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HISTORY OF NSA GENERAL-PURPOSE ELECTRONIC DIGITAL COMPUTERS

1964

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NSA GENERAL-PURPOSE

ELECTRONIC DIGITAL COMPUTERS

By

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PREFACE

The author has attempted to write this material so that it will be easily understood by those who have had only limited experience with computers. To aid those readers, several terms and concepts have been defined, and Chapter 1 includes a brief discussion of principles of computer operation, programming, data-preparation problems, and automatic programming. Engineering terminology has been held to a minimum, and the history of programmer training, personnel and organizational growth, and the like has not been treated. To some small extent, the comments on operational utility bring out the very real usefulness of computers for the solution of data-processing problems.

The cutoff date for events related here was the end of December 1963.

S.S.S.

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CHAPTER 1
BACKGROUND

Most writers on digital computer development tend to start with discussions of the abacus and continue with Charles Babbage's *Analytic Engine*, the desk calculator, and the big relay calculators of Bell Laboratories and Harvard. Indeed, the development of computing machinery did follow such a path. But the role of computers at NSA can be better appreciated when considered from the viewpoint of application.

Punched Card Equipment and the Computer

The extraordinary versatility and efficiency of electronic computers have made them useful in handling almost every class of data-processing and analytic problem. From this point of view and in this respect, at NSA, punched-card equipment -- keypunch, reproducer, sorter, collator, and tabulator -- could be called the forerunners of the electronic computer.

For the 15 years beginning about 1935, NSA's predecessors used punched-card equipment to attack wider and wider ranges of problems. During this time many special-purpose machines were also built, including some designed as attachments to punched-card equipment. The use of punched-card equipments as general-purpose tools continued to grow until, by the end of World War II, 750 machines had been installed.

Punched-card equipment -- keypunch, reproducer, sorter, collator, and tabulator -- were the forerunners of the electronic computer in every respect excepting speed and automatic operation. This is true because of the use of the punched-card as a unit record, flexibility of plugboard together with switching capabilities in each machine, and versatility inherent in successive card passes through different equipments. The following types of data analyses could be done using punched-card equipments:

expanding, reproducing (Reproducer)
distributing, sorting (Sorter)
merging, selecting (Collator)
counting, printing (Tabulator)

The general-purpose computer logically corresponds to punched-card equipment in that a variety of elementary operations (the order code) can be combined in a variety of ways

(the programs) and applied to unit records (data stored in specific memory locations). The versatility is further increased by treating the program steps (instructions) as data themselves and eliminating the necessity for manual operations between successive logical operations. Finally, the great difference in speed made possible by electronic circuitry in the large computers has virtually eliminated the punched-card approach as our principal general-purpose tool.

Computers in NSA

With the earliest design work on computers, in 1946, came the realization of the potential usefulness of such machines for Agency purposes. Quite probably this Agency's predecessors were the first to develop sophisticated analytic applications of such machines. This story is detailed later in the discussions of ATLAS I and ABNER. The use of computers by NSA has increased considerably, beginning with one of the first machines in the country, installed in December 1950.

NSA's computer installation probably ranks among the largest in the country. The chronological listing (Table 1, page 93) shows these acquisitions in the order of their installation and includes references to the page in the text where each computer is discussed.

Computer Principles

Most modern electronic digital computers, beginning with the successors to the famous ENIAC, have been composed of four principal units: input-output, storage, arithmetic, and control (fig. 1). Data and instructions, prepared in advance on some machine-readable medium (punched cards, tape, and the like), are fed into the machine system, and the data is operated on automatically, according to the steps specified in the instructions. Such instructions are stored in the same internal storage medium as the problem data but are interpreted by the control unit. An "instruction" normally indicates: (1) the operation to be performed by the arithmetic unit, (2) the location in storage (its address) of one or more operands, and (3) the address of the result of the operation. One of the reasons for the great flexibility of the modern computer is its ability to modify its own instructions or the course of problem solution, depending upon intermediate results. A variation of this capability is the technique of causing the incoming data-stream characters themselves to form addresses for insertion in skeleton instructions later to be executed.

