6673
Memorandum M-2089

Electronic Computer Division
Servomechanisms Laboratory
Massachusetts Institute of Technology
Cambridge, Massachusetts

SUBJECT: BI-WEEKLY REPORT, PROJECT 6673, MARCH 16, 1951

1. GENERAL

(C. R. Wieser)

The radar relay link is out of service and probably will be until about March 26.

Until the relay link is operating again, the principal effort will be directed toward improving the interception programs, particularly the smoothing and prediction part of interception. This will include continuation of the study of both linear and non-linear smoothing. In order to get a more satisfactory test of interception programs without actually running an interception, programs for a simulated interception will be prepared. These programs will use recorded radar data for the simulated target so that the target prediction will be realistic.

As long as the relay link is out of service, the engineering group will test and study our relay link terminal equipment. The principal effort will be directed toward improving the signal-level margins, which are far too low for extended reliable operation.

2. ENGINEERING

(D. A. Buck)

An A.C. power distribution panel was constructed and installed. In addition, relays were added to the chasses which require three-phase power so that they now go on when the switch on the new panel is thrown. The panel incorporates convenience outlets on the front and a 25-amp. circuit breaker. Relays will soon be added which will break the D.C. lab. power, thus providing one-switch control for the entire equipment. This will simplify the instructions required for personnel to shut down the equipment during after-hours sessions.

Parts have been ordered for the high writing rate oscilloscope needed for work on the computer-input end of the demultiplex equipment. It is planned to use stockroom spools of coaxial cable to accomplish the delay required to trigger the scope with the same pulse at which we are looking.

The R. F. transmitter for use in communication with the aircraft during interception has been sent to the Bedford-Barta

2. ENGINEERING (continued)

(D. A. Buck) (continued)

telephone line so that instructions sent to the aircraft might be recorded "as relayed". The levels have been adjusted so as to be equal when either link is operating.

Measurements on the voltage levels within the demultiplex equipment indicate that the required minimum levels have shifted upward since the equipment was first put into operation.

The joystick cable connections are being removed from room 224. It will be possible in the future to operate the joystick from test control only.

(H. J. Kirshner)

An unsuccessful attempt to connect the Barta to Bedford private wire voice link to the Barta switchboard was made. Although two way communication could be established between the Barta Building and Bedford through the switchboard, it was found that the automatic ringing signal, produced when Bedford wishes to call Barta, would produce no indication on the Barta switchboard.

This flaw makes the system useless, since the purpose of the modification would have been for Bedford to call Barta should no one be present in room 224. Fortunately an "outside" phone is available at Bedford in close proximity to the private wire phone. This enables the people at Bedford to call the Barta Building through normal channels.

Some difficulty was encountered with the digital display scope. The causes of the abnormal operation proved to be a broken condenser lead to the scope chassis and an open filament in a 5U4 on one of the power supply chasses. In the course of correcting these anomalies, it was discovered, with the aid of AFCRL personnel, that small changes in the 300, -200 and -105 DC supply voltages will cause large scale changes in the zero settings of azimuth and range on the D.R.R. Display Scope.

(R. Best)

A new deflection yoke has been received from the Air Force Cambridge Research Labs, with approximately equal defelction sensitivities in both axis. This yoke is satisfactory for the final display system, and more are being made.

2. ENGINEERING (continued)

(R. Best) (continued)

Two deflection amplifiers are being built in the shop to be used in a rack-mounted 16-inch display system, and these amplifiers may later be put in the final cabinet.

(R. E. Hunt)

Construction is now complete and testing is underway. The unit should be ready for use by 3/23/51 completely installed. There will be a remote control panel in Room 224 and in the test control room. The camera and control may be plugged into either remote control panel.

Some tests were made to ascertain whether pictures taken of the 16 inch scope or 5 inch scope would have better clarity and spot size. The results show that pictures of the 16 inch scope are better by a factor of 2 or 3. This is because (a) the spot size diameter vs. screen diameter is smaller for the 16 inch unit because of intensification time limitations on the 5 inch unit, (b) the intensity is much greater for the 16 inch unit, which makes it possible to use standard or even fine grain films.

We will proceed to adapt the camera to the 16 inch display units.

Layout work is progressing at a satisfactory rate at the drafting room. Drawings of the scope unit should be complete about 3/30/51, or before. These units can then be constructed.

