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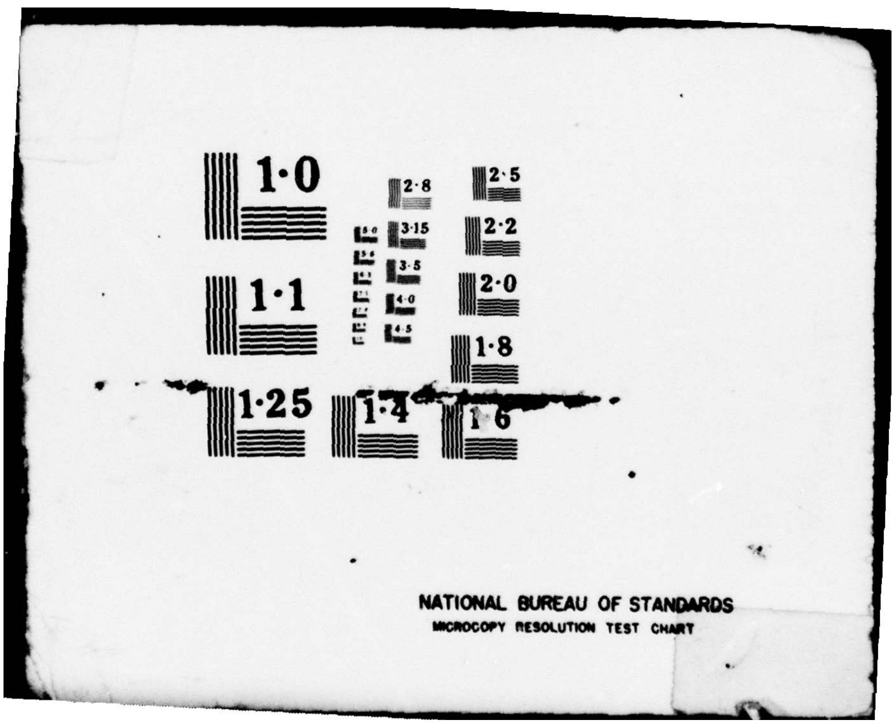
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This is volume V of six volumes of training material prepared for an experimental course of maintenance instruction on the AAFCS M33 fire control system. This volume contains instructional material for the COMPUTER subcourse of a program of fire control radar instruction. It includes lesson plans and practical exercises designed to be covered in 92 periods of instruction.

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Technical Supplementary Material

for

HumRRO Technical Report 46:

DEVELOPMENT AND EVALUATION OF AN EXPERIMENTAL PROGRAM OF INSTRUCTION FOR FIRE CONTROL TECHNICIANS (RADAR VI)

Lesson Plans

Practical Exercises

Prepared By

U.S. Army Air Defense Human Research Unit

Under the Technical Supervision of
The George Washington University
Human Resources Research Office
operating under contract with
The Department of the Army

Fort Bliss, Texas
June 1958

FOREWORD

This is volume V of six volumes of training material prepared for an experimental course of maintenance instruction on the AAFCS M33 fire control system. This material was developed during research conducted by the U. S. Army Air Defense Human Research Unit at Fort Bliss, Texas, in cooperation with the U. S. Army Air Defense School. A detailed account of the research, the results and recommendations emerging from the experiment, and the rationale by which this material was prepared and used, is included in HumRRO Technical Report 46, "Development and Evaluation of an Experimental Program of Instruction for Fire Control Technicians." It is recommended that readers familiarize themselves with the contents of this report before attempting to use the training material contained in these volumes. A copy of this report may be obtained by writing to the Director, Human Resources Research Office, The George Washington University, Washington 7, D. C.

VOLUME V

COMPUTER

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TABLE OF CONTENTS (continued)

DIAGRAMS [1/]

1/ Diagrams refer to drawings that have been specially prepared by the authors.

DIAGRAMS (continued)

INTRODUCTION

This volume contains instructional material for the Computer subcourse of a program of fire control radar instruction which consists of the following subcourses:

I	Operation Orientation
II	Electronic Fundamentals
III	Acquisition Radar
IV	Track Radar
V	Computer
VI	Maintenance and Supply

It includes lesson plans and practical exercises designed to be covered in 92 periods of instruction: 50 periods of conference and 42 periods of practical exercises. Each instructional period was approximately 50 minutes in length. A detailed breakdown of instructional topics and time allotment is presented in table 1, page 3.

The Computer subcourse is designed to provide the student with the information and skills necessary to maintain, repair, and adjust the computer subsystem of the AAFCS M33.

Instructional material contained herein is that issued to instructors. Material issued to students was identical with two exceptions; (1) copies of practical exercises were not issued, and (2) instructor's notes, suggested explanations, and problems (shown in boxes in the lesson plans) were deleted.

A difference in format exists between material in this volume and that used during the research, in that the experimental lesson plans were printed only on the left-hand pages of the volumes. This arrangement provided student and instructor with convenient and appropriate space for notes.

It will be noted that each page of lesson plans and practical exercises is coded at the top of the page. This code is interpreted as follows: the first letter "I" indicates that these publications were issued to instructors, the second letter indicates the volume (in this case "C" for Computer), and the number following the dash indicates the number of the lesson plan in the volume. The code found on practical exercises is similar except for the "P" preceding the number that follows the dash.

Experience gained during the course of an experiment frequently enables researchers to suggest modifications in design and/or material that should lead to significant improvement of the product. Several modifications have been incorporated into this volume to the possible benefit of the user.

The following changes were made in the content of this volume of the Computer subcourse as compared with the subcourse as it was experimentally evaluated:

1. The first conference, "Computer Block Diagram," was altered to include a brief explanation of the problems solved by the computer and an explanatory analogy between hunting and the gunnery problem. Experience indicates that the subjects of placement and operation of computer controls, originally covered in the first conference, could best be taught on the equipment. Therefore, the topics are here included as part of the first practical exercise.

2. The conference on the "Observed-Target Coordinates Section" has been rewritten to provide a more detailed explanation of the manner in which the computer determines the present-position of the target.

3. The conference on the "Summing Amplifier" and the associated practical exercise were not included in the Computer subcourse when it was experimentally evaluated.

Changes relating to topic time allotments are indicated in table 1. Numbers indicate recommended hours of instruction for each topic: where recommended time differs from time actually allotted during the experiment, actual time consumed during the experiment is indicated in parentheses.

Although materials in this volume have been carefully prepared, imperfections may still exist. Your cooperation in eliminating them is requested. Notification of errors and suggestions for improvement should be forwarded to the Director of Research, U.S. Army Air Defense Human Research Unit, Fort Bliss, Texas.

Table 1

SUMMARY OF INSTRUCTIONAL* PERIODS ALLOTTED TO TOPICS INCLUDED IN THE COMPUTER SUBCOURSE

TOPIC	CONFERENCE	PRACTICAL EXERCISE
Introduction Computer Block Diagram	4	3
Associated Circuits	4	3
Azimuth, Elevation, and Time-of-Flight Servos	4	3
Predicted-Target Coordinates Section	4	3
Ballistic Synthesis	4	3
Summing Amplifier	4 (0)	3 (0)
Preoperational Checks	4	3
Plotting Boards	4	3
Pen Interchange, Reference, and Timing Marks	4	3
Fire and Cease-Fire Marks	4	3
Review	4	3
Examinations	6	9
Total	50 (46)	42 (39)

*Does not include 59 periods devoted to nonacademic time: Commander's time, physical training, etc.

LESSON PLAN

COMPUTER BLOCK DIAGRAM

OBJECTIVE:

1. To explain the five basic steps of the air defense problem and the symbols used to indicate data flow through the computer.

2. To give the student a basic understanding of the computer and the problems it solves.

> INSTRUCTOR'S NOTE: Throughout the computer discussion we will be referring to the computer used with 90-mm guns. Wherever circuits in computers used with 120-mm guns differ, these points should be brought out.

INTRODUCTION:

The purpose of the computer is to furnish data representing firing information to the guns.

Before the mission of the target can be interrupted, the following steps must be completed.

