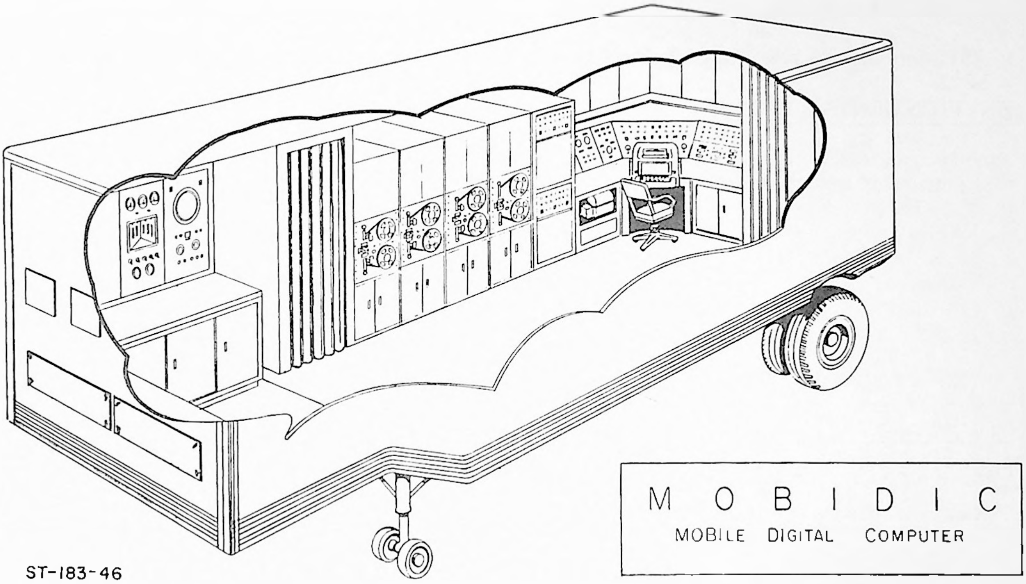


Figure 46. MOBIDIC.

b. Basic Characteristics.

(1) Internal number system: binary.

(2) Word length (bits): 36 (plus sign, parity).

(3) Instruction: essentially single address.

(4) Arithmetic system: fixed point.

(5) Add time (including storage access): 16 microseconds.

(6) All operations are parallel.

c. Internal Storage.

(1) Magnetic core storage is 4, 096 words, with an eight microsecond access time.

(2) Up to six additional magnetic core storage units may be added.

(3) Magnetic drum can be added as auxiliary storage.

d. Input-Output.

(1) Up to 64 input-output devices may be used with the computer (some may be remotely located).

(2) Up to eleven magnetic tape units may be used with the computer.

(3) Input-output converters provide buffering and code conversion between the input-output equipment and the computer. Each converter is capable of controlling the computer while the computer is doing other processing. Computation is interrupted only during information transfer between a converter and the computer. For example, a computer with two converters is capable of reading, writing, and computing simultaneously.

(4) A 39-bit real time register serves as a temporary buffer for data arriving at the computer in real time. When the register is full, its contents are transferred to the main memory.

e. Checking Features.

(1) A parity check is executed on transfers to and from core memory.

(2) A check for overflow is made in the arithmetic unit.

(3) There is a marginal check on all circuits.

f. Miscellaneous.

(1) The computer may have from four to seven index registers.

(2) All registers of the computer are adjustable.

130. BASICPAC

a. General Characteristics. The BASICPAC is a medium-sized, general purpose transistor computer housed in an S-109 shelter on a 2-1/2-ton truck. Input-output equipment consists of magnetic tape, paper tape, and typewriter.

b. Basic Characteristics.

(1) Internal number system: binary.

(2) Word length (bits): 36 (plus sign, parity).

(3) Instruction type: single address.

(4) Arithmetic system: fixed point.

c. Operating Characteristics.

(1) All operations are serial by character.

(2) Basic operation time (add time) is 24 microseconds.

d. Storage.

(1) Core storage: 4, 096 words.

