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SUBJECT: UTILIZATION OF MAGNETIC DRUM AND HIGH-SPEED RANDOM-ACCESS STORAGE

To: WWII Planning Group

From: R.L. Walquist

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Abstract: Several techniques are discussed whereby a computer utilizing a large magnetic drum memory and a small high-speed random-access memory can have an effective operating speed approaching that of a similar computer for which all memory is of the high-speed random-access type.

During the last week discussions were held with D. Hogan (who has worked on the ERA 1101 Computer) with regard to their methods of programming. Certain points were discussed which related to their methods of forced programming the 1101 in order to decrease the solution time of problems. Although forced programming has been tried by others with varying amounts of success, two features of the 1101 computer are worthy of mention. These are interlaced storage positions on the drum and a means for allowing the programmer to skip or index the program counter of the machine. Each of these is discussed briefly below.

The 1101 computer uses a standard ERA drum, with adjacent storage positions around the periphery of the drum being available at 8 microsecond intervals. However, the "fast" order time is around 64 microseconds for operations similar to our ca, su, ts, etc. Thus, if successive orders were taken from adjacent storage positions on the drum, a drum revolution would have to occur for each order. In order to circumvent this difficulty, the addresses of the storage positions are interlaced, such that address location 150 occurs 8 drum storage positions away from address position 151. This interlace allows successively numbered storage positions to occur at the correct rate for carrying out all "fast" operations. This scheme works fine until one of the "slow" orders (similar to our mr, dv, sl, etc.) occurs. Since these orders require a much longer time for execution than the basic 64 microseconds, some additional means must be provided if a complete drum revolution is not to occur each time one of these "slow" orders is used. The method adopted in the 1101 computer has been entitled, "Skip-Program-Counter."

The mechanism for carrying out the skip-program-counter operation is as follows: The 1101 computer has available a 24-digit register length, 6 of these digits being used to specify the order and 14 to specify a drum storage location. This leaves 4 binary digits of an operation which ordinarily would have no useful function. The 1101 computer makes use of these digits by adding to the program counter a number of times corresponding to the number in these 4 digit positions. Thus, if a multiply order should occur at storage address 100, the number 2 in these digit positions would be used to index (skip) the program counter to address number 103. The next order would be taken out of storage position 103, positions 101 and 102 being by-passed. This procedure allows for a multiplication time equal to 3 times the "fast" order time. Similar procedures are used for all of the other operations which require more than the minimum time of 64 microseconds. Thus, any order requiring more than 64 microseconds can be carried out in a time interval equal to some multiple of this basic 64 microseconds, without requiring a full drum revolution.

It might be noted that it is possible to simplify this skip-program-counter technique if all the "slow" orders take approximately the same time for execution. A single digit, instead of the 4 used in the 1101 computer, could thus suffice to skip the program counter the necessary number of times. It is also possible to eliminate any extra digit altogether; here the order itself would carry out the skipping automatically. However, such a scheme might prove highly detrimental to the person trying to program the computer.

The two features mentioned so far cannot by themselves solve all the problems associated with minimum solution time for problems. Additional difficulties arise whenever the same piece of information must be used by several different orders around the circumference of the drum. If such a piece of information is stored on the drum at a single storage location, it is usually impossible to have it available to all of the various orders without allowing a complete drum revolution for locating the piece of information. A second difficulty arises when the addresses of the orders stored on the drum must be changed to deal with a new piece of information at a different storage location. Both of these difficulties are recognized by the people programming the 1101 computer; they are considering the addition of a small amount of high-speed random-access storage to help alleviate this problem. The random-access storage would be used to hold the pieces of information (problem data) called for by the various orders on the magnetic drum; it also would be used for those parts of the computer program which are used quite often and require that their addresses be changed each time they are used.

It is possible to overcome this problem of indexing the addresses of the program by the B-box technique which has been discussed at WWII meetings in the past. If the B-box technique was applied, then only the pieces of information being operated on by the computer program need be in the high-speed random-access storage. The B-box would take care of the indexing of the required addresses of the orders on the drum. Under these conditions, it should be possible not to have to remove any orders from the drum for the purpose of changing the addresses of these orders. Also it should not be necessary to wait while the drum searches for

information, since this information would always be available in the high-speed random-access storage.

The techniques which have been mentioned for increasing the effective speed of a drum computer are applicable because computer programs, for the most part, do not require completely random access to storage. The whole idea of automatically "adding one" to the program counter is based on the fact that programs usually have their successive orders stored in successive storage positions. Only when one runs into a cp or sp order does this sequence break down. If a program contains a great many cp and sp operations, the sequence will break down quite often; the question thus arises as to how this problem might be overcome when using a magnetic drum storage. Within the limits set by the drum storage system, it is possible to have the address section of a cp or sp order refer to a parallel block (a different block from the one in which the order occurs) of registers along the axis of the drum. Thus an sp order at angular position 100 in the first block of registers could refer to angular position 101 in the second block of registers without requiring any more than a "short" order time for the sp operation to take place. In other words, within limits, even cp and sp orders could be handled without requiring excessive time for their execution.

The above features of the 1101 computer (plus the benefits arising from the use of a B-box in a computer with magnetic drum storage) are felt to be important enough to be considered by the WWII group in their planning of the new computer. It appears that it will not be possible to provide for all of the necessary storage in WWII as high-speed random-access storage and that the deficit will be made up of magnetic drum storage. If such is the case, then the above techniques might well be incorporated in WWII. The advantages offered by such an arrangement are many:

1. A magnetic drum memory (which has proven to be one of the most reliable forms of computer storage) would comprise the major amount of storage in the machine; the high-speed random-access memory could be held to some convenient minimum;

2. Either part of the memory could function as a separate entity in case the other part failed (similar to test storage and electrostatic storage in WWI);

3. With the drum integrated as internal computer storage, programs stored on the drum could be executed directly without having first to transfer the program to the high-speed random-access storage (as will be required in the use of the auxiliary storage drum with WWI);