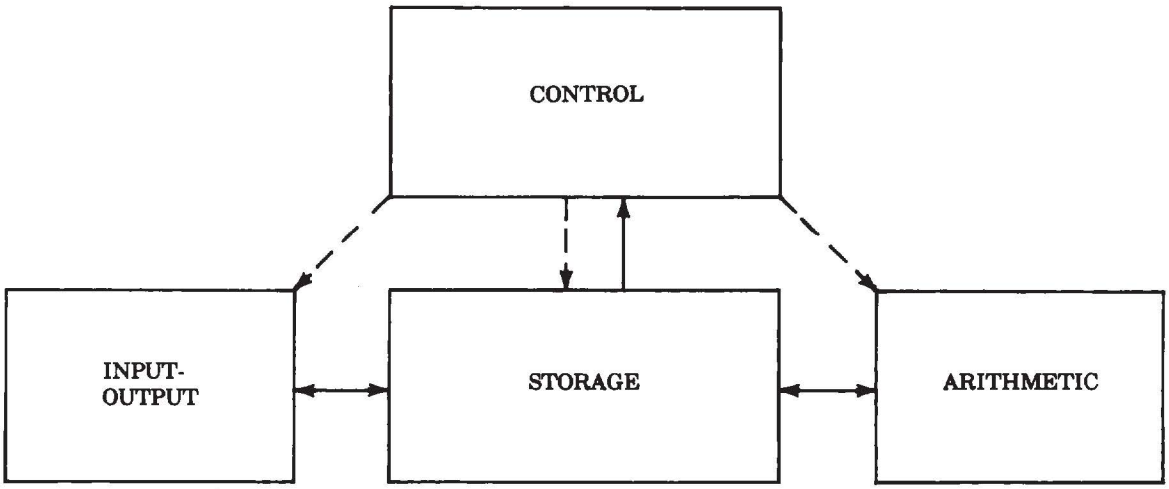

Figure 1.—Block Diagram of Digital Computer

Programming Principles

Any analytic or data-processing requirement, however complex, can be logically reduced to a succession of elementary operations that follow from binary decision-points (yes-or-no choices), provided knowledge exists of a logical method of attack. A flow chart (fig. 2) for a sample problem shows the use of such dichotomous, or two-choice, logic to break a complex problem into the major steps that will lead to possible solution. In similar fashion, each of such major steps is susceptible to further breakdown into smaller, more detailed, steps, and so on down to the individual elementary machine operations that are the smallest logical unit and that correspond to the individual computer instructions.

Data Preparation

An important and essential aspect of the use of any data processing machines is the initial step -- the preparation of data for input. In connection with the general-purpose use of punched-card equipment, the key-punch has been mentioned as providing means of transforming information into a form that can be read by other machines. The key-punch perforates cards in specific positions to represent data under study. Punched paper tape is also used as machine input and is usually punched in 5- or 7-level codes. Recently the use of magnetic tape has increased, although it must usually be prepared from punched cards or tape. Two points should be emphasized:

1. Our method for going from hard copy to machine-readable mediums has not improved -- a small army of key-punchers and paper-tape punchers is still employed.
2. The existence of several media, here and in the field, requires the use of large quantities of equipment and time just to convert from one medium to another (frequently several times within one job). Many machines, including several general-purpose computers, have been built for the sole purpose of data conversion and rearrangement.

Automatic Programming

In the preceding brief description of the principal parts of the typical computer and of organizing a problem for computer attack, the necessity for a breakdown into elementary operations was pointed out. Most of these elementary operations are more detailed -- require much finer attention -- than people are accustomed to. When a workable program

