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Engineering Note E-356

Equipment and Techniques for Inserting
Information into WWI

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July 12, 1950

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Page 1 of 9

Air Traffic Control Project
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SUBJECT: EQUIPMENT AND TECHNIQUES FOR INSERTING INFORMATION INTO WWI

To: Mathematics, Block Diagrams, and Input-Output Groups

From: C. W. Adams

Date: July 12, 1950

Abstract: The terminal equipment to handle the insertion of numerical data into Whirlwind I will consist of Eastman Kodak reader-recorder film units and Flexowriter typewriters, printers, tape readers and tape punches. Information will be typed in duplicate in a standard form using Flexowriter equipment. The computer will automatically convert Flexowriter-coded information into its proper form. It will also automatically select any desired routines or subroutines from a film library and put these routines into any desired storage location. Brief descriptions of the terminal equipment and a general outline of the techniques proposed for using the equipment are given in this note.

Table of Contents:

A) Introduction	2
B) Brief Description of the Proposed Terminal Equipment.	2
C) Brief Description of the Proposed Library Film	3
D) Procedure by which a Coded Program can be Prepared for WWI.	5
E) Procedure by which WWI can be Prepared to Perform a New Coded Program.	7
F) Conclusion	9

A. Introduction

Although several notes have been written in the past few years describing the Whirlwind order code and methods using that code, and although a number of coded programs have already been written, no specific techniques have heretofore been described for actually setting the computer up to perform a computation. Now that the computer has become a physical reality and the necessary terminal equipment has been obtained, however, it becomes necessary to describe the techniques and the equipment which are to be employed in preparing programs in a form usable by the computer.

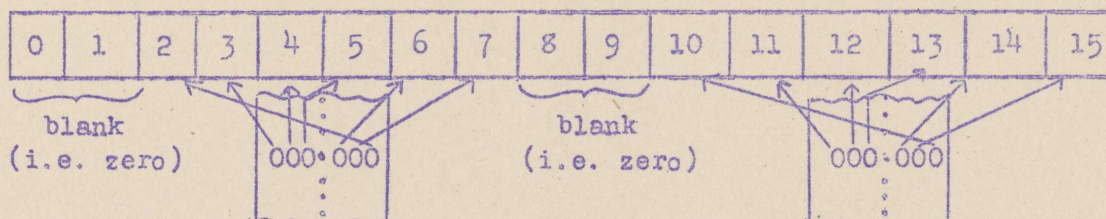
B. Brief Description of the Proposed Terminal Equipment

According to the present plans, input-output equipment will consist of (a) six Eastman Kodak reader-recorder units; (b) three complete Flexowriter units each consisting of a typewriter, a printer, a tape punch which can be actuated by the typewriter, and a tape reader which can control the printer; and (c) three cathode-ray display tubes, one of which is primarily intended for photographic recording of plotted results. The manner in which these units will be used is described below and is illustrated in the attached pictorial schematic (E-35714).

The Eastman Kodak reader-recorders are capable of reading or recording binary digital information on film at a rate of 2000 words per second. Each word can be 25 binary digits long. For checking purposes, the complement of each word is recorded or read concurrently with the recording or reading of the word (no extra time is required for handling and checking the complements). Only 16-digit words will be used in Whirlwind I, so that 9 digit spaces will be unused on the film. It should be emphasized that the reader-recorders can do only one job at a time -- i.e., that each particular unit is at any given time either a reader or a recorder but not both. Furthermore, a recorder works with unexposed and undeveloped film, a reader with exposed and developed film. The film produced by a recorder must be developed in an external unit at a rate of about 6 inches per minute (10 words per second). The movement of film from a recorder to the developer and thence to a reader is manual. Developing cannot begin until recording is complete; reading cannot begin until developing is complete.

