1762

30

~~CONFIDENTIAL~~

UNCLASSIFIED

6889
Memorandum M-1461

Page 1 of 6

Digital Computer Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: WHIRLWIND II MEETING OF APRIL 11, 1952

CLASSIFICATION CHANGED TO:
Auth: DD254
By: R.R. Everett
Date: 2-1-60

To: Whirlwind II Planning Group

From: N. H. Taylor and R. P. Mayer

Date: April 21, 1952

Members Present:

I. Aronson
W. Attridge
G. Briggs
D. Brown
N. Daggett
D. Eckl
R. Everett
H. Fahnestock
J. Forrester
H. Grosch
W. Hosier
J. Jacobs
R. Jeffrey
W. Linvill
R. Mayer
J. McCusker
A. Moritz
J. O'Brien
W. Ogden
R. Pacl
W. Papian
R. Pfaff
C. Schultz
R. Sims
N. Taylor
R. Walquist
R. Wieser
J. Woolf

The next few meetings will be an attempt to summarize the activities of other groups that are working on WWII. Everyone is urged to come at nine o'clock sharp, as the meetings will begin at that time.

There have been several block diagram meetings during the past week, which W. Hosier is writing up. If anyone who is not already on the list would like to receive copies of these write-ups, please see B. Sanderson.

In ten or twelve weeks - that is, by the first of July - we should like to make an evaluation of what we are trying to do from logical and engineering points of view. Questions which need to be answered are:

Is WWI too complicated?
Does it have too many registers?
Does it have to make too many decisions?
What kind of arithmetic element (AE) should we have? - how complicated should it be? - what will its speed be?

UNCLASSIFIED

Security Information
~~CONFIDENTIAL~~

Is the destructive read-out going to be satisfactory? - just what read-out times are involved and are these going to be adequate?
Will the transistor become developed fast enough for us to use it?

R. Walquist was on hand to give his opinion on a large number of subjects, as follows:

He first brought up the question of the number of digits required to handle a single piece of information. If the area to be covered is 500 miles square and 1/2-mile boxes are used, then 10 bits will be required for each "x" value and for each "y" value. If 5 or 6 bits are included for proper smoothing and to avoid round-off error, then the total number of bits required for each piece of information is 15 or 16 bits. If the desired accuracy increases, it will be necessary to use more bits.

If a 2-kc slowed-down video is used, this will allow range up to 32 miles quantized in 1/2-mile units and azimuth quantized in 256 units. If it is desirable to have ranges quantized in 1/10-mile units, then the azimuth should have 512 quantized units. But this would require a transmission channel with 20-kc bandwidth, if the slowed-down video system is used.

He next discussed the number of instructions required and the time available for performing these instructions.

The entire job that has to be done by the computer can be broken into three general sections:

1) Conversion of "r, θ" signals to "x, y" and correlation with known targets.
2) Smoothing and tracking of targets, and control of interceptors.
3) Identification, ground observer data, flight plans, weather information, etc.

With all this to do in only 15 seconds radar scan time, it would be nice if the correlation and conversion (including any necessary drum transfers) would take only 5 seconds.

In the Cape Cod system, we assume that this 5 seconds will be broken up as follows: For conversion, 0.6 seconds. For correlation, 2.7 seconds. For drum transfers, 0.4 seconds. For bookkeeping and other "red tape", 1.3 seconds. These figures assume 100 targets, 5 returns from each target, 50 microseconds per instruction, and instructions as outlined below.

Assuming that only 25 instructions are needed to convert "r,Θ " to "x, y", then the total time for converting 500 signals at 25 instructions per conversion and 50 microseconds per instruction is about 0.6 seconds.

In order to correlate, it is necessary to find the magnitude of the difference in "x" between the incoming signal and the stored target and to compare this with an allowable error. The same must be done for "y" values. Then the decision can be made as to whether the incoming signal is correlated with the stored target. It should be pointed out that the allowable error may be different for different targets, depending on whether they have just entered the system or have been tracked for some time, and whethey they are moving slowly or not. In order to perform this correlation for one incoming signal and one stored target, it is necessary to use 4 instructions for each coordinate: 2 instructions (with a *dm*) for comparing the signal and target, one for subtracting the deviation, and one for *cp*. Since there are 2 coordinates ("x", "y"), this requires 8 instructions for checking one signal with one target. If a B-box is used for specifying which target should be checked against, then one more instruction must be added to change to a new target. Thus 9 instructions per target are needed to check one incoming signal against all stored targets.

In the Cape Cod system, using WWI, neither the *dm* operation nor the B-box will be available. It is expected that 18 instructions per target, instead of 9, will be required. The time for 3,000 correlations, each with 18 (50 microsecond) instructions, is 2.7 seconds.

The more advanced system should be able to handle 1,000 targets instead of 100. Still assuming 5 returns per target, there will be 5,000 returns instead of 500. It should be noticed that 5,000,000 correlations must be performed if each of the 1,000 targets must be correlated with each of the 5,000 returned signals. At 10 microseconds per instruction and 9 instructions per correlation, this would take 7.5 *minutes* for correlation alone. It is assumed, however, that some rough correlation can be done by breaking down the targets into physically distinct sections, as discussed below. For instance, if a 500-square-mile area is broken into 256 boxes, each box will contain about 4 targets (with the 1,000 targets evenly distributed). Assuming 6 targets per box, and that each of the 5,000 signals must be correlated with only the 6 targets found in the appropriate box, then only 30,000 correlations are needed. Thus each instruction of the correlation program must be performed 30,000 times, so if each instruction takes 10 microseconds, this means 0.3 seconds are required for each instruction of the correlation program. If there are 9 instructions, then the total time for the complete correlation process is 2.7 seconds. (Altitude information is not being covered in this discussion because it requires a somewhat different analysis).