1. The acquisition radar must detect a target roughly in azimuth and range.

2. The designator circuits must relay this information to the track radar.

3. The track radar must locate the target accurately in azimuth, elevation, and slant range.

4. The computer must receive this information and send the appropriate directing voltages to the guns so that the mission of the target can be successfully interrupted.

PRESENTATION:

> INSTRUCTOR'S NOTE: During the next few weeks many of the students will be confronted for the first time with the concept of the computer and its solution to the air defense problem. It is for this reason recommended that the first portion of this conference be devoted to a definition and description of what the computer is as well as the problems it is called upon to solve.
>
> The following discussion is presented only as a guide for this portion of the conference which should in no case extend for more than two 45-minute periods.
>
> Attention is called to the method used in the sample discussion to gradually build up to the computer from the simple principles used in hunting which it is assumed are well known to all. New terms are gradually brought into play and are underlined for emphasis.

After a projectile leaves the muzzle of a gun, many forces begin acting upon it to vary its velocity and direction. Any one of these forces, if not taken into consideration, can seriously affect the success of the air defense mission.

The effects of these forces have plagued marksmen back to the day man laid his club down and started throwing rocks at his enemies. The formal study of these forces is called ballistics, and it may be that the student already knows more about the science of ballistics than he at first suspected as the following example may prove.

An experienced shotgunner notices a low-flying duck approaching at about 300 yards. He will certainly not start shooting immediately since he knows that, at best, even with a full choke, he cannot kill at more than 60 or 70 yards.

He will, instead, raise and unlock his gun and mentally estimate whether the bird will come within range of his gun. If he sees that the bird is going to fly within range, he will then begin estimating the bird's speed and height so that he can judge the amount of lead he will give. At the time the gun is fired, it will be aimed at a point ahead and above the present position of the duck by amounts determined by the duck's speed and range. The point at which the gun is fired is chosen instinctively by the hunter, and, if he were asked why he chose that spot to shoot at, he might be at somewhat of a loss to explain himself. Therefore, a brief analysis of the gun's aim with respect to the bird may be of value at this time.

The point in space occupied by the bird at the time the gun is fired is known as its present position. The point in space where the shot collides with the bird is called the point of intercept. When the hunter fires, he does not fire at the bird's present position but at the point of intercept, and whether or not he takes the duck home is going to depend not only on his hitting the intercept point but also on his picking the correct intercept point.

In determining the amount of lead that he gives the bird, the hunter takes into account not only how fast the target is moving, but also the speed of the shot: muzzle velocity. It can be seen that if the bird flies faster, it covers more distance in a given time and will, therefore, have to be led more. Another factor that determines the amount of lead is the distance the shot will have to travel in order to hit the point of intercept: slant range. As the slant range becomes greater, the time required for the shot to reach the point of intercept becomes greater. The total time required for the shot to reach the point of intercept from the instant the shot is fired is called time of flight. 2/

To estimate where the point of intercept is, the hunter must take into account such things as target speed, slant range, and time of flight. After he has estimated the point of intercept, he must also take into account the limitations of his gun and formulate a plan for hitting the point of intercept. This entails estimating the wind velocity and direction and how gravity will affect the shot. If the hunter makes all his estimates correctly, the bird and the shot come together at the point of intercept, and the duck population is decreased by one.

2/ This is also referred to as time to burst.

The foregoing example does not differ appreciably from the problem the computer must solve, and it is included only to present in simple terms the problems involved in shooting down a flying target. It is assumed that the student followed the preceding discussion with little difficulty since he was only given new expressions and terms for ideas with which he has been long familiar.

The problem that the computer in the AAFCS M33 is called upon to solve is a bit more elaborate than shooting ducks. To begin with, the computer is capable of predicting the point of intercept for targets flying well in excess of mach 1 and at ranges out to 40,000 yards. The computer can also give a continuous solution to the problem with mathematical exactness.

For purposes of explanation, the computer can be broken down into the following groups:

1. Observed-target coordinates section,

2. Prediction coordinates section,

3. Servo section, and

4. Ballistic section.

INSTRUCTOR'S NOTE: Draw diagram 1 in one corner of the blackboard.

In the following explanation of the computer block diagram, it will be to the student's advantage to keep in mind the hunter and the duck. Although the purposes differ, the problems involved are the same.

To arrive at a correct solution to the air defense problem, the computer must, as did the hunter, observe the target for a while to determine its direction and speed. This is accomplished through the track radar.

In automatic operation, the antenna of the track radar is pointed directly at the target, and the position of the antenna bears a direct relationship to the azimuth and elevation of the target. The track range computer, under automatic operation measures the range to the target.

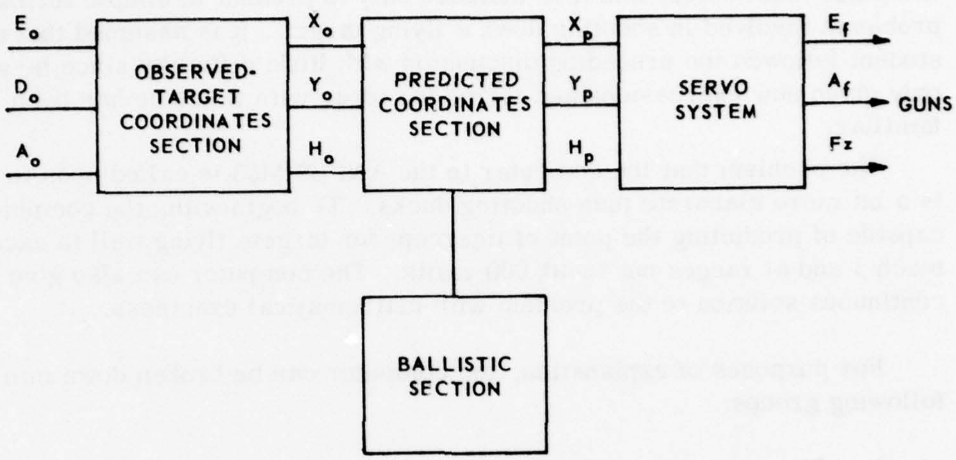

Diagram 1. Simplified computer block diagram.

The computer uses the position of the antenna and the range computer to find the present position of the target in rectangular coordinates.

> INSTRUCTOR'S NOTE: Discuss the difference between spherical and rectangular coordinates and, also, how the position of the track radar represents the spherical coordinates of the target's position.

The circuits within the computer are arranged in such a manner that they can only accept data regarding target position in rectangular coordinates. As mentioned before, the track radar locates the target in spherical coordinates. The coordinates are defined as:

A_O = azimuth observed,

E_O = elevation observed, and

D_O = slant range observed.

These data are sent to the first portion of the computer and converted to rectangular-coordinate data by a pair of data units which are positioned by the track antenna. The outputs from the two data units are:

X_o = <u>target position on east-west axis,</u>

Y_o = <u>target position on north-south axis,</u> and

H_o = <u>distance above horizontal plane passing through the center of the antenna.</u>

The values of X_o, Y_o, and H_o pinpoint the target's present position at a given point in space. Since the target is moving, it will now be necessary that the computer predict where the target and a projectile traveling, for example, at 2,675 feet per second will meet. When the computer finds the intercept point, it develops the rectangular coordinates of this point and sends them to the servos where they are reconverted to gun-positioning coordinates. Remember that the computer's solution for the intercept point is based on observation of the target's present movements and position, and it compares exactly with the hunter's leading the duck. The computer defines the intercept point by using the following values:

X_p = <u>predicted east-west position of the intercept point,</u>

Y_p = <u>predicted north-south position of the intercept point,</u> and

H_p = <u>predicted distance above horizontal plane of the intercept point.</u>

In the next few days, the student will find that the computer's solution to the target's present position is very easy to understand, and that the only concept he may find difficult is the computer's solution to the intercept point. The examination of the many variables that must be considered in solving for X_p, Y_p, and H_p involves most of the work in understanding the computer.