The Flexowriter equipment punches or reads tape at a rate of about 8 lines per second. Each line of tape contains a feed hole and room for 7 punched holes; and each typewriter key corresponds

uniquely to a single 6-binary-digit (hole or no hole) character, the seventh space being left blank. The tape can be read as soon as it comes out of the punch. Two 6-digit characters are then put into a 16-digit coded word in Whirlwind I or on film, the remaining 4 digits of the word being always zero, in the following fashion:



Extra equipment will be provided so that each character typed on tape will be followed automatically by its complement for checking purposes. Punching or reading the complement on tape is, unlike in the film equipment, a separate operation. Two characters and their complements, and therefore 4 lines of tape, are required to make up one word. Furthermore, the coded information punched on tape must be converted eventually to pure binary form and each pure binary word will generally be made up from 8 typed characters (see page 5). Therefore, each binary word will require 8 characters and their complements, 16 characters in all, and will therefore be handled at a rate of about 1/2 word per second. Samples of a first tape (no complements), a second tape (with complements), and a film recorded from the second tape are shown in the attached photograph (A-35681).

The cathode-ray display tubes will have their deflection plates connected to decoders which will provide horizontal and vertical deflections proportional to the size of the binary numbers read into the decoders by the computer. Thus points can easily be plotted on the tube faces in Cartesian coordinates. Alternatively, horizontal or rotating time-base sweeps may be provided to permit Cartesian or polar plots in which a single computed coordinate is plotted against time (this relies on a constant time interval occurring between successive points). The decoders, and consequently the display tubes, will very likely be able to handle binary words faster than the computer can provide them. In fact, the present temporary display system, working with the computer using 32 registers of very-rapid-access test storage, displays up to 50,000 words per second.

C. Brief Description of the Proposed Library Film

In addition to the equipment just described, there will be a library film on which are stored in pure binary form an initial program and a set, or library, of standard routines and subroutines.

The initial program is the program, written once and for all, which is to be read into the computer initially in order to direct the computer:

- (1) To read-in the desired main program word by word from film or from tape;
- (2) To convert the words from Flexowriter-coded form to pure binary;
- (3) To store each converted word in its assigned location;
- (4) To determine, from specific information given with the main program, the subroutines which are needed and the storage locations in which each is to be located;
- (5) To select the proper subroutines from the library film and store each in its assigned storage location;
- (6) To adapt each subroutine to its assigned storage location; (i.e. each subroutine must originally have been written assuming that it is to be stored starting at some definite storage address, whereas in each application it will be actually stored starting at some other register and must therefore be adapted).
- (7) To start execution of main program.

The standard routines are programs which are used frequently enough to warrant their being stored on the library film for easy reference when needed, thus eliminating the need for any hand operation in preparing the computer for a routine program. For instance, an accounting or inventory problem may be done once each week with new data, or an oil well or ballistic problem may be performed each time a new situation has given rise to new data. Such programs will be put on the library film in pure binary form and will then be available once and for all.

The standard subroutines are programs written to perform frequently-used computations, such as the evaluation of $\sin x$ or $\log x$. Subroutines, unlike routines, do not stand by themselves but are intended to be components of a larger program (cf. E-329: Techniques for Using Standard Automatic Subroutines). These routines and subroutines are to be stored in pure binary form in numerical order on a roll of film, the number of each of the routines and subroutines being assigned

in the order in which it is written. The distinction between a standard routine and a standard subroutine is logically important, but in practice the two can be handled in identical fashion so that the distinction is of no practical importance.

D. Procedure by which a Coded Program can be Prepared for WWI.

In order to actually prepare the computer to solve a problem, a coded program for the particular problem must be written out in full, leaving enough space for the standard subroutines desired. The address of the storage register in which each word (order or number) to be stored must be clearly indicated according to the convention that the words are stored consecutively unless otherwise indicated. Thus the first word is to be stored in some explicitly indicated storage register; and the succeeding words are to be stored consecutively (except that, at any time, a new address given explicitly will indicate that the next word is to be stored at the new address and succeeding words consecutively from there). If a standard routine or subroutine has been used in the program and is to be taken automatically from film, its library number is simply indicated at the place in the program at which it is to be stored. If more than one subroutine is desired, the library numbers of each are given. These subroutines will then be automatically selected from the library film by the computer (under the direction of the initial program) and will be stored in consecutive storage registers, starting at the indicated place in the program.

