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SUBJECT: BI-WEEKLY REPORT, PROJECT 6673, NOVEMBER 10, 19[illegible]

1. ANALYSIS

(W. G. Welchman)

A meeting was held at which Wieser outlined his future program of study, Linvill gave an account of his work, and Nelson discussed points of similarity and differences between the problems of his project and those of 6673.

A 6673 group discussion was held to consider what we propose to do when we are able to use Whirlwind. The actual sequence of events will of course depend on the results of the early experiments with tracking programs and with the guidance of one aircraft. It may well be that we shall run into difficulties that will hold us up. The policy however is to proceed to a trial interception using a collision course, as soon as the operation of the tracking and guidance programs the computer and the radar indicate that an interception experiment could be attempted with reasonable confidence of success. When this state of affairs is reached no further work will be needed on the radar or the computer, and we must have interception programs ready in advance if we are not to delay progress.

Discussion indicated that the basic programs needed for the various stages are in good shape, though modifications will undoubtedly be suggested by the early experiments. More work is needed on interception programs, but it now appears that we can offer a choice of procedures from which the Valley Committee will be able to select those most suited to the purposes for which they want an early demonstration.

To anticipate the next bi-weekly period, a preliminary discussion with Rader and Harrington of the Air Force Cambridge Research Lab took place on Tuesday Nov. 14 to discuss arrangements for the demonstration. The outcome of this discussion was as follows:

(a) The two aircraft concerned will be flying at a prescribed altitude and will be directed to

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(W. G. Welchman) continued

prescribed points by visual reference for the start of each interception.

(b) The target will be a C45 with a speed between 130 and 160 mph. The interceptor will be an A26 with a speed between 260 and 300 mph.

(c) Operations will be confined to a sector of not more than 100 degrees, probably between azimuths of 200° and 300°.

(d) It will be possible either to use MTI with range limits of 20 to 60 miles or to dispense with MTI and use ranges between 30 and 80 miles. In either case it will be possible to suppress radar echoes outside the operational sector.

(e) It is felt that, for the demonstration, it would be unwise to tell the interceptor pilot either the bearing of the target or the time to interception (or distances to the target or to the collision point). He should only be given instructions for a collision course until he is within a few miles of the target, when he will be told that the operation is over.

(f) It is realized that in actual operations it would sometimes be necessary to reduce the lead angle a short time before the interceptor is expected to pick up the target in order to bring the target within the field of view of the interceptor's airborne radar. This refinement need not be introduced for the early demonstrations.

(J. M Salzer)

Some additional work was done on various subroutines with the help of H. Saxenian and C. Gaudette. A simple expression suggested by Mr. Welchman was optimized to about 5% accuracy and coded in 15 orders plus 5 registers. Preliminary work on finding a polynomial approximation for arcsin x in the range $-1 \leq x \leq 1$ indicates some difficulty at $|x|$ close to 1. It appears that a 5th-degree polynomial can give a maximum error of about

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(J. M. Salzer) continued

$\frac{1}{2}$ to 1 degree. If it is known that $|x| \leq 0.9$, a 3^{rd}-degree polynomial can do a clean job. A standard approximation to arcsin x using Legendre polynomials was suggested by Professor Franklin for investigation. Although these formulae give the least mean-square error with a polynomial of any degree, they give a very bad maximum error.

Worked on guidance and interception problem with Arnow. The simplest instruction to transmit to the plane was found to be the desired heading, rather than the desired change in heading. Although in computing the heading magnetic and wind corrections must be considered, for the change in heading the smoothed velocity of the target must be known rather accurately. With the present quantization the smoothed velocity is difficult to obtain without substantial delay. The same refers to the problem of wind correction in general, unless the components of wind velocity are given.

Following the suggestion and initial groundwork of Dr. W. K. Linvill, I have started work on a doctorate thesis. I am trying to develop techniques for dealing with control systems employing digital computers. Some preliminary steps were made in analysing various integrating and differentiating operators. If the tools tried turn out to be effective, they will enable one to synthesize, not only control programs, but numerical processes in general. As an example, starting with the single-integration trapezoidal rule and a double-integration formula developed by Madwed, I have synthesized in the frequency domain an improved single-integration formula which turned out to be Simpson's Rule.