The following are considerations in the computer's solution for the value X_p. A target flying directly east will have a value of X_o that is steadily increasing by an amount proportional to its easterly velocity. If the target flies east at a steady altitude, Y_o and H_o will remain constant, and the only change will be in the value of X_o. If the target is flying east at a constant speed, the value of X_o increases linearly with time.

> INSTRUCTOR'S NOTE: Explain how the distance covered by an object flying at a steady rate can be computed by multiplying its rate by time.

The amount of change of X_o in a given time is detected in the rate or first-derivative networks in the computer. The symbol X represents the amount of change of X_o with respect to a given unit of time. If the target is moving at a perfectly constant velocity, then $\dot{X}$ represents the target's speed.

If a target speeds up while flying east, the value of the symbol $\dot{X}$ will increase at some rate determined by how fast the target is gaining speed. The rate of change in X is detected in the second-derivative networks and designated by the symbol $\ddot{X}$.

The direction and manner of the target's flight will then determine the values of X_o, $\dot{X}$, and $\ddot{X}$, as well as the corresponding values of Y and H.

To solve for X_p, the computer must know the speed of the projectile (approximately 2,675 ft/sec) and the predicted distance to the intercept point. With these two bits of information it will then proceed to solve for the values of ΔX, ΔY, and ΔH which correspond to the amount by which the hunter led the duck.

The triangular prefix called delta in front of X, Y, and H denotes the total amount by which X, Y, and H are expected to change from the time the gun is fired until the target and projectile meet at the intercept point.

The computation of the intercept point is by no means the end of the computer's job for it must also take into account all the physical forces that may act upon a projectile while it is in flight. This is performed by the ballistic section of the computer and results in the gun's being aimed so that the projectile passes through the intercept point after the various forces have acted upon the projectile.

The final block in our simplified block diagram of the computer is the servo section which receives the information regarding the intercept point from the predicted-target coordinates section and the ballistic data from the ballistic section. The function of the servo section is to combine all information regarding the target and the path of the projectile and to convert the information into data to be sent to the guns.

A_f = firing azimuth,

E_f = firing elevation, and

Fz = fuze setting.

INSTRUCTOR'S NOTE: Show training film TF-9-1843 (20 min)

REVIEW:

The five basic steps in the computer's solution of the air defense problem follow.

1. Location of the target in spherical coordinates.

   a. The (mechanical) position of the antenna determines the observed azimuth A_o and observed elevation E_o of the target.

   b. The track radar determines the observed slant range D_o of the target.

2. Conversion of the observed-target coordinates from spherical into rectangular coordinates.

   a. The output voltages taken from the arms of the elevation-data potentiometer represent observed ground range R_o and observed altitude H_o.

   b. The outputs taken from the arms of the azimuth-data potentiometer represent distance on the E-W (X) axis and N-S (Y) axis.

3. Prediction of the predicted coordinate or the amount of lead voltage necessary for hitting the target. The sum of lead voltage and observed-position voltage results in a predicted-position voltage.

4. Correction in the ballistic section for ballistic and nonstandard atmospheric conditions.

5. Conversion of rectangular firing information into firing data by the A_f, E_f, Fz, and time-of-flight servos.

INSTRUCTOR'S NOTE:

1. Explain the type of data that is sent to the guns by the computer.

2. If time remains, go over the simple block diagram of the computer. Make certain that each student knows the purpose of each block.

3. Make certain that each man has a copy of the check sheet and familiarize the class with the various symbols used.

PRACTICAL EXERCISE

COMPUTER BLOCK DIAGRAM

AAFCS M33 SETUP: Fully energized (including the computer).

EQUIPMENT NECESSARY: Null-voltage test set and multimeter.

PRELIMINARY TROUBLE: None.

DEMONSTRATION:

1. Since this exercise is an introduction to the computer, it is desirable for the instructor to have the system in complete operation at the beginning of the demonstration.

2. If possible, the tracking radar should be in AUTO and tracking a a moving target. The computer should be energized with the OPERATION switch in FIRE FOR EFFECT and the INPUT DATA switch in REMOTE. Plotting boards will be plotting the course of the target.

3. Demonstrate the effects of all the controls on the correction panel on the computer's solution of the tracking problem. The effects of moving any of the controls can be seen on the SERVO dials and usually on the plotting boards.

4. While the plotting boards are in operation, the purpose of the three different boards can be explained.

5. Show the effects of the four- and eight-second data smoothing on the predicted plots. Point out that, with eight-second data smoothing, the plots are smoother just as firing information is smoother.

6. Explain the use of the timing marks, the fire and cease-fire marks, and the reference marks. Demonstrate how the marks appear.

7. Point out the meters on the rate-indicating panel and discuss their purpose.

8. Discuss the purpose of the six built-in problems, called static tests, and how their solution is an indication of the operating accuracy of the computer.

9. Demonstrate the pen interchange by shorting the pens together with a screwdriver and discuss the purpose of the interchange.

10. Place the computer in STATIC TEST and demonstrate with the plotting boards that the first four tests are in quadrants 1, 2, 3, and 4. Point out the rate and acceleration meters in tests 5 and 6.

INSTRUCTOR'S NOTE: Point out the physical location of all units and discuss their functions.

11. The computer proper is subdivided into the following:

    a. Power-control panel,

    b. Correction panel,

    c. Azimuth, elevation, fuze, and time-of-flight servos,

    d. Power-supply bay,

    e. DC amplifier bay, and

    f. Servo-amplifier bay.

12. The plotting board is subdivided into the following:

    a. Early warning plotting board,

    b. Horizontal plotting board,

    c. Present altitude board,

d. Predicted altitude board, and

e. Rate-indicating panel.

13. Power-control panel.

a. COMPUTER POWER switch applied ac power to the computer and plotting boards.

b. Fuzes and fuze indicator lamps and their respective circuits serve to protect the computer from overloads. Open circuits are indicated by lighted indicator lamps.

c. DC READY lamp when lit indicates that 30 seconds have elapsed and dc voltage may be applied.

d. 320V DC POWER switch and lamp which indicates that B+ voltages are applied to the computer when it is lit.

e. 270V DC POWER switch and lamp which indicates that 270 volts are applied to the low-power servo amplifier when it is lit.

f. BATTLE SHORT switch bypasses the interlock and 30-second timer circuit.

g. VOLTAGE CHECK meter and switch provide a visual indication of various voltages in the computer.

14. The correction panel contains controls used to insert ballistic and nonstandard atmospheric conditions. The selection of inputs to the computer and the mode of operation are also controlled from this panel.

a. FUZE-SPOT control provides ballistic correction (-5% to +5%) for errors in fuze number.

b. WIND-VELOCITY control provides ballistic correction for winds from 0 to 70 mph.

c. MUZZLE-VELOCITY control provides correction for variations of muzzle velocity.

1) For AAFCS M33C, dial reads from 2, 450 to 2, 900 feet per second.

2) For AAFCS M33D, dial reads from 2, 800 to 3, 300 feet per second.

d. AIR DENSITY control provides for variations of air density. Correction limits are to ±20 percent of normal.

e. LIGHT switch provides illumination for dials at correction panel.

f. PARALLAX control X, Y, H provides for parallax correction to a maximum of 500 yards in any one direction.

g. DEAD TIME control provides correction for personnel and materiel delays in cutting of fuze and firing of round. Correction limits are from zero to four seconds.

h. MINIMUM ALTITUDE control provides a means of establishing a minimum predicted altitude. Correction limits are from -500 to +1, 000 yards.

INSTRUCTOR'S NOTE: Give the proper positions of dials under standard conditions.

i. AIR SURFACE switch and lamp when lit indicates that the computer will predict for surface target only.

INSTRUCTOR'S NOTE: This switch was placed into the set for the sole purpose of surface firing. Explain the use of this switch with contour map and in coastal firing.

j. INPUT DATA SELECTOR switch provides for selected inputs of X, Y, and H from:

1) Track system (LOCAL position),

2) Six predetermined problems (positions 1 through 6), and

3) External source (REMOTE position).

k. OPERATION switch provides selected modes of operation for checking out various portions of the computer.