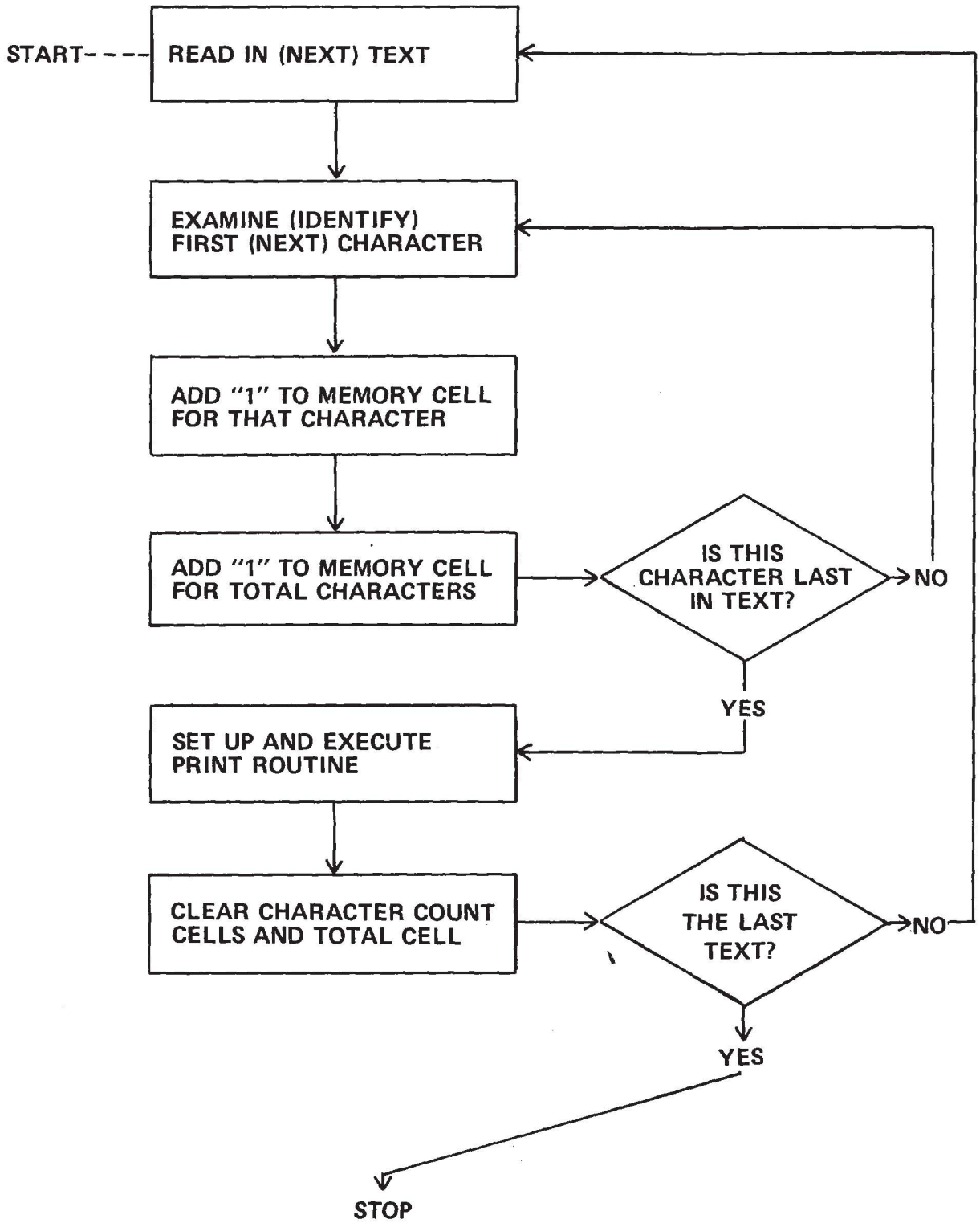

FIGURE 2. TYPICAL PROBLEM FLOW CHART -- FREQUENCY DISTRIBUTION OF ALPHABETIC TEXT

(or routine or subroutine, as smaller subdivisions are called) is completed, it is natural to try to avoid the necessity of repeating the whole operation the next time this particular function is required. As a result, routines of standard functions are commonly stored in "libraries," and special programs, called "compilers," perform the function of combining several such routines and adjusting addresses for varying conditions. To facilitate the writing of machine-language instructions, the instruction codes of many computers use mnemonics that must later be converted into the individual computer words. Programs for performing this conversion automatically are called "assemblers." Higher forms of languages have been developed that use a combination of rigorous English and mathematical notation to express functions and parameters of problems and thus release the analyst/programmer from becoming a full-time machine specialist. Programs for transforming these higher languages are called "translators;" they generate actual computer programs ready to execute a problem solution. Special programs for regulating overall computer operations, keeping records, monitoring various types of simultaneous operations, and for many other purposes are called "supervisors" or "executive" routines. In the past, programmers in NSA have been less inclined to use these techniques than computer users in other fields, primarily because commercially developed systems have been unsuited to the specialized nature of Agency operations. More recently, however, such techniques have become the rule, and the great ALPHA language-development effort required for HARVEST, for example, will certainly have a far-reaching effect on future large systems.