Each item in the program -- each order, number, storage address, and subroutine number -- is typed out as a single line in a columnar form on a Flexowriter typewriter. The following conventions must be observed:

- (1) An order is written as a conventional pair of small letters, a single space, and four decimal digits (e.g. ca 1234 or sl 0015).
- (2) A number is written as either a + or a -, a single space, a decimal point, and four decimal digits (e.g. + .1234 or - .9870).
- (3) A new storage address is written as a capital letter A followed by four decimal digits (e.g. A0793).
- (4) A desired subroutine number is written as a capital letter S followed by four decimal digits (e.g. S0093).

- (5) Each item is written in a single, separate line, thus requiring a carriage return at the end of each item.
- (6) These four different items can be intermixed at will except that all orders are to be given before any subroutine number is given.
- (7) The end of the program is indicated by typing a line of 7 virgules (i.e. ///).
- (8) No other symbol or machine function is to be used except those permitted above and the exact form given must be adhered to, including spaces, decimal points, zeros, and plus signs.

For checking purposes, the manuscript form of the program is copied twice on two different Flexowriter typewriters by two different typists. The first typing is performed in a straight-forward way, with the standard Flexowriter procedure for nullifying typographical errors being followed where necessary. The tape prepared by the first typing is put in a tape reader and each character on the first tape is automatically compared with the character typed by the second typist. As long as the first typing and the check typing agree (overlooking automatically any errors that were correctly nullified in the first typing), the desired character is punched on a second tape (or in special cases it can be recorded on film or read directly into WWI), while if the two fail to agree, an alarm is sounded and nothing is recorded. In the event of an alarm, the typist must determine the source of error, correct it, and proceed. Thus, in the second typing, the procedure for nullifying typographical errors is unnecessary and is replaced by the new procedure of simply retyping if the second typing caused the error or of overriding the first tape if the error was in that tape. On the second tape, each character is followed automatically by its complement. This complement is used for checking the actual punching and subsequent reading of the tape. The checked tape can then be recorded on film (or in special cases read directly into the computer).

Briefly then, the transfer from the typewriter to the computer is usually accomplished by first punching duplicate tapes and then preparing a film, although in special cases the transfer can be performed directly, or via film or via tape alone. The intermediate processes are intended to serve as buffers of increasing speed between the low typing speed and the high computer speed. Generally, the computer's time will be too valuable to permit it to take much

information directly from a typewriter because the efficiency would be much less than 1%. By the same token, reading a self-checking punched tape is nearly as slow as good typing and so the tape-to-computer link is also usually inefficient. The advantage of the intermediate use of tape is that it is cheap, fairly reliable, sturdy, easily handled and easily read, so that it is ideal for use in a manual process which may require correction of many errors. Then the routine, automatic transfer from tape to film can be accomplished at the convenience of the faster, more expensive recorder with no unnecessary delays for a typist to correct her mistakes. A film can be prepared from the tape whenever a recorder is available, and the recorded film can then be read into the computer at the proper time, reliably and rapidly.

E. Procedure by which WWI can be Prepared for a New Program

The computer can be actually started up by the following steps. A film kept in one reader, the library reader, is so arranged that when the reader is started, the first recorded words encountered on the film by the reader will be the start of the initial program, recorded in pure binary form. The computer is cleared by means of a pushbutton, and toggle switches are set to select the library reader and to indicate the address of the storage register in which the first word taken from the library film is to be stored. Then the computer and the reader are started simultaneously by a pushbutton. Since the control switch of the computer is initially clear and since the cleared position (00000) designates the operation ri, the computer performs operation ri which reads in the pure binary words of the initial program one at a time as they come from the library film and transfers them into consecutive storage registers, starting at the register indicated by the toggle switches and continuing until storage is full -- i.e. until a word has been put in register 255,511,1023 or 2047 depending on the storage capacity available in the computer. The storage register into which the first word is put is so selected that the last word of the initial program falls into the last available storage register (255,511,1023 or 2047). When that last word has been read in, the computer automatically stops the library reader and starts to perform the initial program which has just been read in.