1) FIRE FOR EFFECT is the normal operational position.

2) TRIAL FIRE position is provided to determine muzzle velocity of the guns. (This is a check on ballistic corrections.)

3) TRACKING TEST is provided to check out the battery for orientation and synchronization.

4) DYNAMIC TEST is provided to check out the prediction circuits.

5) STATIC TEST is provided to check the accuracy of the computer by using precalculated problems.

l. NORMAL and TEST REMOTE lamps indicate the mode of operation in which the computer is set. The NORMAL lamp is lit only when the OPERATION switch is in FIRE FOR EFFECT and the INPUT DATA switch is in LOCAL.

m. TIME TO BURST RESET button resets the time-to-burst integrator to a starting position.

n. AMPLIFIER UNBALANCE lamps indicate troubles or unbalance in dc amplifier.

INSTRUCTOR'S NOTE: At correction and rate panel, indicate proper energizing position for each switch and control.

15. Plotting boards. Electro-mechanical devices are used to present a graphical record of the firing mission in order to determine battery efficiency and to evaluate tactics. A timing mark, generated every 20 seconds, and fire and cease-fire marks facilitate interpretation of the plot.

a. The horizontal plotting board is a graphical representation of the X and Y coordinates. The two pens plot present and predicted information on a scale of 1:100,000, from the origin which represents the position of the guns.

b. Present altitude board develops a plot of the present altitude position of the target.

c. Predicted altitude board plots the target's predicted altitude position against the trajectory curve of a projectile.

16. Rate-indicating panel. This is the operating control position for the computer, automatic plotting board, and ceiling lamps.

a. ACCELERATION meters indicate rate of acceleration of the target in yards per second in the X, Y, and H axes.

b. HORIZONTAL and ALTITUDE PREDICTION switches select the most accurate computation.

1) LINEAR selection predicts for targets flying on a linear course.

2) TANGENTIAL selection predicts for targets flying on a slightly curved or slightly accelerated course.

3) QUADRATIC selection predicts for accelerating targets.

c. RATE meters indicate the rate of movement of targets in yards per second in their respective axes.

d. HORIZONTAL and ALTITUDE DATA SMOOTHING switches select either a four- or eight-second data-smoothing circuit whichever is necessary for accurate prediction.

INSTRUCTOR'S NOTE: The position of the switch under firing conditions is up to the operator. Indicate position under STATIC TEST conditions.

e. PLOTTING CONTROL selector switch (fig 22)[3/] controls the operation of the plotting boards. The different selections are used to orient plots and to test out a portion of the plotting boards. The different types of selections are:

1) REFERENCE MARK,

2) STAND-BY,

3) OPERATE,

4) PLOT, and

5) TEST.

INSTRUCTOR'S NOTE: Give a brief explanation of each position mentioned above.

f. PLOTTING CONTROL PEN LIFT button when depressed lifts all the pens from the paper when the PLOTTING CONTROL switch is in PLOT position.

g. PLOTTING CONTROL PEN INTERCHANGE button is a circuit provided to check out the pen-interchange circuit for the horizontal plotting board.

h. PREDICTED ALTITUDE LIMIT lamp when lit indicates that the predicted altitude is below a limit determined by the setting of the MINIMUM ALTITUDE dial at the correction panel.

i. ON TARGET lamp when lit indicates that a target is being tracked by the track radar.

3/ Figures are direct references to figures in the AAFCS M33 Schematics.

j. PREDICTION OUT lamp when lit indicates that the prediction circuits are disabled.

k. COMPUTER READY button and lamp, when the button is depressed, turns on a light at the rate-indicating panel and at the monitor-control panel. These lamps, when turned on by the computer operator, indicate to the tactical control officer that the computer is furnishing correct firing information to the guns.

l. COMPUTER NOT READY button when depressed lamp signals the tactical officer that the computer information is not correct.

m. CEILING LIGHTS control knob controls the intensity of the ceiling lamps over the tactical-control console and computer.

n. HORIZONTAL PLOT LIGHTS control knob controls the intensity of light for the horizontal board.

o. ALTITUDE PLOT LIGHTS control knob controls the intensity of light for the present and predicted altitude boards.

p. METER AND SERVO LIGHT control knob controls the intensity of light for the rate meters, servo dials, and correction-panel dials.

17. The fuze servo. Computes and transmits fuze settings for use at the guns. Associated controls on the fuze servos are:

a. FUZE dial (correction limits are from 0 to 32 fuze numbers), and

b. FUZE SPOT dial and knob (correction limits are from -1 to +1 fuze numbers).

18. The plotting boards are composed of:

a. Horizontal board,

b. Present altitude board,

c. Predicted altitude board, and

d. Rate-indicating panel.

LESSON PLAN

COMPUTER SERVO LOOP

OBJECTIVE:

1. To review the low-power servo amplifier (LPSA).

2. To explain the operation of the computer modulator.

3. To present a practical review of the:

   a. 30-second delay timer, and

   b. ±320v and +270v power supplies.

4. To explain the operation of the -200v and ±250v regulators and associated circuits.

5. To explain the purpose for, and the characteristics of, the dc amplifier.

6. To discuss the mathematical computations performed by the input networks of these amplifiers.

7. To explain the operation of the automatic zero set.

INTRODUCTION:

1. Since the computer performs its computations with dc voltages, some provision must be made for converting dc voltages into ac voltages. The ac is necessary to drive the ac motor whose mechanical output is used to:

   a. Position the arms in the servo, and

   b. Position the pens of the plotting board.

2. The accuracy of the computer depends, to a large degree, upon the accuracy and the stability of the voltages supplied to its various components.

3. Direct-current amplifiers are used in the computer because of their ability to accurately reproduce a given input signal. The input and output networks associated with these amplifiers provide versatility, and the automatic zero set increases the amplifier stability.

PRESENTATION:

1. Computer Modulator and LPSA.

   a. The computer-modulator chassis utilizes the dc error from the summing amplifier and converts it into an ac error signal for use in the low-power servo amplifier. This signal, after amplification, eventually becomes one phase of a two-phase signal sent to the ac motor that is used to drive the computer servos and plotting pens.

      1) The phase and amplitude of the ac signal is dependent upon the polarity and magnitude of the dc error voltage.

         a) The phase will determine the direction of motor rotation.

         b) The amplitude will determine the speed of motor rotation.

      2) V1 and V2 make up a balanced modulator (fig 20-5).

         a) R2 serves as an impedance-matching and limiting circuit for the modulator.

         b) R2 and R8 serve as part of an impedance-matching and limiting circuit for the computer servos.

c) V1, V2, V3, and V4 (fig 20-5A), in conjunction with R2 and R8, make up the servo-limit circuit which limits the input of the servo modulators to ±4.6 volts.

3) V3A in the modulator is a cathode follower which provides V3B with a reinforcing signal at the cathode.

4) V3B serves to amplify and isolate the output of the balanced modulator.

5) C4 is a coupling capacitor.

6) R15, R16, and R19 serve as a mixing and impedance-matching circuit for the output and tachometer feedback signal.

7) The tachometer feedback is fed to pin 5 of P2.

8) The resistor R23 is adjusted for no drift when there is no input to the modulator.

INSTRUCTOR'S NOTE: Tell students to make sure that R23 is misadjusted and to notice the drift in both directions before zeroing out.

b. The low-power servo amplifier (fig 20-6), an important link in the computer servo loop, amplifies the small ac error signal to drive the servo motors. The mechanical output from these motors is used to position arms in the servos for the final solution of the air defense problem.

INSTRUCTOR'S NOTE: Review data flow, common troubles, and ease of trouble-shooting the LPSA at the control drawer.

2. Power Supplies and Associated Circuits.

a. The ±320v power supply (fig 23-24) is identical to the one in the radar cabinet and is used in the computer to furnish almost all of the dc voltages.

1) This power supply is controlled by the 320V DC POWER switch located on the power-control panel.

2) The strapping for the computer 320v power supply is not interchangeable with the one in the radar cabinet.

INSTRUCTOR'S NOTE: Explain the different methods of strapping and the correct checks to determine proper strapping.