3. ANALYSIS FOR BEDFORD EXPERIMENTS

(D. R. Israel)

Janice Rossback has joined the project, and has tentatively been assigned to the group working on analysis for Bedford Experiments. Several introductory discussions have been held during the past bi-weekly period with Mrs. Rossback, Frank Heart, and Dave Kemper. Rossback and Heart will concentrate on studying experimental aspects of smoothing, while Kemper is writing some introductory programs for automatic initiation.

The PWTWS (printing-while-tracking-while-scanning) program has been altered to make $\alpha = 2/32$, $a = 10/32$. A large amount of data has been printed with the new program, and this data has been analysed and plotted up by Frank Heart. This data coincides quite closely to the expected results as indicated by our tests with synthetic data. There still remains a question of whether the smoothed velocities are yet smoothed enough, a definite answer to this question will be provided as soon as an interception can be carried out (see below). All the data taken has been saved for inspection by interested parties.

A good deal more thought has been given to the smoothing problem. One idea which has arisen is that we might do better if instead of smoothing x and y positions and velocities, we smooth r and Θ positions together with the magnitude of the velocity of the aircraft and the heading angle. This procedure would enable us to take advantage of the better quantization in the r coordinate, and will also couple the two coordinates (x, y and r, Θ) together.

Gaudette's program for sinusoidal smoothing has been successfully operated upon the computer. As has been previously noted, there are a number of variable parameters which must be dealt with. Although the sinusoidal program indicated that better smoothing can be obtained, the work on this phase has been suspended temporarily in order that thought be given to the synthesis of a possible figure-of-merit.

It has been suggested that an interesting display program could be made by running a synthetic interception between a computer-controlled point (an interceptor) and a live target from Magnecord tape. The general program for tracking a single aircraft has been altered for this application, and it will shortly be coupled with Attridge's program. This program will be operated next week.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(D. R. Israel) (continued)

During the recent period of inactivity, modifications were made at Bedford so that a 100° - 120° sector to the West is blanked out, and no radar information in the sector is made available to us. This move has been made as a means of decreasing the minimum range of the radar; however it introduces some interesting possibilities in programming if a signal can be given to the computer at the start of this sector. One particular example is the printing out of data for two tracked aircraft. Arnow is undertaking the programming of this problem.

Friday, March 16, was chiefly spent in watching Navy-Air Force films at AFCRL. These films, although of World War II vintage, were quite interesting as regards various methods and types of interceptions.

All paper tapes to be used in the Bedford Experiments are presently being stored in Room 224 along with a copy of each program.

(R. L. Walquist)

The new multiple target tracking program (RTP-V) has been completed and successfully run on the computer. As was mentioned in the last bi-weekly, this program sacrifices part of its target capacity in order to obtain a better functioning program. The principal details of the program are as follows:

1. The target capacity has been reduced to 5 as compared to the original 10 of RTP-III.
2. The tracking of false targets, when real targets are not being tracked, has been eliminated.
3. The 5 targets may be located in any manner in the area covered by the radar set (all 5 targets may fall at the same azimuth).
4. The number of targets being tracked is displayed in a flip-flop register and is continually changed as targets are added or eliminated.
5. The light gun will both initiate on a new target and eliminate an old target without the necessity of setting any toggle switches to distinguish between the two cases.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(R. L. Walquist) (continued)

A memo is in the process of being written which will explain the operation of the two multiple target tracking programs now available. If possible, an estimate will be made of the maximum number of targets that can be tracked by the programs assuming no storage limitations. A study of multiple interceptions, using the programs, will also be made.

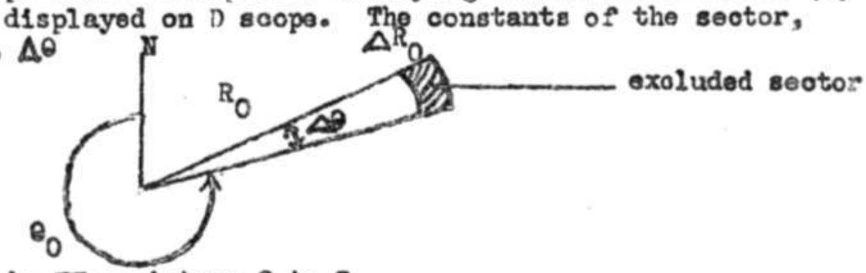
(J. Arnow)

The program for printing polar coordinates of a tracked aircraft has been completed, repaired twice, and believed to be ready to operate.