In addition to the library reader there is a second, or input, reader in which is the film, prepared from the Flexowriter tape, containing the coded characters corresponding to the typewritten form of the desired program. The film is divided into blocks of four words corresponding to one line of typewritten copy, with enough space between blocks to allow the film to be stopped between blocks without coasting into the next block. Directed by the initial program, the computer starts the input reader, takes in one block of

coded characters, stops the input reader, translates the block just read in, and then continues to take in one block at a time, starting and stopping the input reader once for each block. If the information in the block turns out to be an address, this new address is translated and is stored in the register which is assigned to keep track of the address at which the next word is to be stored. If the block turns out to be an order or a number, it is properly translated into pure binary and is stored in the register designated by the address indication. Then the address indication is increased by one in preparation for the next word.

The first block that turns out to be a request for a subroutine initiates a small program that starts the library reader and reads in a subroutine-selection routine, storing it in registers formerly used by the initial program for translating orders. This selection routine then allows the library reader to run and counts, checks and discards the words read in by that reader until the desired subroutine is reached. After the desired subroutine has been read into the computer, the library reader is stopped. The address section of each order in the subroutine is examined and is changed if necessary to adapt the subroutine to the storage location now assigned to it.

To facilitate the performance of the procedure just described, one prepares the library film according to the following conventions. The standard subroutines are all numbered and stored consecutively on the library film in pure binary form in blocks -- one block for each routine, so that these blocks are of varying length rather than being always just four words long. The first word of each block is the block number and hence the subroutine number. The second word in each block gives the total number of words (orders and numbers) in that subroutine and the third word gives the number of orders in that subroutine. Each and every subroutine is written originally (before adaptation by the computer) as if it is to be stored beginning in storage register 1024. The address sections of orders referring to other registers within the subroutine are then no less than 1024, while the address sections of orders like sl, sr, rf and rs are always kept less than 1024. The orders are all at the beginning, the numbers all at the end of each subroutine. Knowing how many orders there are, and that the orders come first, the computer can tell whether it is dealing with an order or a number. By examining the address section of each order and changing only those that are not less than 1024, the computer can properly adapt the subroutine to its assigned location in storage. It can then store the adapted subroutine (both orders and numbers) in the proper registers, start the input reader

again, and continue with the next block of Flexowriter characters. More requests for subroutines can be handled in the same way, but no more orders can be translated because the order-translating portion of the initial program has been replaced by the subroutine selection routine. The purpose of replacing the one by the other is simply to reduce the amount of storage required by the initial program at any one time.

F. Conclusion

Much of the equipment described in this note is still being developed and tested, so that the system illustrated in the attached pictorial schematic will not come completely into being for at least a year. In the meantime, a direct tape-to-computer reader with checking, shifting and control performed by the computer, will be used as a primary source of input. As soon as film equipment passes the testing stage, film will be prepared from tape, again making use of the computer for checking, shifting and control. This interim system, which will be described in a forthcoming note, will require new programs for handling the direct type read-in, but the techniques described in section D will be essentially no different in the interim than in the final system.

Techniques for manual control (i.e. stopping the computer at a designed place, examining contents of specified electrostatic storage registers, and inserting new orders or parameters) will be necessary to give the programmer control over the computer after it has been started on a program. These techniques will probably involve the use of the toggle-switches and flip-flops comprising test storage, and they will be described in a note as soon as they are worked out in full.