Special-Purpose Attachments

In large-scale equipment planning, more and more use is being made of the combination of several kinds of equipment into single operating complexes. Actually, this procedure parallels what was done many years ago when attachments were built to function with the IBM Tabulator. In 1954 the FARMER proposal first suggested the idea of special attachments to a computer, and the design of HARVEST made specific provision for the attachment of external function devices. The currently popular application of this principle is the designing of highly efficient counting, comparing, or other processing devices for attachment to a general-purpose computer for use in sophisticated attacks on complicated problems to achieve greater efficiency than would be possible using the computer alone.

Impact of NSA on Commercial Computer Developments

In addition to contracts for computer purchase or lease and the development of engineering techniques, the primary

influence of NSA on industry has been felt in those instances where technical leadership or management foresight has influenced or led directly to industrial computer pioneering. A few examples follow.

First, the sponsorship of the ATLAS I by NSA's Navy predecessor led directly to placing Engineering Research Associates on a firm footing as one of the country's pioneering computer firms. ERA's commercial 1101 and 1103 computers were almost identical to ATLAS I and ATLAS II respectively. With the merger of ERA and the Eckert-Mauchly Corporation into the Remington-Rand-UNIVAC organization, the 1101 and 1103 became a part of the UNIVAC line. Through the National Bureau of Standards, NSA's Army predecessor contracted for the construction of a mercury delay line memory for ABNER. The Technitrol Corporation not only built memories for ABNER and the National Bureau of Standards' SEAC, but later constructed the second ABNER and received a series of contracts for equipment using similar components. Technitrol went on to market a varied line of special and general-use equipment, much of it based on this experience. Another example is NSA's NOMAD contract with Raytheon Corporation. The NOMAD design was the direct forerunner of the Datamatic 1000, which was transformed into one of the early machines in the Honeywell line. The realization, in 1955, that the transistor had a bright future as an electronic component, led to this Agency's sponsorship of the construction by Philco Corporation of NSA's first practical, transistorized computer, SOLO. Marketed commercially as the Transac S-1000, it became the world's first commercial transistorized computer. Beginning with the EDPM Type 701, the Agency-IBM experience is very impressive. Probably very few realize that IBM based much of its early computer philosophy upon NSA's experience with large data-processing problems. Certain features of the 704, representing improvements on the 701, resulted from suggestions by NSA personnel; similarly, the 702 was improved to become the 705. The PLANTATION (later RANCHO) study contract for HARVEST design, as well as NSA support for memory and magnetic tape researches, not only influenced IBM's 7030 (STRETCH) but also resulted in solving a number of fundamental logic and processing problems never before confronted in the computer field. Finally, the LIGHTNING researches into ultra-high-speed computer circuits and components -- work done under contract by IBM, Remington-Rand-UNIVAC, RCA, and others -- have undoubtedly had the greatest influence in the development of new computers and other digital equipment with basic operation times measured in nanoseconds (billionths of a second).

CHAPTER 2

AGENCY-SPONSORED COMPUTERS

In addition to operating an extensive computer installation, NSA has been a prime sponsor of computer developments. Of the nine electronic computer projects discussed in the following sections, two, ABNER and CUB, were designed and built by NSA (or predecessor) personnel. The rest were built under contract, following logical designs conceived or inspired by NSA personnel.

ATLAS I and ABEL

In the summer of 1946, Moore School of Electrical Engineering, University of Pennsylvania, sponsored a series of lectures on electronic computers. Among those who attended was LCDR James T. Pendergrass, a young mathematician at Navy's Communications Supplementary Activities, Washington (CSAW). As a result of hearing the computer proposals described at that time, LCDR Pendergrass prepared a report in which he proposed that the Navy acquire such a machine. His report included a general description of the proposed machine's logic, its code of instructions, and coded examples of typical problem solutions. The particular design advocated was of the class known as one-address logic, and was based on the I.A.S. Computer then being developed at the Institute for Advanced Study, Princeton, New Jersey. CSAW went ahead with plans for construction of ATLAS I, and CSAW personnel perfected most of the basic algorithms, or detailed machine logic for executing each instruction. The contractor, Engineering Research Associates of St. Paul, Minnesota, used MIT's WHIRLWIND I logical design to a great extent. ATLAS I was delivered on 8 December 1950 and was running before Christmas. It employed parallel circuitry, contained approximately 2700 tubes, and cost about $950,000. Figures 3 and 4 show views of this machine.