(2) Minimum access time to optimally placed word: 12 microseconds.

e. Input-Output.

(1) Typewriter, paper tape reader and puncher.

(2) Up to four magnetic tapes may be used.

(3) The input-output converters will be similar to those of the MOBIDIC.

131. LOGICPAC

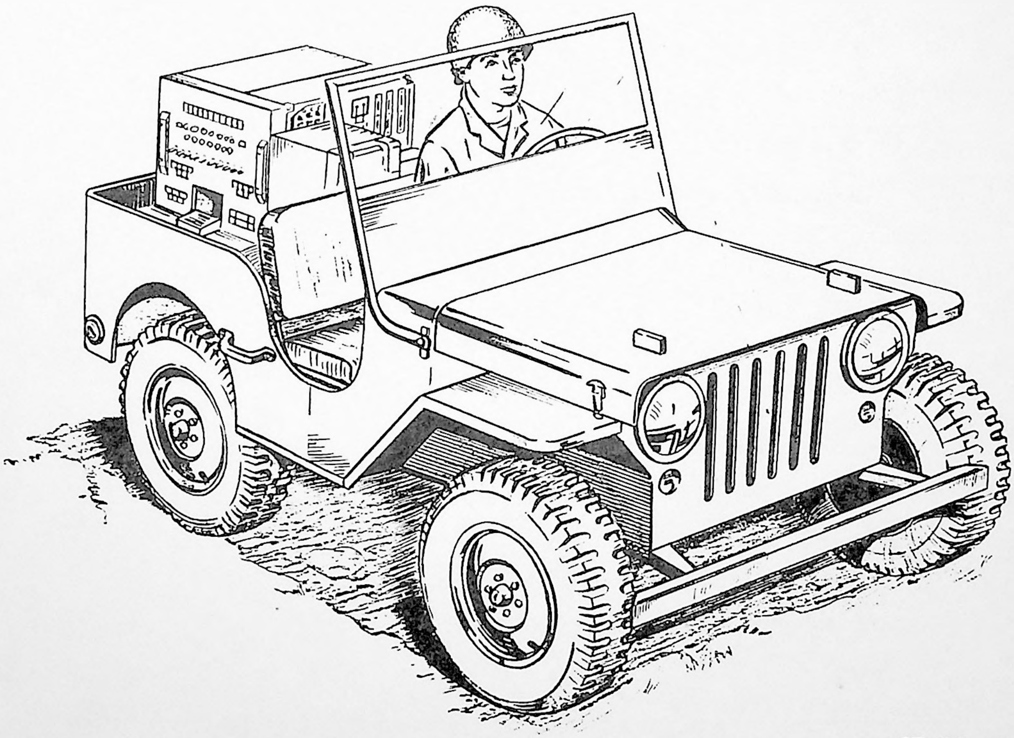
a. The LOGICPAC is a medium-sized transistor data processor similar in most respects to the BASICPAC, but with more logical capacity.

b. Because of its increased logical flexibility and greater tape-handling ability, the LOGICPAC is better suited to file processing, whereas the BASICPAC is the better machine for computation.

132. COMPAC

a. The COMPAC (Compact Processor and Computer) is a very small, light weight, medium-to-high speed, multi-purpose, stored program digital data processor and computer belonging to the Fieldata family of automatic data processing equipment. The minimum man-pack version of the COMPAC will weigh 90 pounds and occupy 3.5 cubic feet. Typical operation times are 14 microseconds for transfer of control, 24 microseconds for addition, and 240 microseconds for multiplication, all including memory access to the computer's magnetic core memory.

b. Figure 47 shows an artist's conception of how the COMPAC will appear when mounted on a 1/4-ton truck.



ST-183-47

Figure 47. COMPAC Central Processor.

133. INFORMER

a. General Characteristics. The INFORMER is a large capacity random-access storage device housed in an S-109 shelter mounted on a 2-1/2-ton truck. It is possible to address any location in the memory, or to have the INFORMER search its memory for particular information.

b. Interrogation. The INFORMER is capable of locating documents that conform to a complicated set of criteria, such as --

(1) Does the document include an item?