3) When the voltage is within tolerance on the ±250v scale position at the power-control panel, the ±320v power supply is in adjustment.

4) Overloads are eliminated by fused circuits.

5) The more common troubles can be detected visually.

b. The +270v power-supply chassis (fig 23-21) contains not only the +270v power supply but the +75v regulator and -28v supply.

1) The -28v power supply, normally a trouble-free circuit, is used primarily to energize relay circuits.

2) The +75v regulator, a parallel circuit, supplies screen voltage for all dc amplifiers and for all zero-set amplifiers.

3) The +270v power supply furnishes the plate voltage for the output stage of all LPSA used in the computer.

c. The 30-second delay timer (fig 23-1) is interchangeable with the *one in the radar cabinet. It is a protective device used to* allow a warm-up period before energizing the computer completely.

d. Because of a demand for accurate voltages in the computer, the ±250v regulator (fig 23-23) plays a very important role.

1) V3 and V4 establish a reference voltage of -216 volts for the cathode and -108 volts on the grid of V5.

2) V5 detects errors in the -250v output.

3) V6 corrects for errors in the -250v output.

4) V1 detects errors in the +250v output.

5) V2 corrects for errors in the +250v output.

6) Z1 is a comparison circuit for the ±250v outputs.

7) The zero-set amplifier amplifies the difference in error.

8) Common troubles may be detected visually.

9) The adjustment of the ±320v power supply is critical for the proper operation of the regulator.

INSTRUCTOR'S NOTE: Explain, if necessary, the operation of the ±250v regulators.

e. The -200v regulator (fig 23-22).

1) A -200 volts are used in the cathode circuit of the output stage of all dc amplifiers and is a critical voltage. A shunt-type regulator is used to regulate the -200v output.

2) V1 detects error in the -200v output.

3) A -250v is used as a reference voltage.

a) V2 and V3 correct for any error in the -200v output.

b) R16 is not a critical adjustment.

c) The -200v output is primarily dependent upon the correct -320v input.

f. An understanding of ac and dc distribution is important for the purpose of isolating and detecting malfunctions.

3. DC Amplifiers, Input Networks, and Automatic Zero Set (figs 20-2 and 20-3).

INSTRUCTOR'S NOTE: Distinguish the input networks from the dc amplifier proper.

a. The two primary functions of the dc amplifier are:

1) To reproduce voltage with opposite polarity accurately, and

2) To provide isolation between components.

b. One of the prime requisites of the dc amplifier is that it have a zero output with a zero input.

c. For proper operation of these amplifiers, several exact potentials must be supplied to each stage.

1) V1A receives and amplifies the input signal. Bias is provided by a cathode resistor.

2) The output of V1A is coupled directly to V2.

3) The output of V2 is resistance-coupled to V5.

4) V5 is a simple amplifier stage.

5) The output of V5 is sent to the computer modulator.

4. Provisions for Preventing Drift or Oscillation in the DC Amplifiers.

a. Networks of precision resistors included in the amplifier circuit to decrease drift.

b. Automatic zero-set amplifiers.

1) The automatic zero set (AZS) corrects for drift five times per second.

2) The correction signal from the AZS acts essentially as an input voltage to the dc amplifier.

a) This signal is an amplified sample of the input signal.

b) It is opposite in polarity to the input signal.

c) It changes the gain of V1.

d) It returns the dc amplifier output to the correct value.

3) There is one AZS for each of the four banks of dc amplifiers.

4) Any failure of the AZS to correct for drift in a dc amplifier is readily identified by the unbalance light circuit.

INSTRUCTOR'S NOTE: Indicate the location of the unbalance lamps. Show how rapid isolation of the malfunctioning amplifier can be accomplished by switching amplifiers from one bank to another.

5) The correction for drift is not instantaneous.

5. Computations Performed in the Computer.

a. Weighting,

b. Algebraic addition,

c. Multiplication,

d. Differentiating, and

e. Integrating.

6. Different Input Networks are used for Each Different Type of Computation (fig 20-3).

> INSTRUCTOR'S NOTE: Formulas are available for each type of network if needed for proof. Students should not be required to retain any mathematical derivation.

SUMMARY:

1. The computer modulator converts the dc error signals into ac error signals.
2. R23 and R53 are used to correct drifts in the servo loops.
3. The low-power servo amplifier is used to amplify the small error signal which drives the motor.
4. The purpose of the ±320v power supply and regulator circuits is to furnish the computer with exact voltages.
5. The adjustment of the ±320v power supply determines this exactness.
6. The +270 and -28 voltages are less critical than the other voltages. The voltage-check meter may indicate that these voltages are slightly out of tolerance without affecting the accuracy of the computer.

TROUBLESHOOTING COMMENTS:

1. The LPSA in the computer are interchangeable with those in the control drawer. Also, it is more convenient to troubleshoot the LPSA chassis at the control drawer.
2. Alternating-current and direct-current signal substitution may be used at the modulator to isolate troubles.
3. The computer-modulator chassis are interchangeable throughout the computer.

PRACTICAL EXERCISE

COMPUTER SERVO LOOPS AND POWER SUPPLIES

AAFCS M33 SETUP:

1. MAIN POWER switch on.
2. All computer doors open.

EQUIPMENT:

1. Null-voltage test set,
2. Multimeter, and
3. Two-inch screwdriver.

PRELIMINARY TROUBLE:

Loosen J5 on the track modulator until the TRACK green lamp goes out.

DEMONSTRATION:

1. Locate the computer modulators and LPSA.
2. Take the cover off the azimuth servo and point out the drive- motor tachometer and its connections as well as the gearing system.
3. Use a test lead to short the grids of either V1 or V2 of the azimuth modulator. Demonstrate the balance adjustment.
4. Mention that the successful completion of this adjustment will prove that everything between the modulator and the drive motor is working correctly.

5. Demonstrate the use of 6.3 filament voltages for signal-injection purposes in the LPSA.

6. Demonstrate the effects of a missing feedback on the azimuth servo by disconnecting terminal 774.

7. If all the servos are violently oscillating, it is sometimes hard to determine which servo is originating the oscillation. Demonstrate that stopping the faulty servo with a screwdriver will also stop the oscillation in the other servos.

> INSTRUCTOR'S NOTE: Explain that all servos in the computer interact with each other, and, therefore, if one oscillates, it will usually cause all the rest to oscillate.

8. Demonstrate the effects of voltages that are out of tolerance in the computer by removing V4 in the ±250v regulator. Point out the AMPLIFIER UNBALANCE lamp.

9. Monitor the -200v, remove V1, and point out the unbalance lights.

10. Point out that the computer ±320v power supply is identical with the two in the radar cabinet, and that the difference in voltage output is caused by the strapping only.

11. Repeat comments as in 10 for the -28v, +270v, and +75v power supply.

12. Locate the static-test voltage divider. Place the computer in STATIC TEST NO. 1 and the plotting boards in PLOT. Remove or loosen the static-test voltage divider. Point out the effects on the plotting board.

13. Set in a tracking test problem and place the INPUT DATA switch in LOCAL. Demonstrate how the computer will solve a tracking problem with the static-test voltage divider missing.

14. Remove one of the zero-set amplifiers and point out the effects on the computer. Explain why the associated AMPLIFIER UNBALANCE lamp does not glow.

SUGGESTED TROUBLES:

1. Primary.

   a. Replace one of the zero-set amplifiers with a bad tube.

   b. Replace V3 in one of the computer modulators with a bad tube.

   c. Replace any of the tubes in any dc amplifier with a bad tube.

   d. Interchange the spade lugs going to terminals 773 and 774 in the computer (fig 21-7).

   e. Place a bad tube in any of the LPSA.

2. Review.

   Remove terminal 5 on E45/A (fig 19-70).

INSTRUCTOR'S NOTE: Because of the difficulty of the review trouble, it is suggested that the instructor let both groups work on it during the time between primary troubles. Have your explanation ready.

