An Integrated Computation System for the ERA-1103*

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The development of faster, more capacious, and more expensive computers has brought with it larger programming staffs, more handling of programming material outside the computer, and the urgent need to make the most of the scheduled production time of the computer. In order to make efficient use of machine and personnel time, the programming staff at The Ramo-Wooldridge Corporation has developed a computation scheme for the ERA-1103 in which almost all data for program assembly and check out is stored in its most convenient and readily accessible form on magnetic drum and magnetic tape. Since part of the information stored is the means for handling the information itself, the system is automatic; appropriate data transfers are made, check sums computed, translation and input-output functions performed, and suitable indications given in the case of untoward circumstances. The computation system has been in operation since April, 1955.

The accomplishment of this system represents the belief that "automatic programming" means a great deal more than an assembly or compiler program. The input language should properly be only a part of an over-all system to optimize the use of the computer in reducing programmer, computer, and clerical time in bringing problems to the production stage.

The ERA-1103 computer is especially adapted to an integrated computation system involving the internal storage of a comprehensive system of service and subroutines. Besides the 1024 words of electrostatic storage serving as the quick-access internal storage of the computer, the 1103 has 16,384 words of drum storage also regarded as internal storage since all drum addresses may be used in the instructions. The computer employs a two-address logic having many useful and powerful instructions. The speed of operation for electrostatic storage operands ranges from approximately 40 microseconds for a transfer operation from one cell to another, to approximately 250 microseconds for multiplication of 36-bit numbers.

The input-output organization of the computer is such that almost all the time of the input-output equipment cycle may be used for computation and two or more equipments may be used simultaneously. The system makes use of two input-output registers which serve as buffer storage to the equipments. The units connected to The Ramo-Wooldridge 1103 allow handling of paper tape or punched card information as follows: a card reproducer for card input-output, a line printer, a Ferranti paper tape reader, a 60 character per second paper tape punch, and an electric typewriter.

The main feature of the computation system consists of the storage of the entire utility routine library on the magnetic drum locations with allocations as

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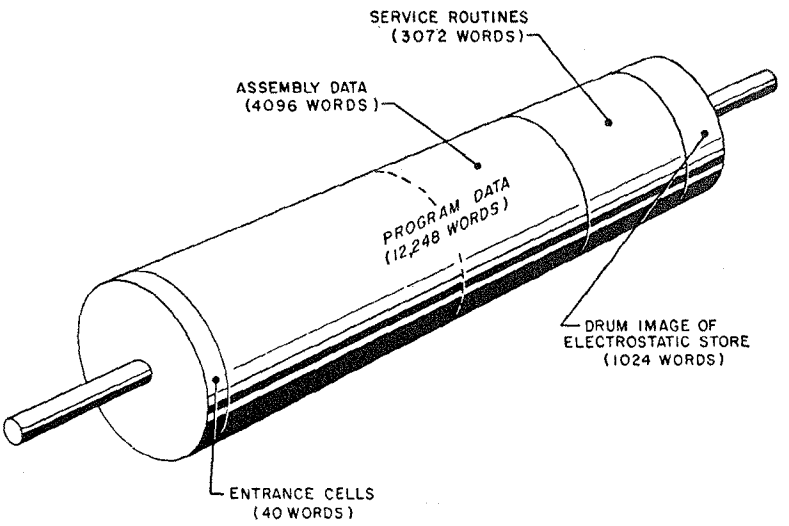

FIG. 1. Schematic of drum storage. (Total storage = 16,384 words)

shown in Figure 1. A total of 3072 words are reserved for the storage of service routines for program debugging and data transfer functions. In the higher address portion of the drum, 1024 words are reserved for the temporary storage of the contents of the electrostatic storage. That is, in the execution of the service routines and subroutines these words are available to store temporarily the contents of the electrostatic storage. The remaining 12,198 words are reserved for the normal storage of the production program with the exception of approximately 40 words in the low address portion of the drum. These 40 words are used to provide standard jump positions to the various service routines included and essentially serve as extra hardware to the computer as switches.

Although the assembly program and subroutines for program assembly are not normally stored on the drum during program running, 4096 words of drum storage are reserved for the storage of these routines during periods of program assembly.

As will be explained below, all data are also stored semi-permanently on magnetic tape for quick restoration of the library.

As stated above, about 40 words are reserved at the low address portion of the drum for storage of certain entrance words to the service routine library. The following is a partial list of entrance cells assigned and in use:

40000	Program start
40001	Ferranti read-in
40004	Memory dump (Flexowriter tape punch)
40006	Internal storage to magnetic tape transfer
40007	Magnetic tape to internal storage transfer
40008	Assembly program
40010	SNAP (Floating point interpretive)
40012	Automatic Sampler
40013	Memory Dump (Punched Cards)

The use of these entrance words is as follows: Supposing a memory dump is needed, control is transferred to cell 40004 and the computer started. Control then reverts to the memory dump routine stored on the magnetic drum and the program is executed.