Upon investigation of data taken while tracking the same target twice, it was noticed that there were some inconsistencies in target returns to the computer. That is, a target failed to show up at a specific point when it had appeared previously at that point. It was then felt that the data from a test pattern could be checked by the computer to determine any erratic behavior in the equipment. Some thought has been given to this problem, but it would appear that the greatest obstacle is obtaining a test pattern that makes no errors for a period of five minutes or thereabouts.

(O. Aberth, O. N. Becker)

As a phase in our initiation to programming we have completed a test program designed to exclude an (r, θ) sector from the incoming magnetic tape data. All points not lying within the excluded (r, θ) sector are displayed on D scope. The constants of the sector, R_0, ΔR, θ_0, $\Delta\theta$



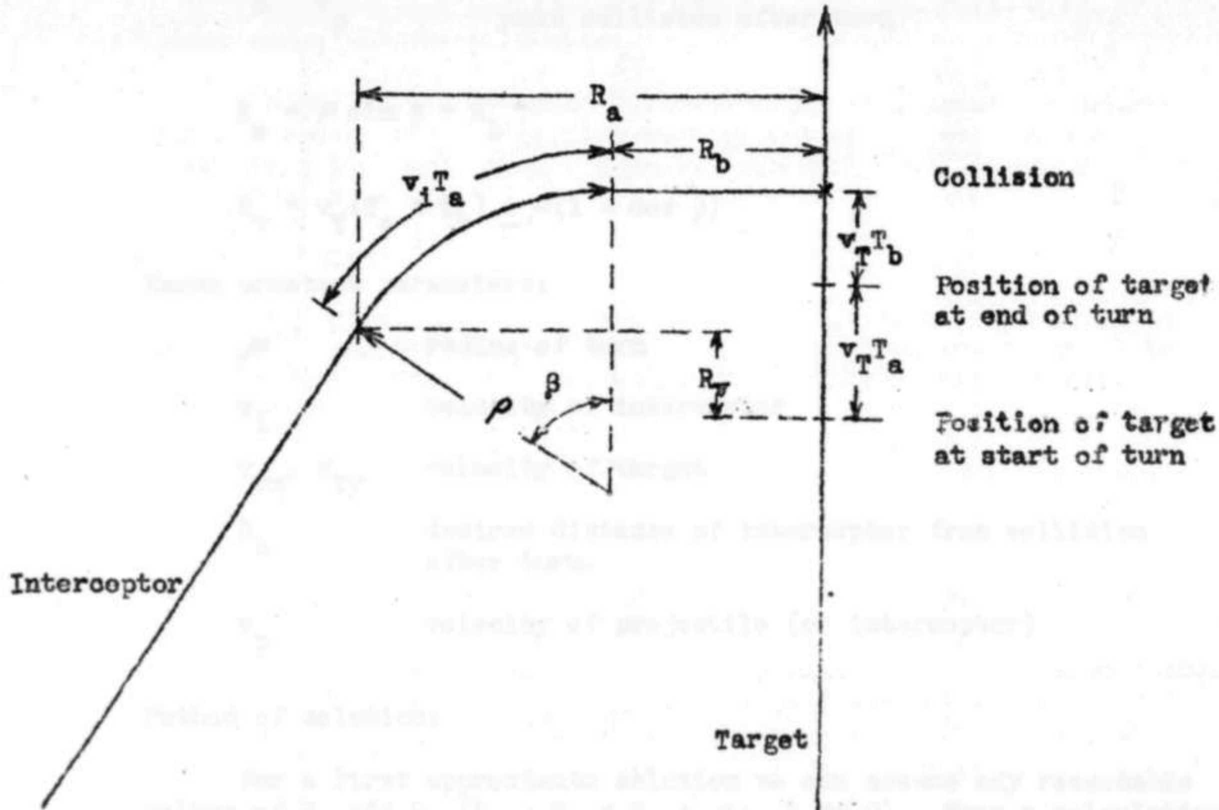
are stored in FF registers 0 to 3.

This program was tested on the computer, and sector magnitude and location determined which will just eliminate Mt. Monadnock from the radar display.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(W. S. Attridge, Jr.)

I have been working on a solution for the problem of bringing an interceptor up to a point a definite distance away from the target's path and traveling perpendicular to the target such that it will be in a collision course or can fire a projectile for a collision course with the target.