LESSON PLAN

OBSERVED-TARGET COORDINATES SECTION

OBJECTIVE:

1. To present the operation of, and reasons for, the observed-target coordinates section.

2. To explain the purpose of the data converters.

3. To teach a logical method of troubleshooting the observed-target coordinates section.

INTRODUCTION:

To effectively predict the point in space that the target will occupy when the projectile arrives, the computer must, first of all, determine the present position of the target.

The observed-target coordinates (OTC) section performs this function by using information developed in the track radar. The outputs of the observed-target coordinates section are three voltages (X_O, Y_C, and H_O) which electrically define the target's exact present position.

PRESENTATION:

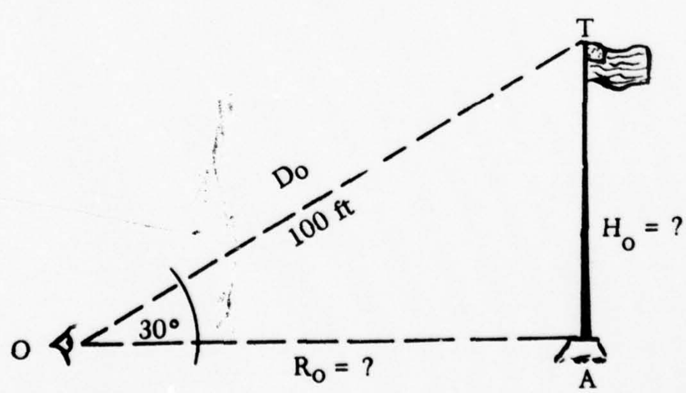

Diagram 2. Solution for H_O and R_O.

Example 1: Many of you have encountered the type of problem shown in diagram 2 in which it is asked, "If a sighting is taken between points O and A and subtends an angle of 30° with a sighting taken between points O and T, what is the height of the flagpole if line OT is 100 feet?"

$$\sin 30° = 0.5$$
$$\therefore H = 100 \times 0.5 = 50 \text{ ft.}$$

What is the horizontal distance to the pole?

$$\cos 30° = 0.866$$
$$\therefore R = 100 \times 0.866 = 86.6 \text{ ft.}$$

This little problem is the same as that which the observed-target coordinates section of the computer is called upon to solve, as can be seen by the following example.

Example 2: What is the target's altitude H_o and ground range R_o when the radar-range computer is set at 10,000 yards and the track antenna is at 400 mils as shown in diagram 3.

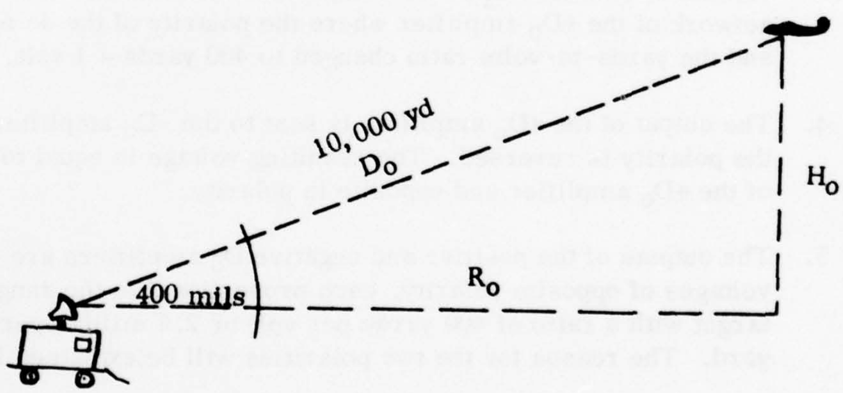

Diagram 3. Finding H_o and R_o.

$$17.7 \text{ mils} = 1°$$
$$\therefore 400 \text{ mils} = 30°$$

The target's altitude will be

$$\sin 30° \times 10,000 = 5,000 \text{ yd.}$$

The ground range will be

$$\cos 30° \times 10,000 \text{ yd} = 8,660 \text{ yd.}$$

In both examples, the length of the hypotenuse of the triangle and the value of one angle was given. The solution for the other two sides of the triangle involved merely multiplying the hypotenuse by either the sine or cosine function of the given angle.

INSTRUCTOR'S NOTE: Have students open their schematics to figure 21-2.

1. The range-data potentiometer is located under the track-range computer in the radar cabinet. The wiper arm is positioned by the range servo to some point on the potentiometer between 0 and -250 volts.

2. When track range is set at 40,000 yards, the output of the D_O potentiometer is -250 volts. At zero range, the output will be zero. With this arrangement, the ratio of voltage to yards is 1 volt = 160 yards.

3. The voltage leaving the D_O potentiometer is a negative dc voltage proportional to the slant range to the target by the ratio of 160 yards per volt. The voltage passes through terminal 172 in the radar cabinet to terminal 42 in the computer and, thence, to the input network of the $+D_O$ amplifier where the polarity of the dc is reversed and the yards-to-volts ratio changed to 400 yards = 1 volt.

4. The output of the $+D_O$ amplifier is sent to the $-D_O$ amplifier where the polarity is reversed. The resulting voltage is equal to the output of the $+D_O$ amplifier and opposite in polarity.

5. The outputs of the positive and negative D_O amplifiers are two equal voltages of opposite polarity, each proportional to the range of the target with a ratio of 400 yards per volt or 2.5 milliamperes per yard. The reason for the two polarities will be explained later.

6. The total output voltage of the $+D_O$ amplifier is impressed across the $+H_O$ portion of the elevation-data converter which is a sine-wound potentiometer.

> INSTRUCTOR'S NOTE: Explain the differences between sine- and cosine-wound potentiometers and linearly wound potentiometers. Mention also that potentiometers can be wound to correspond to any type of function.

7. The wiper arm of the potentiometer is positioned by the elevation of the antenna, and the output voltage is D_O sine E_O which is the solution for H_O or observed altitude.

8. The $-R_O$ section of the elevation-data converter functions in the same manner except that it is wound as the cosine function. The output is D_O cosine E_O, which is the solution for R_O, or observed ground range.

It should be noticed that the $+H_O$ card extends for a short way past the point where it is grounded. This is because in some instances it is necessary to use the computer for elevations below the horizontal.

9. When the observed ground range R_O to the target has been found, the computer must still find the rectangular coordinates of the target's azimuth. The circuits used in this operation will be found on figure 21-3.

> INSTRUCTOR'S NOTE: Explain the location of the four quadrants used in radar, as opposed to the system used in trigonometry, and the polarity of X and Y for each of the four quadrants. Also discuss how the polarity of R_O must change to give the different polarities of X_O and Y_O. This will set forth the reasons for the $+R_O$ and $-R_O$ amplifiers as well as for the quadrant switches shown on figure 21-3.

10. The problem involved in solving for Y_O and X_O when the values R_O and A_O are known is identical to the problem solved in the elevation-data converter.

> INSTRUCTOR'S NOTE: Describe the solution for X_O and Y_O and how the quadrant switches function to provide the proper polarities of output.

11. The INPUT DATA switch can be considered the final portion of the observed-target coordinates section. Inspection of the switch will reveal that the only position of the switch in which data will flow from the OTC to the rest of the computer is the LOCAL position. The next six positions of the switch send voltages to the computer from the static-test voltage divider. These voltages represent prearranged problems, the answers to which are found in the check sheet.

The operating efficiency of the computer can be determined by comparing the exactness of the computer's answer to all six of the problems.

TROUBLESHOOTING:

1. One of the simplest methods of checking the OTC is to set in a test problem with the tracking radar and watch the results on the plotting boards. The test problem may take the following form.

   At the tracking console, set in a nominal value of track range (usually 20, 000 yd), 800 mils elevation, and a slow aided rate in azimuth. Place the computer in FIRE FOR EFFECT, DATA switch to LOCAL, and plotting boards to PLOT. With the aided rate set in, watch the horizontal board to see that a circle is traced at about 14, 140 yards. At the present altitude board, the pen should be at a point 45° above the horizontal. If the foregoing checks are successfully made, it can be assumed that the observed-target coordinates section is normal.