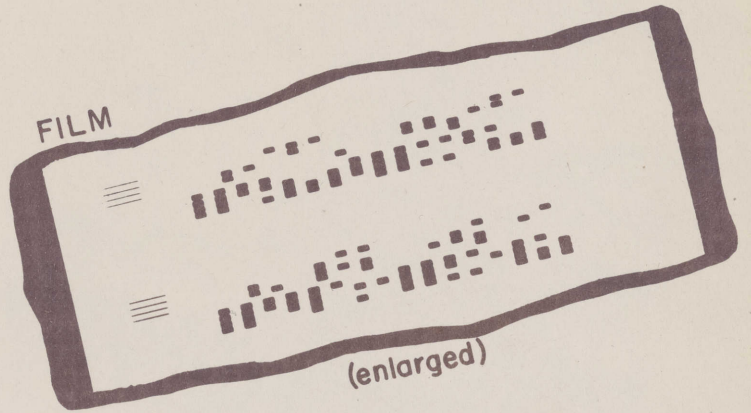
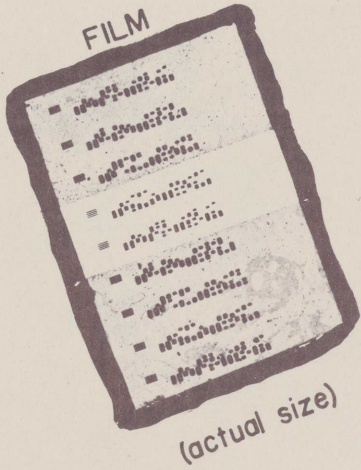
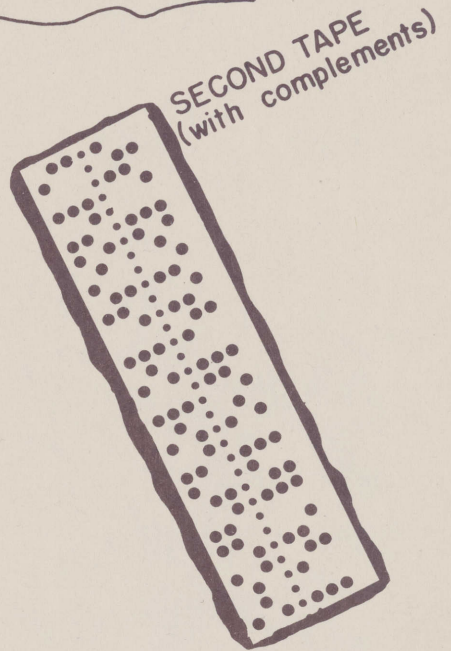
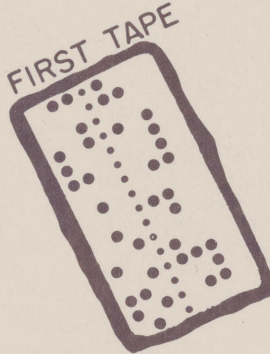
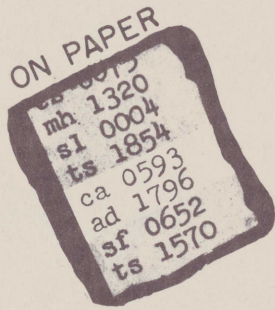
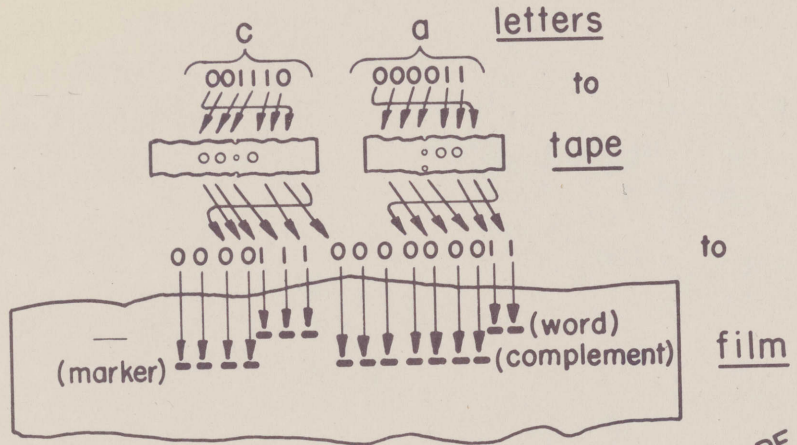
The techniques described in this note are to be considered as proposals subject to considerable modification.