(2) Does the document not include an item?

(3) Does the quantity of a particular item described by the document fall within certain numerical limits?

-- and many others. Any combination of these criteria may be used to specify a set of documents.

c. Storage.

(1) High speed core storage of 8,192 words is provided.

(2) Disk file of 5 million words, 0.2 seconds maximum access time.

(3) Up to 10 magnetic tape units may be used.

134. DATA COORDINATOR AND RETRIEVER

a. General Characteristics. The DATA COORDINATOR AND RETRIEVER supervises and coordinates the operation of a data-processing center consisting of several computers (MOBIDIC's or smaller) and large capacity memory storage devices (INFORMERS). It is constructed of transistor-magnetic circuitry and housed in an S-109 shelter.

b. Function. The DATA COORDINATOR AND RETRIEVER is capable of --

(1) Communication switching and termination for digital information transfer to and from other data-processing centers and remote input-output equipment.

(2) Buffering all incoming data until such time as it is stored in an INFORMER or used by a computer.

(3) Storing all programs needed for the various processing jobs.

(4) Scheduling the workload among the several computers.

(5) Transferring the proper program to the proper computer at the proper time.

(6) On-the-spot changing of schedules for optimum handling of fast-action requirements.

(7) Requesting information that may be stored in other data-processing centers.

(8) Allowing intervention by the operator for manual rescheduling of the workload or for interrogation of the system.

c. Input-Output.

(1) Up to 20 communication terminals may be used. These may be any combination of the following:

AN/TSQ-33
AN/TSQ-32
TH-5

(2) Up to 16 (input-output) magnetic tape units may be used.

(3) Two paper tape reader punches.

(4) Two typewriters.

(5) One disk file (input-output) unit.

135. EMPLOYMENT OF ADPS IN A THEATER OF OPERATIONS

Data processing equipment will be employed throughout the theater of operations as TOE items. Some of the units using the equipment will have specific missions, while others will act as service centers. As a general rule, all data processing centers will be integrated with the communication system serving the theater. The communication system will enable staff personnel to influence computer decisions and to interrogate it from a remote point for timely information.

a. The computer and storage capacity at each echelon will be provided by such machines or combinations of machines as appear best suited to the special tactical requirements for mobility, displacement by increments, concealment, reliability, interchangeability of elements or components, fail-safe operation, ease of maintenance, and ease of operation. The number of input, output, and recording devices at each echelon and their distribution will depend on the applications at that echelon. The studies presently underway will serve as a guide to the location and number of these devices. Considering the probable nature of tactical operations in a pentomic environment, it is obviously necessary to provide each echelon with at least enough data-handling capacity to permit survival on the battlefield even when cut off and isolated from higher and lower echelons. In some cases manual methods may suffice for such minimum capacity operations, and in such cases manual methods are expected to be fully utilized.

b. Requirements for data storage in the PENTANA field army fall into two broad categories: (1) working files required by individual officers or echelons, and (2) reference files which can be common to several users. Each of these categories can also be subdivided according to the requirements for (1) quick-access memory and (2) low-speed storage. (The latter term as used here should not be misunderstood. Low-speed storage for an electronic computer is hundreds of thousands of times faster than manual operation.) As a basic concept in the development of the over-all ADPS system it has been recommended that each echelon above the company have organically available to it a working file storage capacity, both quick-access and low-speed. Each such echelon may also have the ability to interrogate the over-all data system storage for reference information as required.

c. The generally recognized undesirability of "putting all the eggs in one basket" is particularly true of a tactical military organization. Therefore, two or more small capacity devices have customarily been recommended for areas where it is quite apparent that one large device could handle the load, possibly with somewhat improved efficiency. Further, to insure continuity and preservation of stored information, the system will provide for duplicate storage of information at a different location. This will make it possible to reconstitute files accidentally or purposely destroyed.

d. To provide appropriate and technically correct guidance for optimum utilization of the ADPS, each commander must have specially trained ADPS personnel on his staff. At the combat group level, it may be feasible to assign this as a dual capacity duty; but certainly at division and higher levels, the magnitude and complexity of the ADPS will necessitate full-time specialists in this field.