Although the original proposal had specified that the ATLAS high-speed internal memory was to utilize Selectron[1] tubes, a decision was made to substitute a 16,384-word magnetic drum of a type similar to one already placed in operation by E.R.A. in other special-purpose equipment built for the Navy. Also, whereas LCDR Pendergrass's proposal described a machine with 36-bit[2] words (each word containing two one-address instructions), the ATLAS I design was finally based upon 24-bit

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1 Selectron was the specially-designed electrostatic storage tube under development by Jan Rajchman at RCA's Princeton Laboratories. The development never achieved sufficient reliability for use as a practical computer memory.

2 "bit" -- binary digit

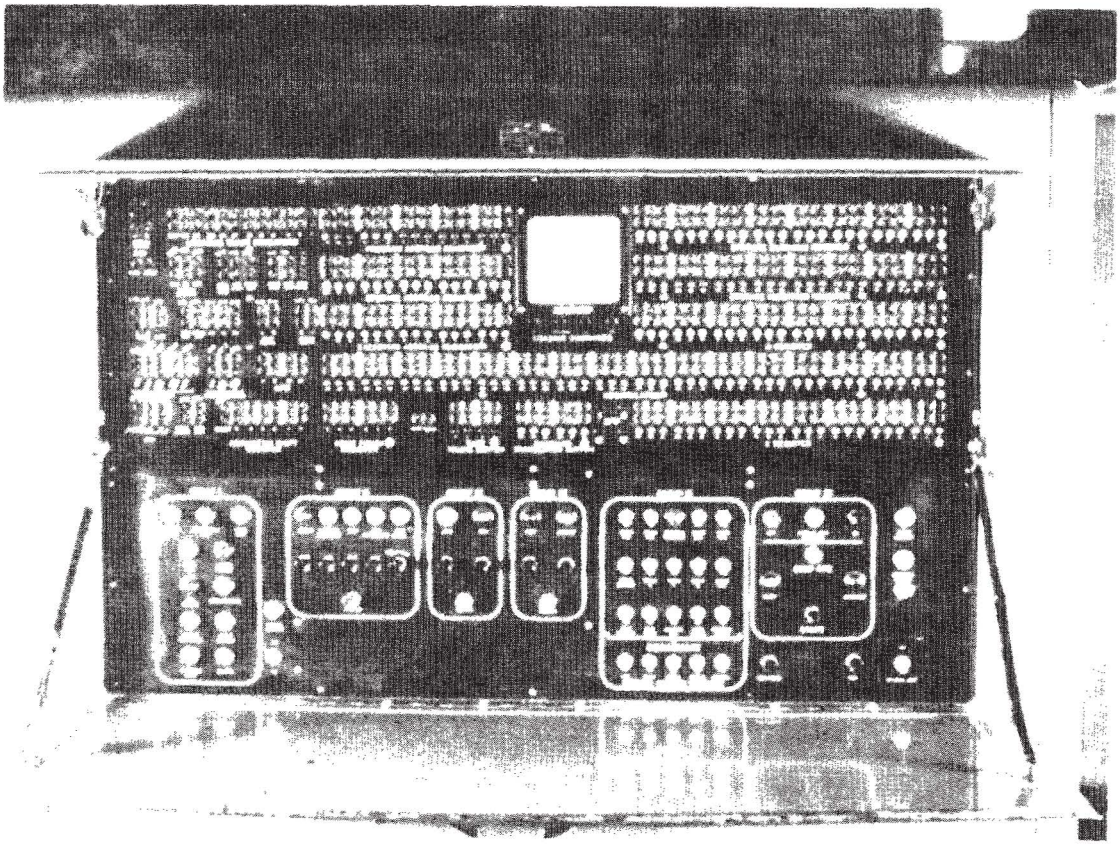

Figure 3 —ATLAS I Console

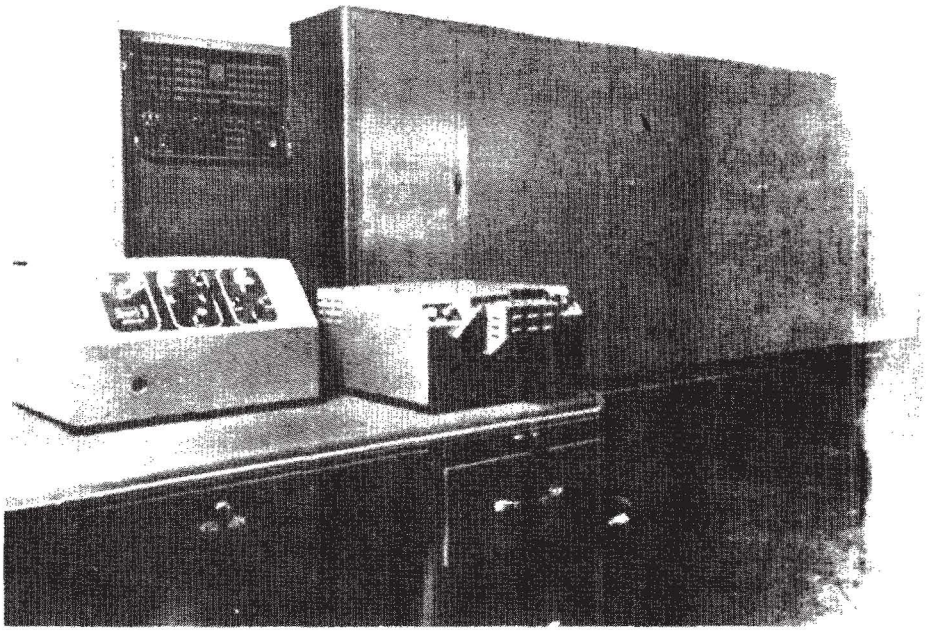

Figure 4—ATLAS I Main Frame, with Input Tape Reader in Foreground, Console in Background

words (each with one single-address instruction). The drum memory was equipped with a flexible feature called "interlace," that permitted variations in address layout to be made for each program, using a plugboard setup. In effect, "lines" around the drum were renumbered by transposing certain bits of the address selection register in order to allow longer or shorter intervals between successive effective addresses, according to the particular needs of the program. Careful programming in conjunction with careful planning of the interlace plugging made it possible to attain extremely high speeds for given programs, compared to running time of programs written without attention to interlace. Thus, access time[1] could be reduced to 32 microseconds under the best conditions, compared with an average of 8,500 microseconds or a maximum of 17,000 microseconds. In May 1951, a modification, the "skip" feature, was