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Digital Computer Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: WHIRLWIND II MEETING OF APRIL 4, 1952

To: Whirlwind II Planning Group

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

Date: April 9, 1952

Members Present:

G. Briggs	J. Forrester	R. Mayer	I. Reed
D. Brown	H. Grosch	A. Moritz	H. Rising
D. Eckl	W. Hosier	J. O'Brien	R. Sims
R. Everett	R. Jeffrey	W. Ogden	N. Taylor
H. Fahnestock	N. Jones	R. Paul	R. Walquist
	W. Linvill	W. Papian	

The meeting today started out with an attempt to analyze the requirements for memory. A memory size of 64 x 64 registers was proposed, and memory sizes of 128 x 128 and 16 x 16 x 16 were also suggested. There was some discussion as to whether two-dimensional or three-dimensional storage of each individual digit column should be used, but the decision on this should eventually come from someone in W. Papian's group. R. Everett suggested that 4,000 registers should be used in internal storage and that additional storage would be required for input and output data. H. Grosch suggested that drums should not be used for this.

The next question we discussed was the word length of individual registers in storage. A number of proposals were made for putting "x" data, "y" data, radar set number, altitude ("z") data, etc., in one register. R. Walquist suggested that these pieces of information should be included in the same register only for the input-output processes, where speed of information handling could be speeded-up by the parallel insertion of information, and that there was probably no need for storing different pieces of information in the same register (for computing) unless there were an easy way of extracting this information. H. Grosch suggested that this could be done by special extraction orders or by using a method of specifying access to a single register or a double-length register on any single instruction. J. Forrester pointed out that the altitude information would probably not arrive at the same time as the other information and that it would probably not be an advantage to include "z" with "x" and "y". He also suggested that computation inside the machine could be made more efficient in certain cases, such as simultaneous correlation of "x" and "y" data, if the "x" and "y" information were stored in a single register. N. Taylor suggested that this could be done by extending the length of the accumulator, such as by making the B-register of WWI capable of addition, etc. H. Grosch suggested that the terminal equipment should handle triple word lengths, memory should handle single word lengths, and the arithmetic element should handle double word lengths. N. Taylor felt that the biggest point of this discussion was that it should be possible to correlate "x" and "y" information at the same time.

It was next pointed out that the radar information is in polar form ("r, θ") and must be converted to find "x,y". There was some discussion as to whether "x" and "y" could be converted accurately enough without knowing "z". I. Reed suggested that the altitude could be found by calculations involving dr and dθ (assuming a straight-line course) and that, in general, some average height could be assumed for preliminary calculations. N. Taylor suggested that the enemy probably would not fly in at an average altitude and so this would probably be the worse assumption. H. Grosch suggested that he would be coming in from overhead, but it was pointed out that the radar scan frequency would then not be fast enough to see him more than once, and that our system is not designed to handle that type of attack. It was pointed out that full coverage from a 0 to 15 mile altitude could be obtained between, and over, radars if they are 30 miles apart and have a 45° (vertical) beam pattern. J. Forrester suggested that some height-finder data will be available to the computer soon after any aircraft enters the area and that this information can be used to modify any "x,y" information which has been calculated with an assumed altitude.

The biggest calculation job here seems to be that of correlating radar data with airplanes that are known to be in the vicinity. This presents no problem if the planes are widely spaced, but if they are closely packed, it is necessary to know which radar return corresponds to which altitude. This requires accurate "r, θ" to "x, y, z" conversion. J. Forrester pointed out that we should be careful not to put too many vacuum tubes (or other components) in the arithmetic element simply to handle this conversion problem. N. Taylor suggested that the correlation might be carried on in the magnetic drum. I. Reed suggested that it should at least be carried out at high speed because routine tasks should be carried out at the highest speed possible. At some later date we should discuss the problem of whether the external equipment should include an independent computer.

There was considerable discussion about the number of digits required to handle each piece of information. It was assumed that radar information would be available over a 500-mile range in 1/10-mile steps, resulting in 5,000 quantized units which could be handled by about 12 with no soldered connections. D. Brown pointed out that one goal that is now being worked toward is to reduce storage access time without reducing reliability of the equipment. J. Forrester pointed out that our thinking about cores, and especially transistors, should not blind us to the fact that these components have no <u>proven</u> over-all advantage over vacuum tubes.