136. OPERATIONAL CONCEPT

The fundamental and most inportant operational concept of ADPS is that the system is a tool of command, not a substitute for command. No data processing system is expected to make decisions. It is expected, however, not only to make it easier for the commander to make decisions, but also to help him make more accurate and significant decisions. Just as a G2 states the enemy capabilities without stating his intentions, so will the data processing system predict the consequences of several alternative courses of action without prescribing which one is to be followed. Command decision remains a human function. All the ADPS can do is provide more information of greater accuracy more quickly, furnish high-speed analyses of alternative measures, and expedite the execution of the commander's personal decision.

a. Accessibility. To serve as a useful tool of command the ADPS must be responsive to the commander's desires. Physical attributes of the system must not restrict the commander's freedom to move and maneuver. Input to the system must be simple and error-free. Output from the system must be in such form as to be of immediate use to the commander (an overlay rather than a three-foot long column of decimal digits which require decoding and translation). The user's access should be comparable to the accessibility of his telephone. Consequently, input-output equipment should be placed for the convenience of the staff officer, rather than concentrated at the data processing service center.

b. Control. The commander must be free to state when the system shall be operational, when it shall move and to where, when he can best spare time for maintenance, and what the user priorities shall be within the scope of his command. These are further areas in which the system must be responsive to the commander's desires. As a corollary to these freedoms, however, the commander must have a competent and qualified person to recommend practical and feasible command decisions regarding the employment of ADPS. Installation, maintenance and technical operation of the ADPS (and of the supporting communications system) must be under the control of technically qualified specialists who should preferably not be under the direct operational control of the user. If the user has direct responsibility for operating the system, it thereby becomes a burden to him rather than an aid.

c. Additional Automatic Facilities. Automatic addressing will insure that data traffic is handled expeditiously and will automatically distribute the load over available resources in accordance with established priorities. Built-in priority codes will insure the necessary precedence within the system without manual intervention. The system will embody automatic "snoop and peep" capability, so that any station at any echelon may place an inquiry into the system without the necessity of indicating where the answer is to be found. The system will automatically search local storage for the answer and, if it is not available there, the machines will progressively search other files at other installations until the desired information is found.

d. Security Capability. The system must also embody a dual purpose security capability. In addition to encrypting certain classes of information to safeguard it from the enemy, the system must of necessity contain an internal security program which will allow certain classes of stored information to be barred to all but specified users. An electronic equivalent of a signet ring may be issued to authorized personnel, without which the data system will refuse access to the classified material.

e. Automatic Destruction. It may be noted in passing that electronic storage of record information offers a capability for greatly improved battlefield security. Magnetic drums or magnetic tapes can be erased magnetically (by writing zeros over stored information) in a fraction of a second, whereas it takes measurable time and a destruction plan to burn paper records. Built-in emergency erasing facilities would allow a tactical commander to preserve his records until the last minute, and would permit destruction of the information without physical destruction of the machine, if that should become desirable.

f. Simultaneous Operations. All computers will be constructed and programmed so as to permit simultaneous operations on many problems. Because of the high speed of computer operations and the probability that few problems will be placed upon a computer with precise coincidence (within fractions of a second) it is probable that the required capability for simultaneous operations will be quite reasonable (perhaps in the order of 10 to 15 problems at a time).

137. FUTURE INTEGRATION

A completely integrated data processing-communication system that will meet all these performance requirements is expected to be available between 1965 and 1970. Systems having a somewhat lesser degree of compatability should become available as operational systems between the years 1960 and 1965. Prior to 1960, specialized automatic data processing systems will use commercial equipment. This equipment will provide interim operational benefits and give planning information to the engineers who are developing military equipment for future use.

Glossary of Digital Computer Terms

Access time - The time interval between the instant at which information is --

(a) Called for from storage and the instant at which delivery is completed; i.e., the read time.