3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(W. S. Attridge, Jr.) (continued)

Equations:

$T_a = \frac{\rho\beta}{v_i}$ time of turn

$T_b = \frac{R_b}{v_p}$ time for projectile (or interceptor) to make collision after turn

$$R_a = \rho \sin \beta + R_b$$

$$R_v = v_T(T_a + T_b) \pm \rho(1 - \cos \beta)$$

Known constant parameters:

ρ	radius of turn
v_i	velocity of interceptor
v_{Tx}, v_{Ty}	velocity of target
R_b	desired distance of interceptor from collision after turn.
v_p	velocity of projectile (or interceptor)

Method of solution:

For a first approximate solution we can assume any reasonable values of R_v and R_a ($R_v < R_a < R_b + \rho$; $R_v \approx \rho$). Then a calculation for a collision course to the point at the start of the turn is carried out (as mentioned in the previous bi-weekly). This will give a value for β which should be fairly accurate. Better values of R_a and R_v can be calculated from β using the above equations. Subsequent solutions will give better values for β, R_v and R_a.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(W. S. Attridge, Jr.) (continued)

After the interceptor is set "on" his course, ie., β, R_a, and R_v remain fairly constant, the time to the start of the turn can be sent to the interceptor and the direction of his turn. The time of his turn, T_a, is also relayed to him.

I have started to program a display of a simulated collision using the above solution.

I have started to consider the display of a simulated interceptor's course for a collision with an actual target from the radar using the "collision - pursuit" constant γ mentioned in the last bi-weekly.

(Frank E. Heart)

Spent bi-weekly period getting a further introduction to the problems of smoothing radar data. Part of my time was spent plotting and correlating data taken with the printing-while-tracking-while-scanning programs.

In addition I began some consideration of the following two problems:

1. Smoothing to true velocity instead of x, y, $\dot{x}$, $\dot{y}$, and smoothing in polar coordinates.
2. Use of the computer to produce tapes having the coordinates of simulated courses, and then using these tapes as the simulated data for a given smoothing program. This might allow simulation of more complicated courses than are now being used.

(D. A. Kemper)

The trigonometric check program was run and photographs were taken of the results. It failed to display the proper error curve due to round-off errors affecting addresses from which data was taken. It has been corrected and will be re-run in the near future. If successful, it will be described in a memorandum and made available for general use.

Some time was spent studying one- and two-aircraft tracking and interception programs and radar WWI communication in general. Some thought was given to the problem of automatic initiation by starting to track any aircraft which passes through a specified region of space.

3. ANALYSIS FOR BEDFORD EXPERIMENTS (continued)

(Janice Rossback)

I have been reading E-2000, R-180 and E-193 as well as several smaller reports, which deal with orders or programming. I have also attended course 668 given by C. W. Adams and have started to think about the problem of smoothing velocities, in connection with the Bedford radar data.

4. THEORETICAL ANALYSIS (continued)

4.2 Data Smoothing and Aircraft Control

(John M. Salzer)

For the analytical investigation of data smoothing and prediction, we considered two questions; the type of data to work with and the type of problem to be handled. The latter question has been decided as prediction problems, because such problems are meaningful even without considering quantization. It is then possible to design prediction programs first for clean data and include quantizing effects later. The problem of simulation of data for the programs required some circumspection. For the type of investigation considered an assumption of sinusoidal variation of a single variable as a function of time is ideal because of the use of frequency analysis. On the other hand the motion of planes can best be characterized by a constant speed and circular paths of varying diameters (straight line course corresponding to an infinite diameter). Fortunately, the two requirements are in harmony, since the projection of a uniform circular motion upon one of the rectangular coordinate axes is sinusoidal in time.

C. Gaudette has prepared a program to simulate the indicated data with the use of the general prediction program described by him. In the meantime, several prediction programs were designed by studies of loci in the complex frequency plane. Experiments with the computer should divulge the soundness and accuracy of these studies. These experiments are planned to be started next week. At this time it is safe to draw one conclusion: if these programs perform as the frequency analysis indicates, it is hard to see how the same programs could have been synthesized by the conventional time domain method. Quantities, like velocity or acceleration, do not appear explicitly in these programs, neither do polynomial approximations through points. Such concepts might, however, be included in the programs implicitly.