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(D. R. Israel)

Two new versions of the main display program have been written: the first, which uses a polynomial for the determination of sine and cosine, requires an allotment of 43 storage registers; the second, which uses the polynomial to determine the sine and employs a square root subprogram for the cosine, requires 54 registers of which 16 are the square root subprogram. A complete explanation of these two main display programs has been prepared; this explanation includes a quantitative description of the feed in of radar data -- channel numbers, digit values, etc.

Radar Tracking Program II (tracking of one aircraft) has been revised in accordance with a) the new main display program, b) recent changes in the transmission of range data, and c) the new read-in and manual intervention programs written by Arnow. A similar revision of RTP IV (tracking two aircraft) will be made as soon as is possible, and both a flow diagram and description will be prepared. Present figures for RTP II and RTP IV are:

	Using joy-stick	Using light-gun	Free ES registers using light-gun
RTP II(one a/c)	152 registers	140 registers	116
RTP IV(two a/c)	186 "	176 "	80

In accordance with the above figures, it is seen that 80 registers are available in RTP IV for the computation of the collision course and display of instructions for the interceptor. The problem of the determination of the collision course was investigated in an effort to find a short (in orders) solution. Previous efforts concerned themselves with calculating "time to interception" and encountered serious scale factor problems; as an alternative approach the equation for determining the bearing to be flown by the interceptor was determined. The correct bearing (θ) satisfies the equation

$$X_o \sin\theta - Y_o \cos\theta = \frac{X_o V_{Ty} - Y_o V_{Tx}}{V_i} \qquad (1)$$

where X_o and Y_o are the initial separations of the target and the interceptor, V_{Ty} and V_{Tx} are the components of the target's velocity, and V_i is the speed of the interceptor. The quantities

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X_o, Y_o, V_{Ty} and V_{Tx} can be obtained from the tracking program itself, while V_i will be known. The problem, then, resolves itself into a determination of a θ which satisfies Equation 1. Actually there are two values of θ, one of which can be rejected because it corresponds to a negative time interception (an interception in the past).

Equation 1 can be solved in the above form by Newton's Method or by a trial and error process involving trying a number of values of θ until one is found which satisfies the equation. Both methods require only the determination of sines and cosines, and are short on orders but long on time requirements. Equation 1 is also related to solutions of the difference equation corresponding to the differential equation

$$\frac{d^2u}{d\theta^2} + u = 0$$

with initial values $u(0) = -Y_o$ and $\frac{du}{d\theta}(0) = X_o$. This fact arose in connection with Course 6.535, and offers promise as a method of solution.

Equation 1 can be written also as

$$\sqrt{X_o^2 + Y_o^2}\ \sin\left(\theta + \tan^{-1}\frac{-Y_o}{X_o}\right) = \frac{X_o V_{Ty} - Y_o V_{Tx}}{V_i}$$

and as such θ can be determined if a square root, an inverse tangent, and an inverse sine program are available. Further consideration is being given to possible methods of solution.

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(R. L. Walquist)

A reproducible flow diagram for RTP-III (tracking "n" targets, where "n" is greater than 2) has been completed, and copies of this are now available. The coded program for RTP-III has been temporarily completed using J. N. Salzer's sine-cosine program. It was decided that a finished form of this program should not be attempted until some experience has been gained in running RTP-I and II, since minor changes in all of these programs will almost certainly occur. An explanation of RTP-III is being written and will be completed shortly.

Some time has been spent in considering the various ways in which a collision course can be calculated, using a minimum number of storage registers. Since a calculation of this kind takes place, at most, only once a revolution of the radar antenna, time considerations are relatively unimportant. With the computer idling the majority of the time of a radar sweep, cyclic programs, which envolve few orders but several computer operations, might be used to considerable advantage.

(J. Arnow)

A guidance program to be used in conjunction with RTP II was written. This program allows for the guidance of one aircraft towards a fixed point, inserted into the computer by means of manual intervention. The heading instructions are displayed in a flip-flop register in binary-coded decimal form.

An interception program for the use of equal velocities of target and interceptor was written and is available. This program requires 67 ES registers, assuming that 5 temporary registers are available in RTP IV.

A memorandum describing the use of test storage in 6673 experiments will soon be issued, and will contain a list of constants available in TS and the location of the various flip-flop registers.