J. Forrester pointed out that WWI does its job in the hard way. We should be able to find drastic ways of reducing the amount and complexity of equipment for doing any specific function. For instance, we might be able to take out a vacuum tube with its associated components and soldered connections and replace it with a solderless coil or a core, perhaps building the arithmetic element by using tricky transformer techniques. At any rate, we will soon have to stop the general development of various components and start specific development of those components which seem most promising.

Second, let us consider the thoughts expressed concerning logical design versus reliability and speed. N. Taylor pointed out that the computer must be designed to perform a certain number of functions and that we cannot increase computer speed by cutting down on the number of functions it can perform. J. Forrester suggested that we should be able to start with the single-register design and consider designs involving one register, then two, etc., until a point is reached where there is no appreciable increase in efficiency with increase in the number of registers. In general, J. Forrester feels that we should do better than to double the computer speed by doubling the complexity of the equipment. N. Taylor suggested that a number of registers in WWI can be combined, for instance, the program register could probably be combined with the A-register. He also suggested that in some cases it may be more efficient to include another register, for instance, there may be two A-registers, one for reading-out the number and the other for reading-out the complement of the number (assuming that cores which cannot be complemented are used). I. Reed wondered if storage registers could be used for shifting or adding, etc. N. Taylor said there is no promising core adder yet. H. Grosch suggested that several special orders could be used, each one taking a specified number out of storage, shifting it a fixed number of places and returning it to storage. J. Forrester suggested that since the word length is going to be so long, perhaps we can use some digits of an instruction for special purposes, such as specifying the number of shifts.

J. Forrester suggested that we should make the best possible use of everything in the machine by applying the technique of using the same equipment over and over again, on the theory that a component deteriorates with time rather than with the number of uses.

Next, let us consider the thoughts expressed concerning whether it is necessary to use several computers in parallel in order to gain the necessary degree of reliability. H. Grosch suggested that the only way to obtain the desired degree of reliability, which is near 100%, is by the use of multiple computers. He suggested that experience with WWI indicates that we probably cannot build a WWII reliable enough to make a set of three computers sufficiently dependable, and that a total of six computers would be required, as follows: Three of them would be working on the problem, one would be undergoing repair, and the other two would be reading in the proper instructions and data so that they could swing into action when necessary. He pointed out that it is necessary to consider this problem of multiple computers because the use of computers singly or in multiple will affect the internal design of a single computer, although a choice between many or few should make no difference. N. Taylor felt that we should probably count on using three computers anyway, and that it was therefore not worthwhile considering at this time just how many we would require. J. Forrester pointed out that we cannot make any decision at this time as to just how many computers are needed, so that the only thing to do is to build the best single computer we can possibly build and then see how many we need for the desired over-all reliability.

J. Forrester pointed out that we are not now concerned with the problem of designing the whole system, but only with the problem of designing a single, very reliable, electronic computer. He mentioned that electronics people seem to have a feeling of defeatism concerning reliability and that the way to gain reliability is simply to convince ourselves that it can be done - ("Digital Computers: Present and Future Trends", by J. W. Forrester, Review of Electronic Digital Computers, Joint AIEE-IRE Computer Conference, February, 1952). He feels that the goal should be to provide a computer with 99% reliability, or a minimum of at least 25 times better than WWI reliability, which might be split up as follows: it should break down 1/5 as often and require 1/5 the maintenance time at each break-down.

And finally, let us consider the thoughts expressed by J. Forrester concerning the goal toward which we should be striving at this time. Our goal should be to design the most efficient possible computer which is at the same time fast enough for the job. In order to be efficient and reliable, it should be extremely simple. A factor of 10 can probably be cut from the complexity of WWI's logical design, measured in terms of the number of components (vacuum tubes). Perhaps we can build a 200-tube computer which will be reliable enough to run for one year without service.

J. Forrester pointed out that R. Wieser's group is concerned with the kinds of problems the computer will be called upon to solve and with the kinds of instructions the computer should be able to follow. N. Taylor's group should be concerned with the kinds of components which should be used in the computer, and how these should be interconnected. A gap exists between the recommendations of these two groups, and an attempt should be made to close