Signed: C. W. Adams
C. W. Adams

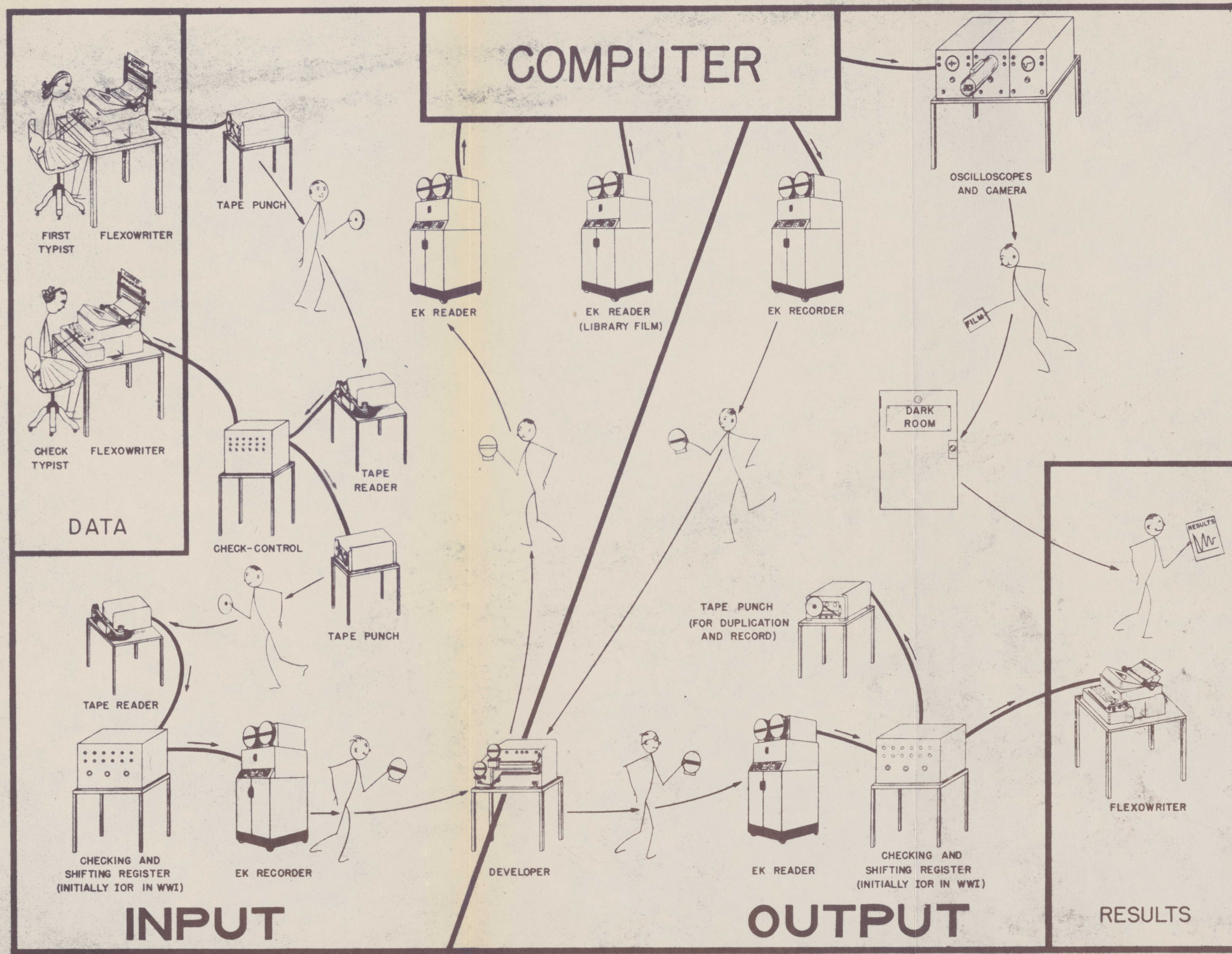
Approved: R. R. Everett
R. R. Everett

CWA:bm

Attached: A-35681
E-35714



TAPE and FILM for WHIRLWIND I INPUT



GENERAL-PURPOSE TERMINAL EQUIPMENT

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