introduced that added flexibility to programming by allowing the program address counter to advance by intervals greater than one (9, 17, 33, or 65). In effect, the operation of the interlace feature was made partly automatic. In June 1951, the installation of a "dial interlace" feature made selection of the interlace plugging simpler and eliminated the necessity of actually changing plugboards. Other features of ATLAS I's original design included logical multiply instruction, vector addition, several forms of ordinary arithmetic instructions, conditional jump instructions, and an elementary input-output procedure using punched paper tape. In 1952, an interesting new feature, the random jump instruction, was added. Employing a separate electronic attachment that supplied random bits of zero or one, this instruction made possible the generation of streams of random characters. The photoelectric tape-reading equipment delivered with ATLAS I was found to be quite slow (140 characters per second) compared with ATLAS I internal speeds; nor was it under program control. It was replaced by the newly developed Ferranti photoelectric tape reader that had a speed of 300 characters per second. Table 2 contains the ATLAS I instruction repertoire.

Shortly after the completion of the ATLAS I design in 1949, a decision was made to construct a relay analog of the equipment, to assist in training programmers and to "debug" its programs (at least logically) before it was delivered. ABEL (fig. 5) was designed and constructed by CSAW personnel in about four months. Logically it was identical to ATLAS I, but its memory drum capacity was 2,047 words instead of 16,384, and its relay circuitry made it several hundred times slower.

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[1] access time -- time required to locate and read a word from memory into the arithmetic unit or vice-versa.