The entrance cells were chosen as indicated for three reasons: first, they are easy to remember; second, the numbers in the 40000 group are easy to set up at the control console of the 1103; and third, they serve as symbolic entries to the extent that drum locations of the corresponding service routines can be changed without notifying the entire programming staff, since the entrance cell remains the same, only its contents changes.

The operation of a typical service routine will describe the need for the temporary storage at the high-address portions of the drum. Since almost all service routines involve the use of input-output equipment, they must operate from electrostatic storage in order to produce the required amount of computation on each cycle of the input-output equipment. (For example, 16.67 milliseconds of computation are available between successive punches of the high-speed paper tape punch). However, in general the electrostatic storage is loaded with program data on which the service routine is to operate. The typical service routine operation involves the following steps:

1. A check sum of the service routine is computed to determine the possible incorrect storage of the routine, and the check failure indicated when appropriate.
2. A part, perhaps all, of the electrostatic storage contents is transferred to the image of the electrostatic storage.
3. The service routine is transferred to electrostatic storage.
4. Control is transferred to the routine in electrostatic storage for execution of the routine.
5. The original contents of the electrostatic storage is restored by means of a transfer from the drum image.

It is seen that the typical service routine is a complete package and the programmer or operator need not concern himself with having to read the routine into the computer nor need he concern himself with the various transfers within the machine to restore the program data back into its original form. It should be noted that because all storage registers of the 1103 are addressable, no part of the service routine need be stored in the electrostatic storage; the routine can be completely stored on the "less expensive" drum storage.

By transferring control to 40008, control is transferred to the assembly program stored on the drum along with a complete set of subroutines. When this happens, certain data transfers occur and the assembly process begins. The input to the assembly program is punched cards; the output to the assembly program is also punched cards and punched paper tape. The assembly program uses symbolic addresses and accepts decimal information translating it to binary form. The assembly program performs the following operations:

1. Translate letter pair operations to octal.
2. Translate pseudo operations to octal.

3. Translate symbolic-decimal addresses to octal.
4. Assemble subroutines from the drum into the program.
5. Translate decimal numbers to octal.
6. Check for certain input data errors.
7. Compute addresses and check sums and include them on the output tape as it is punched.

The program is of the one-pass variety and the card and tape output occurs simultaneously with the input. The punched card output is used for side-by-side listing of translated and untranslated data on accounting machines and the paper tape output is used for later high-speed program read-in.

In order to have the assembly program assemble a subroutine stored on the drum into the program, the programmer need only specify an operation such as

SUB 49312 04410

The last two numbers specify certain data to the assembly program and are copied by the programmer from a subroutine specification sheet. It is emphasized that since all subroutines are stored on the drum, no special attention need be given the inclusion of the subroutine by the programmer or any clerk other than the specification given above.

One of the salient features of the system is that all utility routine library data are stored semi-permanently on magnetic tape. Thus, if any part of the data normally stored on the drum are inadvertently destroyed, or if the entire drum is used for program data storage, the service routine library, the assembly program data (assembly program and subroutines), or both can be quickly restored by a transfer from magnetic tape. In this transfer check sums are formed and compared with previously computed sums stored on the tape. Correct transfers and final storage on the drum are thereby insured.

In almost all cases sum checks are made of stored data before service routine execution operation to ascertain whether the data are correctly stored. Also, sum checks are computed by the assembly program and stored on the output tape which serves as later input for the problem. The input routine for the Ferranti reader computes independently a sum check as the data are being read-in and compares it with the check sum previously placed on the tape by the assembly program.

In summary, there are three modes of operation or three types of operation which the machine operator performs when approaching the machine, depending on the amount of data stored on the drum and magnetic tape:

1. Under normal operation the subroutine and service routines are stored on the magnetic drum. To use the routines, the operator transfers control according to the appropriate entrance cell as listed above.

2. In case the data normally stored on the drum have been removed due to running a large program or use of the drum storage by maintenance engineers, the assembly program data and the service routines are replenished by a transfer of the data from magnetic tape to magnetic drum. This is performed conveniently

on the 1103 by simply performing a "magnetic tape start." The operator has the option of obtaining the utility routine library (with assembly program) or simply the service routine library.

3. In case the machine is absolutely devoid of correct program data either on the magnetic drum or magnetic tape, the data are read into the computer by means of a bootstrap technique from punched cards or punched tape.

The ideas contained herein represent participation by all programmers of the Digital Computing Center of The Ramo-Wooldridge Corporation. Special mention is made of the contributions of Jules Mersel, now of Remington Rand, Robert A. Beach, Donald W. Gantner, Wesley C. Dixon, and Thomas H. Tack.