He finally suggested some ways to save time. The design of the AE is closely related to the type of storage being used. If there are 1,000 targets, at least 10,000 registers are required to store them. It would be nice if the capacity of random access storage could be sufficient to handle all the targets as well as the program. It may be necessary, however, to use a drum as well as the random access storage.

There are various ways of using the drum. For instance, the drum can be used for storing targets or for storing the program or for storing both. If it is used for storing targets that have already been converted and correlated, then every time new information comes in, the old information must be taken from the drum to internal storage, operated on, and then the newly-correlated information must be sent back to the drum, requiring two references to the drum. On the other hand, if the program is stored in the drum, whenever the program is to be run it must be put into internal memory from the drum but does not have to be put back again, so that only one reference to the drum is required.

From this analysis, it can be seen that we should put as much target information as possible in internal storage. It would seem that a minimum of 10,000 internal registers is needed for storing all the data, and if we can have 16,000 registers, perhaps the program could be put in internal storage also.

On the other hand, perhaps we can take advantage of some of the characteristics of the drum and help to process data that is stored there. For instance, the drum must scan all information in each revolution, and addresses can be found by comparison with an address section of the drum. Some preliminary correlation of data can be done using these characteristics. Assuming that the geographic area to be covered is broken up into a large number of boxes and assuming that each box can be identified by the most significant few binary digits of the "x,y" position, then we can take all the correlated-target information from the drum which applies to any box by asking the drum to supply information, not by specifying an address in the usual sense, but by specifying the box number. This process can be done by a block transfer, and if it is assumed that the internal storage is fast enough, then one drum revolution will be sufficient to put into internal memory all the correlated targets which are in the specified box. If there are only 6 correlated targets in a box, then only 30,000 correlations are required, as discussed earlier. The newly-correlated targets can be put back in the drum, in the same order, and in the same places, if the drum has a special marker channel. Thus the computer does not need to remember where the information was taken from the drum. This system must be made to work when a target crosses from one box to another.

Since the drum transfer takes a large part of the calculating time, maybe we should use two banks of internal storage, so that while one is being used for a drum transfer, the other can be computing. Thus two correlation programs are needed, one in each bank, or, if three banks are used, a single correlation program can be stored in the third bank.

It should be remembered that if a double-length AE is used, it will be inefficient unless the second half of the AE is used quite often. It will be used only 18% of the time if it is used only for simultaneous correlation of "x,y" data.

As R. Walquist wandered off to class, H. Grosch asked permission to dream out loud in front of the group. His dreams took the following form:

If it is assumed that 16,000 registers in storage are required, then this will require a 14-bit address. If there are several drums, then it may be necessary to have as many as 18 bits in the address. It has been proposed that 64 operations be built in. Maybe we should have more than that in order to handle some of the special problems that might come up, but let us assume that 6 bits are required to specify all operations. It might be desirable to use a static shift-in-no-time shifting network, which requires 6 bits to specify the number of shifts. Thus 30 bits are required for specifying each instruction. It is interesting to notice that 5 extra digits of an address allows us to add as many as 31 drums to the storage system. Probably no more than 3 extra drums will be required, and this requires an addition of only 2 bits to the address. If the drum is to be replaced by a magnetic core matrix storage, it should be remembered that the cost of such storage increases more rapidly as the size of the matrix increases linearly.

Let us assume that a total of 32 bits are required, in order to take care of additional storage, or drums, which we might decide to add later. Thus the AE should have 32 digits. Then two half-length operations can be carried on simultaneously, such as simultaneous "x,y" correlation with a split accumulator, and also the double-length accumulator can be used for the two numbers involved in multiply operations. (The "z" data, which arrives asynchronously, would probably have to use the half-length accumulator).

As H. Grosch finished his dream, it was pointed out that it might be better to separate "x" and "y" data into different registers, using the additional digit length of the registers for holding identification digits. Another suggestion is to put "x,y" in one register, and "z" data, with identification, in another register.

It was suggested that perhaps there should be two small computers, one for handling information on the drum, and another for handling the logic and arithmetic required in the over-all problem. Although it is necessary to keep the system flexible (since the program is not worked out yet), we can nevertheless rely on the fact that a great deal of the terminal equipment is already rather well-advanced and will probably not change much in the near future.

The remainder of the meeting was spent in discussing a one-register computer designed by J. Forrester and R. Mayer. This register is described in more detail in Engineering Note E-459. Briefly, the "one register" refers to the fact that there is only one "vacuum-tube" register for doing the arithmetic and for switching the control and storage selection matrices. Additional registers are used, but they are built exactly like the rest of the memory and use the same input and output circuits; they are <u>not</u>, however, selected by the storage selection matrix but rather by pulses directly from central control. The storage selection matrix is designed so that a single reading of information from the flip-flops to the matrix selects the storage register which will be read out of and read into, so that the selection flip-flops can be used for receiving the number out of storage without destroying the address into which it must be rewritten.

A traffic diagram was discussed showing how this computer would do program timing and a transfer-to-storage (<u>ts</u>) operation. Assuming a time of 2 microseconds for each reference to storage, the combined program time and <u>ts</u> time would require 13 microseconds. (A half-microsecond readout from the special storage registers is assumed because it is not necessary to use the I/2 method of reading-out of these registers). It was mentioned that a number of other operations have also been worked out, but they were not discussed.

Rollin P. Mayer
Rollin P. Mayer

Norman H. Taylor

RPM/NHT/bs