(R. L. Walquist)

Effort has been directed towards obtaining a somewhat better understanding of the smoothing equations used in our present prediction equations. As pointed out by John Dodd in M-1176 (6782 Bi-weekly of March 2, 1951), the velocity smoothing equation may be written in the form:

4.2 Data Smoothing and Aircraft Control (continued)

(R. L. Walquist) (continued)

(1) $V_n = \alpha\left(\frac{X_n - X_{n-1}}{T}\right) + (2 - a - \alpha)\, V_{n-1} + (a - 1)\, V_{n-2}$

If, for convenience, we let $D_n = \frac{X_n - X_{n-1}}{T}$ and rewrite the above expression:

(2) $V_n = \left[V_{n-1}\,(1-\alpha) + \alpha\, D_n\right] + \left[(V_{n-1} - V_{n-2})(1 - a)\right]$

The first term in brackets is analogous to the familiar single exponential smoothing, while the second term is analogous to a weighted acceleration correction for V_n. V_n may also be written in terms of the D's only and takes the following form:

(3) $V_n = \alpha\left[D_n + k_1 D_{n-1} + \cdots + k_i D_{n-i} + \cdots + k_{n-1} D_1\right]$

where k_i is a power polynomial of i^{th} degree in (1-a) and (1-α).

Three different sets of values are given below for the case where n=8:

(a) $\alpha = 1/10$; a = 6/10

$V_8 = 0.100 D_8 + 0.130\, D_7 + 0.129\, D_6 + 0.116\, D_5 + 0.099\, D_4 + 0.082\, D_3 + 0.067\, D_2 + 0.055\, D_1$

(b) $\alpha = 1/8$; a = 3/8

$V_8 = 0.125\, D_8 + 0.188\, D_7 + 0.203\, D_6 + 0.188\, D_5 + 0.154\, D_4 + 0.114\, D_3 + 0.075\, D_2 + 0.041\, D_1$

(c) $\alpha = 4/10$; a = 6/10

$V_8 = 0.400\, D_8 + 0.400\, D_7 + 0.240\, D_6 + 0.080\, D_5 - 0.016\, D_4 - 0.048\, D_3 - 0.042\, D_2 - 0.022\, D_1$

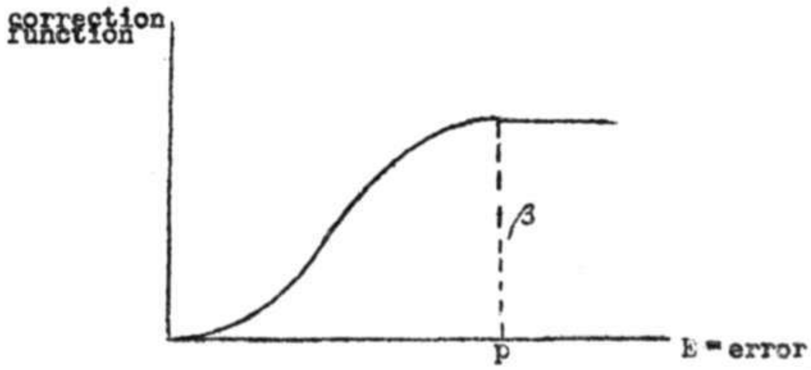
4.2 Data Smoothing and Aircraft Control (continued)

(R. L. Walquist)(continued)

Neither single nor double exponential smoothing can produce a weighting equation such as that obtained in (c) above. Note that for a constant velocity and no position error (i.e., all the D's are equal) the smoothed velocity obtained in (c), as n is increased from 1 to 8, will oscillate about the true value, first overshooting and then decreasing to a value somewhat less than the true value. No definite conclusions have been reached at this time, except to note that the oscillatory case in (c) corresponds to complex values of the smoothing constants derived by John Dodd in the aforementioned bi-weekly.

(C. H. Gaudette)

A new smoothing display program, which uses a sine wave to determine the correction function, has been written. In smoothing velocity the period of the sine wave and the maximum value of the correction function are variable.



Velocity correction function

When the error, E, is larger than the selected value, p, the smoothed velocity is corrected by β. A similar curve is used for predicting position.

A generalized smoothing program has been written for John Salzer. The program uses one-coordinate simulated data, a cosine wave with variable period and without

4.2 Data Smoothing and Aircraft Control

(C. H. Gaudette)

Quantization. The prediction equation used is

$$\tilde{O}_n = u_o\, i_n + u_1\, i_{n-1} + u_2\, i_{n-2} - v_1\, \tilde{O}_{n-1} - v_2\, \tilde{O}_{n-2} - v_3\, \tilde{O}_{n-3}$$

where i_n = n^{th} observed position

$\tilde{O}_n$ = prediction of the $(n+1)^{st}$ position

u, v are constant weights

The constants for a particular case are inserted by a manual intervention subprogram.