2. The plotting board traces for various malfunctions in the OTC are to be listed as in diagram 4 as well as the probable reason for the malfunction.

3. If the pens of the horizontal plotting board go to the center and stay there, a good possibility is that the $-D_0$ voltage from the range computer is missing.

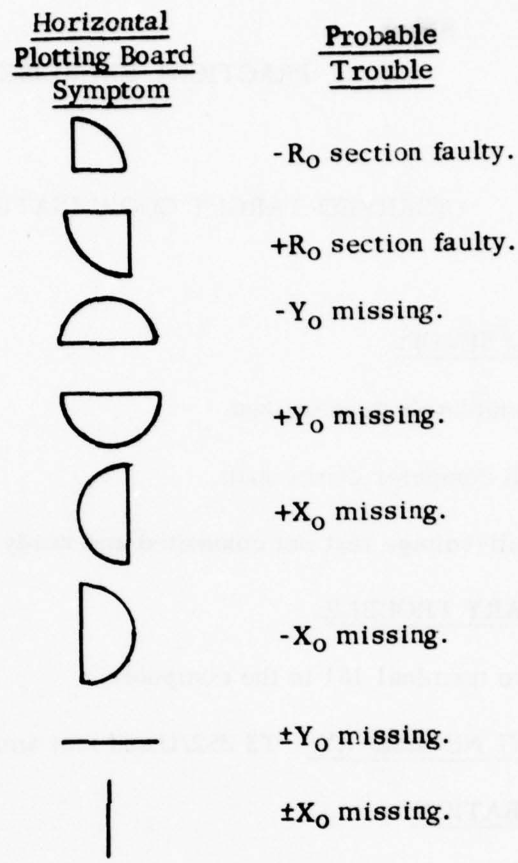

Diagram 4. Observed-target coordinates section symptoms.

4. If the pens go out to the edge of the plotting board even for targets at close range, the trouble is probably a missing ground on the D_o potentiometer in the range computer.

PRACTICAL EXERCISE

OBSERVED-TARGET COORDINATES SECTION

AAFCS M33 SETUP:

1. Completely deenergized.
2. All computer doors open.
3. Null-voltage test set connected and ready for use.

PRELIMINARY TROUBLE:

Remove terminal 181 in the computer.

EQUIPMENT NECESSARY: TS 352/U and test amplifier.

DEMONSTRATION:

1. Set in 20,000 yards track range, 800 mils elevation, and 800 mils azimuth.
2. Use the multimeter to measure the voltage appearing at terminal 172 in the radar cabinet. Explain that this voltage is scaled at the rate of 160 yards per volt and is an electrical representation of the slant range to a target whose coordinates have been set into the track radar.
3. Follow D_0 to the computer and measure it at pin 3 of the $+D_0$ amplifier.
4. Place the computer in LOCAL and the plotting boards in PLOT.
5. Remove D_0 either at 42 in the computer or 172 in the radar cabinet. Point out the effects on the plotting boards and the computer servos.

6. Have the students compute R_0 and H_0 and check their results at 50 and 46 in the computer.

7. Demonstrate how the plotting boards can be used to determine if the observed-target coordinates section of the computer is working normally.

SUGGESTED TROUBLES:

1. Primary.

   a. Remove terminal 173 in the radar cabinet (fig 23-8).

   b. Remove or loosen the static-test voltage divider.

   c. Disconnect terminal 188 in the computer (behind the power panel).

   d. Remove either terminal 56 or 53 (fig 21-3).

   e. Place the AIR SURFACE switch in SURFACE and remove the bulb.

> INSTRUCTOR'S NOTE: Get the student use to making both static tests as well as tracking tests when he checks out the computer.

2. Review.

   a. Use the synchroscope to adjust the ACQ preselector.

   b. Use any ACQ AFC troubles.

   c. Disconnect the video and sync cable behind the clamshell doors.

LESSON PLAN

AZIMUTH, ELEVATION, TIME-OF-FLIGHT, AND FUZE SERVOS

OBJECTIVE:

1. To explain the operation of the azimuth, elevation, time-of-flight, and fuze servos.

2. To explain their associated circuits and components.

INTRODUCTION:

The servos are units that actually produce the data to direct the guns. They compute firing azimuth, firing elevation, time of flight of the projectile, and the fuze number to be cut on the projectile.

INSTRUCTOR'S NOTE: Review a basic servo.

PRESENTATION:

1. The azimuth servo produces the firing azimuth (fig 21-7).

   a. Firing azimuth is determined by inputs $\pm X_p$ and $\pm Y_p$ to the sine and cosine potentiometers. The potentiometers are the main components of the azimuth-servo system.

INSTRUCTOR'S NOTE: Review the inputs to quadrant switches in the azimuth servo.

   b. Two of the four output voltages of the potentiometer are used to drive the azimuth servo.

   1) One output is $-(X_p \cos A)$, and

   2) The other is $+(Y_p \sin A)$.

c. The other two of the four outputs of the potentiometers are used to develop $-R_p$ (predicted horizontal range).

1) One output is $-(X_p \sin A)$, and

2) The other is $+(Y_p \cos A)$.

> INSTRUCTOR'S NOTE: The actual nomenclature for the output voltages of the azimuth sine and cosine potentiometers should only be mentioned and not explained in detail here. Labeling voltages by letters or colors is suggested. Mention also that a negative voltage entering a sum-input network is balanced by a positive voltage when the servo is positioned correctly.

d. When the signals at the azimuth-input network are not opposite in polarity and not equal in amplitude, an error signal is developed.

e. This error will drive the servo system until the two voltage inputs to the summing network are zero.

f. The other input voltages to the summing network are ballistic compensations. These are:

1) J_w, cross wind, to terminal 5 of input network,

2) J_d, drift, to terminal 6 of input network, and

3) Geometric gain to terminal 2 of input network.

> INSTRUCTOR'S NOTE: Explain each of the inputs. Show their relationship to the solution of correct firing azimuth. A drawing illustrating geometric gain for elevation and azimuth is proper here.

g. The relay K5/H22 is associated with the time-of-flight servo (fig 21-11). It effectively increases or decreases the over-all sensitivity of the servo. It is operated when the time-of-flight servo reaches the upper end of the lower limit. The increase or decrease in sensitivity is accomplished by contacts 1 and 9 of K5/H22. The lowest sensitivity of the azimuth servo occurs when the time of flight is maximum.

> INSTRUCTOR'S NOTE: Explain the parallel path to ground for R41, R42, R43, and T6B (fig 21-7).

h. The OPERATION switch (S2C/H19) performs only the function of removing ballistic compensation from the input network when the switch is in TRACKING TEST and DYNAMIC TEST.

i. Part of the output of the amplifier is sent back to the grid of the amplifier through:

1) Capacitor 128, and

2) Varistor I11.

j. This type of feedback will be found throughout the remainder of the computer servos.

k. The modulator and LPSA circuits are the same as those presented earlier in the course.

l. The servo-motor tachometer is the conventional type presented earlier in the course.

> INSTRUCTOR'S NOTE: Show the relationship of the motor tachometer to the azimuth dials and data synchros.

2. The quadrant switches are used to get proper polarity of inputs to the azimuth sine and cosine potentiometers.

3. The elevation servo produces the firing elevation (fig 21-9).

a. Firing elevation is determined by the two inputs, $\pm R_f$ and $\pm H_f$, to the elevation potentiometer.

> INSTRUCTOR'S NOTE: Explain the inputs to the quadrant switch in the elevation servo.

1) R_f is the virtual-target horizontal range and

2) H_f is the virtual-target altitude.

b. R_f is the virtual-target horizontal range and is made up of the following voltages:

1) $-(X_p \sin A)$,

2) $-(Y_p \cos A)$, and

3) R_w, wind compensations.

c. H_f is the virtual-target altitude and is made up of the following voltages:

1) H_p, future-target altitude,

2) H_s, super altitude, and

3) H_w, wind corrections.