(H. Saxenian and C. Gaudette)

A program to display the error between the function

$$f(b,x) = \frac{\pi x\,(b + x)}{2(1 + 2bx + x^2)}$$

and the arctangent is being coded. At present the program will display the curve of this error, by comparing f(b, x) with a more accurate series expansion formula, against x with b manually

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(H. Saxenian and C. Gaudette) continued

variable. Also the program displays the maximum error in degrees and in decimal form for values of b.

In addition we have been investigating approximation formulae of the following functions for John Salzer:

$\sqrt{x}$, arcsine x, sin x, and cosine x.

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2. ENGINEERING

(C. R. Wieser)

During this period Israel, Walquist and Wieser visited Harrington, Wood, Bevans, and Rogers at Bedford during the evening to view previously recorded data on the Bedford digital PPI. During these observations of radar data on commercial and military traffic, notes were made on some targets. These notes included position, course, and a record of the hits and misses of the radar on successive scans.

Following this, the group visited the Barta Building and viewed the same data on our B-scan display. It was concluded that (1) our display has satisfactory fidelity, (2) the B-scan (range vs. azimuth in rectangular coordinates) is very difficult to interpret, especially since we include 360° of azimuth, and (3) that the radar return is consistent over a limited volume of space.

In order to get a better check on the radar characteristics, a flight test was scheduled and run on November 7. The aircraft used was a C-45 flying at 10,000 feet at 160 mph. The pilot was instructed to make all turns approximately one-half-needle-width (1.5 degrees/second). The course, which consisted of alternate straight legs and turns, included ranges of 20 to 60 miles. The first part of the run gave consistent radar returns, but the data soon became inconsistent, and finally the target was lost. This was attributed to trouble with the radar rather than the relay link, and repairs are being made. Another flight test will be made soon.

During the flight test, it was evident that a convenient means of recording comments during tests would be very valuable. Written records are difficult in the dark room, and synchronizing comments with the data is necessary for maximum utility. Buck will investigate means of adding a voice channel to the Magnecorder.

The group at AFCRL will build us the display scope part of a digital PPI for use at the Barta Building. In order to use this equipment, we will have to build the two decoders and synchronizer. We will get schematics of the decoders and synchronizer for study.

(D. A. Buck)

Anomalous operation of the vertical decoder during the last live data test was traced to a cathode-to-filament short

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(D. A. Buck) continued

in V1-2. Replacement of R 7-6 facilitated the linearity adjustment of the decoder allowing the double-zero notch to be removed. Further linearity adjustment of the vertical decoder showed the horizontal decoder to be in poor adjustment in at least the two most significant digits. This has been referred to the evening maintenance crew. These small non-linearities will be more noticeable in the proposed 16-inch system than in the present 5-inch system.

Consideration has been given to the possibility of recording a voice channel on the magnetic tape along with the quantized radar data so that comments from Bedford can be heard as the data is displayed. This would allow the tracking program group to discriminate between normal and abnormal operation of the radar equipment. At present it is felt that there is room at the high-frequency end of the tape to squeeze in a voice-modulated carrier.

(H. J. Kirshner)

A better packaged light-gun, employing either a 931A or a 1P21, has been constructed. A blocking oscillator, to be used for shaking light-gun output wave form so that it may key a pulse standardizer, has also been constructed. An amplifier stage, for use between the light-gun and blocking oscillator, is in the process of being tested. The complete light-gun equipment should be ready for use with the computer some time during the week of November 13, 1950.

(R. L. Best)

A rough draft for a thesis proposal on the subject "A Direct-Coupled Amplifier for Magnetically Deflecting on Oscillograph Tube" has been written, and will soon be issued as a M-note. It sums up the history of the display problem to date.

(R. E. Hunt)

A preliminary lay-out of the 16" display scope has been made and approved.

The unit will consist basically of two sub-assemblies. Number 1 includes the scope, horizontal and vertical deflection amplifiers, all controls and panel lights. The second subassembly consists of the power supply, regulator, sweep and blanking circuits.

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(R. E. Hunt) continued

These sub-assemblies fit a blonde-wood cabinet of modern design, but also each is built around a standard 26" panel, so the assemblies may be rack mounted if desired.

Camera and hood adaptors will be provided as well as provision for an illuminated grid. All controls will be illuminated red lucite for operation in the dark.

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