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Memorandum M-1504

Digital Computer Laboratory
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SUBJECT: WWII BLOCK DIAGRAMS GROUP MEETINGS OF MAY 13 & 15, 1952

To: WWII Planning Group

From: W. A. Hosier

Date: May 27, 1952

Abstract: This note summarizes the discussion at the above meetings for the benefit of those who may wish to trace the course of thought on the subject.

Present: May 13:
G. R. Briggs
D. R. Brown
H.R.J. Grosch
W. A. Hosier
R. C. Jeffrey
R. P. Mayer
I. S. Reed
E. S. Rich
N. H. Taylor
R. von Buelow
R. L. Walquist

May 15:
G. R. Briggs
R. C. Jeffrey
W. A. Hosier
R. P. Mayer
B. E. Morriss
I. S. Reed
E. S. Rich
N. H. Taylor
R. von Buelow
R. L. Walquist

As mentioned in accounts of previous meetings, there has been an increasing feeling among the group that the most fruitful source of concrete problems in the design of WWII is likely to be the accommodations it has to make to terminal equipment. Accordingly, beginning with this meeting, R. Walquist and E. Rich undertook to explain some details of the Cape Cod system, as it is proposed to work with WWI. By adequate planning and cognizance of the terminal equipment problem from the start, it is the hope of Taylor and Rich and those who have worked with this problem on WWI that appreciable economy of time and equipment can be realized over what would be needed if we wait until WWII is all designed and then ask how information is to get into and out of it.

R. Walquist spoke first to outline the "boundary conditions" of the problem: what is fed into WWI and what it must feed out, together with some notion of the necessary processing. For a detailed presentation of this, one should refer to Walquist's discussion of June 22, 1951 (E-2023).

The principal difference between the situation then and now is perhaps that the frequency-multiplexing scheme for transmitting radar data has been supplanted by slowed-down video. Beyond what is there presented, certain points were brought out as follows:

Quantized coded returns arriving at most every 500 µs from each of 15 radars cannot be stored on the buffer drum as soon as they are received; due to interleaving of radars in each drum field, the coded return must be held until an appropriate spot on the drum appears.
Further, since the coded return cannot be held indefinitely awaiting unoccupied space on the drum, but must be replaced by the next return from that radar, the probability of its being stored at all is a function of the number of returns already on the drum. Other arrangements such as the use of more than one drum field for a given radar might raise this probability, but would render block transfer from drum to computer more difficult and might require indexing of returns according to radar. As it is, there is a great excess of allocated buffer drum storage capacity (128,000 bits) over the anticipated peak of radar returns (5000 16-bit words = 8,000 bits) - a factor of 16, which might not be necessary with a different type of buffer storage. For example, Mr. Reed suggested that magnetic stepping registers might do - radar returns being fed in singly at one end and removed in a block from the other end.

R. Mayer asked whether it were possible to synchronize and stagger the main bangs of the 15 radars to simplify the problem of storing data. For example, this might permit storing on the drum in sequence, or common use of one range coder. Presumably this would mean holding the main bang of one radar to ±15 µs so that all 15 could be recorded in the 500 µs available. Aside from the obvious physical difficulty of making sure the far-flung system was properly synchronized, varying delays in the telephone lines and other links of the communication network would render such a project most difficult.

As for the problem of synchronizing the drum with output equipment, Walquist pointed out that the slower mechanical equipment like typewriters and punches can accept data once a drum revolution (16 milliseconds) without slowing down at all.

It may be desirable to decentralize computer control, at least to the extent of having an in-out control that can do certain things independently of central control.

Correlation, as explained in E-2023, is done according to radar set, to reduce the total number of necessary correlations at the expense of a somewhat more complicated program. x,y-coordinates are used for this rather than r,θ, principally because smoothing is simpler with x,y data.

It seems to be generally agreed that correlation is better done at the central computer than by some auxiliary device at each radar, since the number of such auxiliary devices would be 70 to 100 times the number of computers, and they would add to the difficulty of maintaining the radar stations.

For the present, we must apparently take the system of slowed-down video over telephone lines as a starting premise; in fact, the Cape Cod system is intentionally built on compromises that could be got working in a year. In, say, 5 years, this picture may change: CW radar, for example, might well generate its own binary-coded returns. All proposals so far advanced for transferring information from telephone lines to the computer have been something in the nature of bottlenecks; it would seem that we ought to be able to devise a more "natural" scheme for doing this.

Following Walquist, E. Rich gave an exposition of the magnetic drum system planned for use with WWI in the Cape Cod network, essentially along the lines of his report (M-1358) of December 27, 1951. The most annoying aspect of the present in-out system on WWI, he emphasized, is the difficulty in trying to use 2 pieces of terminal equipment - e.g., printer and scope display - simultaneously, since all relevant orders have to go through the same in-out control. The buffer drum would emancipate the typewriter somewhat from this tyranny.

The block transfer order has to have two means of "exit", due to uncertainty of block length. With eight radars interleaved in each of two drum channels, 256 lines is a maximum block length. It might be desirable in transferring blocks to be ready in all cases to transfer 256 words if that many were present; however, 256 ES registers would have to be allocated to receive the data, and this is not always desirable if fewer will do. Therefore, block transfers may be made, say 50 words at a time; when this is done, one must know whether (a) more words remain to be removed in another transfer or (b) all words in the "stack" have in fact been transferred. Thus the two types of "exit".