(b) Ready for storage and the instant at which storage is completed; i.e., the write time.

Accumulator - The portion of the machine which stores a number, and which, on receipt of another number, adds it to the number already stored. It is a type of register which will accumulate the sum of a series of numbers applied to its input, and is the main arithmetic unit of the machine.

Address - A number which designates a particular location in the storage (memory) device where data are written in or read out.

Alphanumeric - A system in which each alphabetic and numeric character is represented by a group of binary digits, usually six such bits to express one alphanumeric character.

Applications study - The detailed process of designing a system or set of procedures for using automatic digital computers for a definite function or operation, and establishing specifications for equipment to meet specific needs.

Auxiliary equipment - All data-producing equipment, including the input and output equipment, which directly supports or services a digital computer. It does not include communications equipment.

Base - (See Positional notation).

Binary number system - A number system to the base two; i.e., it has two characters (usually denoted by "0" and "1").

Binary-coded-decimal system - A system in which each decimal digit is represented by a group of binary digits. Normally four binary digits express one decimal digit.

Bit - A contraction of binary digit ("bi" for binary, "it" for digit). In the binary number system it may be either an "0" or a "1" and is the smallest unit of information.

Buffer storage - Storage used to compensate for a difference in rate of flow or time of occurrance when transferring information from one device to another.

Business-type operations - As used herein, those functions which involve handling of supply, personnel, financial accounting, production control and statistical data.

Check, automatic - A self-checking process performed by the digital computer to test the validity of the machine's computations. Usually composed of several types of checks (parity check, redundancy check, control check, etc.).

Data processing - The preparation of source documents which contain basic elements of information, and the processing of these data in a form for the computer to produce records and reports.

Electronic digital computer - A machine or group of machines (input, storage, computing, control and output devices) which use electronic circuitry in the main computing element to perform arithmetic and logical operations automatically by means of internally stored program instructions.

Feasibility study - The preliminary process of determining the over-all soundness of applying ADPS to the solution of a problem.

Point - In positional notation, the symbol which separates the integral part of a numerical expression from its fractional part. In decimal notation it is called a decimal point. In binary notation it is called a binary point. A fixed point machine means that the numbers to be added or subtracted must be of the same power of 10 (in the case of decimals) or the same power of 2 (in the case of binary numerals); that is, the location of the point remains fixed with respect to one end of the numerical expressions. A floating point computer automatically keeps track of the powers of 10 (or 2, as the case may be) along with the numbers. Before adding or subtracting, it checks to see that the numbers have the same 10 (or 2) powers and, if different, it shifts the numbers to the right or left to make them agree in power.

Positional notation - The representation of a number by the arrangement of its digits in sequence, with the understanding that successive digits are interpreted as coefficients of successive powers on a number called the base of the number system.

Examples are:

In the decimal system --

Base (B) = 10

The digital coefficients (d) = 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

∴ The number (N) 8109 denotes

$$(8 \times 10^3) + (1 \times 10^2) + (0 \times 10^1) + (9 \times 10^0) =$$

$$8000 + 100 + 0 + 9 = 8109$$

In the binary system -- (assuming 8, 4, 2, 1)

Base (B) = 2

The digital coefficients (d) = 0, 1

∴ The number (N) 1101 denotes

$$(1 \times 2^3) + (1 \times 2^2) + (0 \times 2^1) + (1 \times 2^0)$$

$$8 + 4 + 0 + 1 = 13$$

Real time - Processing the data at the same time a physical process creates the data, in order that the results of the processing may be useful to the physical creative process itself.

Register - A device capable of retaining information, usually one or two words required in a computation under way in the main accumulator, such as multiplication where the multiplicand is held in temporary storage in a register until the successive additions are completed.

Storage - The device associated with a digital computer which permits retention of information placed in it, with the ability to present the information to the computer when called in and return it to storage when directed. This device is also called the memory of the machine.

Word - A series of digits, plus the sign, in computer language. In a binary machine it might be 30 to 40 bits and represents either information or an instruction to the machine.