4.3 Correlation studies

(R. L. Walquist)

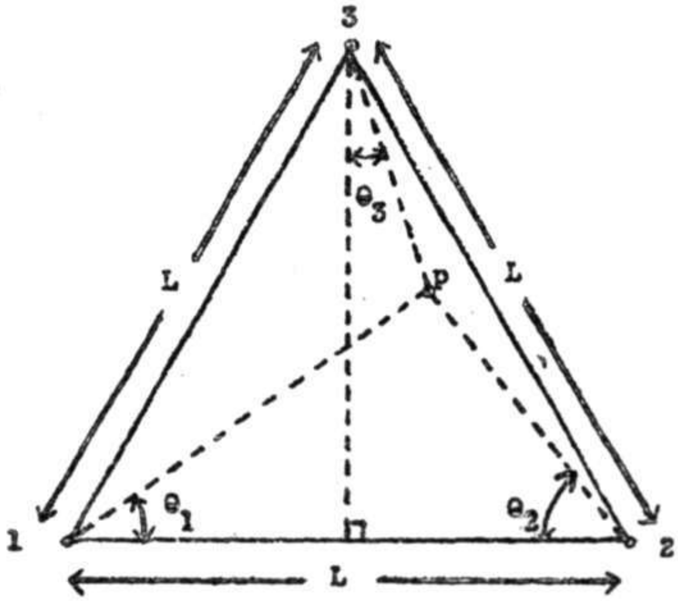
In order to obtain a better insight into the problem of correlating the azimuth readings from three different radar sets, an equation relating the third azimuth angle to the other two azimuth angles has been derived. For the case of an equilateral triangle, and the angles measured as shown in the diagram below, the relating equation is:

$$\tan \theta_3 = \frac{\sin(\theta_1 - \theta_2)}{\cos(\theta_1 - \theta_2) - 2\cos(\theta_1 + \theta_2 + 60^\circ)}$$

As was expected, the size of the equilateral triangle (i.e., the distance between the radar sets) does not enter the equation. Present intent is to program this equation for the computer and photograph the set of curves corresponding to various values of θ_1 and θ_2 .

4.3 Correlation Studies (continued)

(R. L. Walquist)



(F. Van Wyk)

Am investigating the advantages and disadvantages of the use of range-rates in the prediction of the coordinates of an aircraft in flight.

5. COMPUTER OPERATIONS GROUP

(J. Arnow)

Operation of the computer during the past bi-weekly period has been very satisfactory. Only a few random errors occurred and held up progress for a total period of less than five minutes.

Two new forms SL 172, request for 6673 computer time, and SL 173, summary of Computer Operations, have been prepared. The latter form should be submitted on the day following operation.

6. RECORD OF COMPUTER UTILIZATION

(J. Arnow)

3-5-51

1600 - 1800 The program for printing while tracking while scanning was run with successful results and a goodly amount of data was taken.

3-6-51

1300 - 1630 The PWTWS program was run for the benefit of visitors and a number of aircraft were tracked.

1630 - 1715 Program for calculation of a collision course was run with reasonable results.

1715 - 2000 Programs for checking the accuracy of trigonometric and square root subprograms were run.

3-8-51

1400 - 1500 Program for checking collision course calculation was run.

1500 - 1530 Program for checking the accuracy of sine-cosine approximations was run.

1530 - 1600 Smoothing display program was put on the computer.

1600 - 1700 Programs for tracking one and two aircraft were demonstrated.

3-12-51

1600 - 1725 A program for non-linear sinusoidal smoothing was checked out.

3-13-51

1630 - 1715 The program for printing the polar co-ordinates of a tracked aircraft was tried unsuccessfully. A number of programming errors were in evidence.

6. RECORD OF COMPUTER UTILIZATION (continued)

(J. Arnow) (continued)

3-13-51

1715 - 1815 The PWTWS program was used in conjunction with magnecorder reel # 29, but no significant targets appeared and no consistent data was taken.

1830 - 2000 RTP-V, program for multiple tracking was run successfully, but contained a few programming errors which could not be corrected at this time.

3-14-51

1330 - 1600 The PWTWS program was run, and a great deal of data was taken on a number of targets.

3-15-51

1430 - 1600 The multiple target tracking program was corrected and run with very good results. Five aircraft were tracked successfully.

1600 - 1700 More data was taken using the PWTWS program.

3-16-51

1415 - 1530 A program for sector data exclusion was run with very good results.

1530 - 1700 PWTWS program was used to take more data on various aircraft.