One modification introduced in the Cape Cod system since E-2023 was written last June has been to record the azimuth readings of all radars simultaneously each time the computer switches drum fields (about 15 seconds). This relates the azimuth of subsequent returns to a fixed time, and facilitates predicting, particularly when the same target is observed by more than one radar.

A possible criticism of the proposed system, Rich observed, is that it cannot very well accommodate data from radars with ranges over 32 miles (though it might be able to handle the first 32 miles if this were put in a form sufficiently resembling slowed-down video). But since 32 miles is all that was originally specified and should in general suffice, this criticism is not serious.

It would be desirable, though so far no concrete proposals for doing it have appeared, to have the computer able to "concentrate" on areas of high target density.

In addition to the two reports (E-2023 and M-1358) previously mentioned, the following were suggested as useful in understanding the In-Out System:

E-450	E. S. Rich:	WWI Terminal Equipment
E-456	P. W. Stephan:	Block Diagram of Control for Printers and Paper Tape Units
M-1235	B. E. Morriss Jr.:	Operation of In-Out Control
M-1383	E. S. Rich:	Block Diagram of the Buffer Drum System

R. Mayer opened the Thursday meeting by asking R. Walquist if he could state any obvious improvements which might have been made in the Cape Cod system, time permitting. One such, replied Walquist, would be to consolidate the 14 separate coding counters, one on each radar telephone line, now used to convert slowed-down video to binary. Since 500 µs are available between SDV pulses, one counter could easily be time-shared by the 14 lines (or 100 lines, for that matter) and used to add one to each of 14 stored readings every 500 µs. This arrangement would of course lack the safety factor inherent in 14 separate counters. I. S. Reed made the suggestion that small gas tubes could be economically used to build individual counters as long as these were not required to operate with a cycle of less than, say, 20 µs.

An underlying complication of the whole air defense problem, heretofore touched on only indirectly in these meetings, is the presence of stationary radar returns (ground clutter and, relatively speaking, rainstorms).

It has been conservatively estimated that 5% of the clutter would equal total aircraft returns on a typical radar. This means that unless 96% of the computer's correlation time is to be poured down the drain, the great bulk of clutter must be stopped before it reaches the computer. Masses of dense, nearby clutter, through which few or no targets could be seen, can probably be masked out with something as simple as an opaque silhouette on a PPI tube. Isolated pinpoints such as might be expected from distant chimneys or water towers, if not too numerous, can be recorded and rejected at the drum by a coincidence check (see E-2023, Section 2.3). Rainstorms, moving slowly as they do, are harder to deal with. Integrating devices have been proposed which would suppress signals repeated beyond a fixed limit; MTI, "moving target indication", uses a Doppler or phase-shift effect to discriminate between stationary objects and those moving radially relative to the radar. Theoretical 60 db MTI discrimination between stationary and moving objects has in practice been more like 20 db; however, a whole group of Project Lincoln personnel, including sections under Messrs. Van Voorhis and Harrington, are working on aspects of the clutter problem. It was suggested that Mr. Harrington might speak to us at some future session to bring us up to date in this.

R. Walquist described one scheme which he rather liked, although its mechanical nature apparently caused those concerned to take a dim view of it: a rotating mask covers the PPI tube completely except for a narrow radial sector, which follows 20° or so behind the radial sweep of the beam. This narrow sector is in turn covered by a counter-rotating spiral opening which scans it rangewise. Thus, using the integrating effect of the PPI phosphor, a discrimination may be made between fixed echoes and aircraft by the photocell scanning the tube face.

The amount of clutter getting through to be recorded and correlated is also a factor to be considered in recording returns on the drum. The proposed method of recording binary numbers which indicate range and azimuth is economical of drum space as long as the region under survey yields echoes over only a small fraction of its area - say, 1/20. With higher density, one does better to "map" the area right on the drum, recording the SDV pulse directly to indicate target location. Walquist has estimated that if 7% of the clutter got through, this "cross-over" point of density would have been reached. Needless to say, the prospect of mapping the 1,000,000 $\frac{1}{2}$-mile squares in a 500-mile-square (not to mention overlap) would demand something more than a 320,000-bit drum.

Our approach to the clutter problem will probably be more surefooted after the Cape Cod system has been put into operation and we have confronted it "in the flesh".

A note on magnetic drum technique was mentioned: B. Morriss's idea of using cross-connected reading and writing heads in two drum channels to make possible writing in a space that has just been read out of without waiting a whole drum revolution. A digit is read out of channel A; this digit could be processed by the computer and rewritten or supplanted in the same channel except that some 256 µs intervenes between reading and writing heads, and it is awkward to get a delay this long synchronized to $\frac{1}{4}$ µs of drum position. Hence the drum itself is made to provide the delay in a second channel: the original digit is read into channel B, picked up <u>k</u> µs later by a reading head in channel B, then processed and rewritten or supplanted in the writing head of channel A some k + 5 µs after the original reading.

The proposed WWI-Cape Cod system impresses N. Taylor and others as involving an excessive (though unavoidable under the circumstances) amount of unproductive data-manipulation. B. Morriss, for example, feels that the most efficient way to make block transfers is certainly not to have computer and drum push and pull one word at a time through the slot of the in-out register. E. Rich points out that in-out control, not the in-out register, is the present bottleneck. In general, Morriss thinks we are getting off on the wrong foot if we make the computer stop and wait for terminal equipment to complete operations. A divided memory, for example, sections of which were rotated among input, computer, and output, might provide an alternative.

SIGNED W. A. Hosier
W. A. Hosier

APPROVED
N. H. Taylor

WAH/cp