> INSTRUCTOR'S NOTE: A detailed explanation of each voltage mentioned is not necessary.

d. The elevation potentiometers are the same as the azimuth potentiometers.

e. The inputs to the elevation-input network are:

1) $-(R_f \sin E)$ at terminal 3,

2) $+(H_f \cos E)$ at terminal 4,

3) Ballistic correction at terminal 5, and

4) Geometric gain at terminal 2.

> INSTRUCTOR'S NOTE: The operation of the elevation-servo system is the same with the exception of the resistor network in the motor-tachometer circuitry. This network is used for slowing down or braking action which prevents damage to the mechanical stops.

4. The time-of-flight servo (fig 21-11) produces a check on the over-all computer solution by a comparison of a $+D_f$ voltage and a $-D_f$ voltage.

   a. The $-D_f$ voltage obtained from the observed and the predicted circuits is in the form of:

      1) $-(H_f \sin E)$ and

      2) $-(R_f \cos E)$.

   b. $+D_f$ voltage is obtained from the ballistic circuit.

   c. Both quantities of $\pm D_f$ depend on time. When they are not equal in amplitude, the time-of-flight servo will attempt to make them equal.

      1) When both quantities of D_f are equal in amplitude, the time-of-flight servo has solved that particular problem.

      2) When the quantities of D_f are unequal in amplitude, the time-of-flight servo hunts for the solution to the problem.

> INSTRUCTOR'S NOTE: Explain that the first time-of-flight voltage is an approximation and that the servo will continue to approximate until the error signal is zero. The approximations are so rapid that information is instantaneous and continuous. A detailed explanation of $-(R_f \cos E)$ and $-(H_f \sin E)$ is not necessary for student maintenance of equipment.

   d. Comparison of $+D_f$ and $-D_f$ is done at the input network.

e. A correction for time of flight is being sent to all prediction circuits, thereby producing a new problem, and also to the ballistic circuits.

1) The new problem introduces to the time-of-flight servo another problem for solution.

2) Time-of-flight corrections are being computed continuously until the correct time of flight is obtained.

f. The remainder of the time-of-flight components are the same as previous servos.

5. The fuze servo (fig 21-13) produces the fuze number to be cut by the automatic fuze setter at the gun.

a. The sum of the main driving voltages to the fuze-servo summing network is negative.

1) The voltage that has the greatest effect on the summing network is from T11B/H48 (fig 21-13). The arm is controlled by the time-of-flight servo.

2) Other voltages for ballistic correction introduced at the summing network are the following.

a) Muzzle-velocity correction voltage at pin 6 from V_{1C}/519 (fig 21-13).

b) FM correction voltage at pin 7 from ballistic-synthesis circuits. This voltage contains effects of time, muzzle velocity, and air density.

c) $-H_p$ correction voltage at pin 11 from predicted-target coordinates (fig 21-6).

3) The zeroing or balancing voltages sent to the input network follow.

a) Fuze voltage at pin 3 of the summing network. This voltage is obtained from the fuze potentiometer.

b) Percentage of fuze voltage at pin 8 of the summing network. This voltage is obtained from potentiometer F_S/H19. This voltage is used when a constant percentage of error in the fuze is noticed. This is not fuze-spot correction voltage.

c) Dead-time voltage at pin 1 of the summing network.

b. The remainder of the fuze servo components are the same as those of previous servos.

INSTRUCTOR'S NOTE: Point out that only one synchro is used in the fuze servo system for transformation of data to the gun.

PRACTICAL EXERCISE

AZIMUTH, ELEVATION, TIME-OF-FLIGHT, AND FUZE SERVOS

AAFCS M33 SETUP:

1. Completely deenergized.

2. Computer doors open.

EQUIPMENT NECESSARY: Multimeter and null-voltage test set.

PRELIMINARY TROUBLES:

1. Terminal 88 in the radar cabinet disconnected.

2. Terminal 27 in the radar cabinet removed.

DEMONSTRATION:

1. Point out and discuss the azimuth, fuze, elevation, and time-of-flight servos and the spot controls.

2. Point out the drive motor as well as the gearing to the dial.

3. Have the students measure the motor excitation, tachometer excitation, feedback, and error voltages with the motor in operation.

> INSTRUCTOR'S NOTE: Caution the students against shorting motor excitation to the corner post with the test leads. This is always happening and can be avoided with a little care.

4. Demonstrate the modulator balance adjustment.

5. Demonstrate the checkout of the servos by signal injection.

6. Demonstrate the effects of a missing tachometer feedback voltage.

7. Remind the students that there is ample opportunity for interchanging of chassis in the servos. If an LPSA or modulator is suspected, it can easily and quickly be changed thereby eliminating it as a possible source of trouble or confirming that it is operating properly.

SUGGESTED TROUBLES:

1. Primary.

   a. Open terminal 773 (fig 21-7).

   b. Place a bad tube in the azimuth modulator.

   c. Open terminal 713 (fig 21-7).

   d. Open terminal 882 (fig 21-13).

   e. Place a bad tube in one of the computer LPSA.

   f. Open the normally closed contact of the UNBALANCE TRANSFER switch.

   g. Remove a tachometer feedback ground.

   h. Remove the azimuth plate-load resistors.

   i. Reverse the zero-set leads 14 and 16 on group 2.

   j. Open any of the following terminals.

706	711	721	726
707	712	722	727
708	713	723	728
709	714	724	729

2. Review.

   a. Misadjust the HPSA.

   b. Place a bad rectifier tube in 30-second delay timer.

LESSON PLAN

PREDICTION COORDINATES AND PREDICTED-TARGET COORDINATES

OBJECTIVE:

1. To present the operation of the prediction circuits in:

    a. Linear prediction,

    b. Tangential prediction, and

    c. Quadratic prediction.

2. To present their associated amplifiers, controls, and meter circuits.

3. To explain the operation and function of the predicted-target coordinates section and its various inputs:

    a. Observed-target coordinates,

    b. Parallax,

    c. SDC, and

    d. Testing voltages.

4. To explain the function and operation of the minimum-altitude circuits and controls.

INTRODUCTION:

The prediction circuit is the sixth sense of the computer and provides the lead voltages. Without these lead voltages we would be limited to engaging stationary targets.

PRESENTATION: (fig 21-4).

1. The $-\dot{X}$ amplifier functions as a speed-detecting circuit for the X coordinate. The changing X_o input at pin 3 of the $-\dot{X}$ input network is differentiated to obtain an output which represents a rate of change of X_o voltage or, simply, the speed of the target in the X coordinate. This output is symbolized by $\dot{X}$. The voltage $\dot{X}$ represents target speed in an east-west direction.

   a. The scale factor of the $-\dot{X}$ input network is 15; therefore, the output is 15X.

   b. Its input is controlled by the prediction-control circuit, K11 (relay inside the -X network, pin 7 and 9).

   c. The output of $-\dot{X}$ amplifier is sent to the:

      1) $+\ddot{X}$ input network,

      2) $+\dot{X}_4$ input network,

      3) $+\dot{X}_8$ input network, and

      4) The $-\dot{X}$ overload relay.

> INSTRUCTOR'S NOTE: Should the output of the $-\dot{X}$ amplifier exceed a rate of 500 yards per second, indicated by the rate meter, the overload disables the input to the $-\dot{X}$ amplifier through the overload circuit and the other two rate amplifiers.

2. The $+\dot{X}_4$ amplifier smooths and multiplies the input of the $\dot{X}$ amplifier.

   a. The scale factor of the amplifier is 2.4; therefore, its output is $36\dot{X}$.

   b. In smoothing the input, the output is delayed 1.6 seconds.

c. The input to the network is controlled by a relay inside the $+\dot{X}_4$ network and is varied by the OPERATION switch located on the rate-indicator panel.

d. In STATIC TEST No. 5, a test voltage (TST) is applied to pin 4 of $+\dot{X}_4$ network to check out a portion of the prediction circuit with a static voltage.

e. An SDC voltage (system-delay compensation) is applied to the $-\dot{X}_p$ summing network from $-\dot{X}$ input network and $+\dot{X}_4$ amplifier.

   1) Over-all delay of system is five milliseconds.

   2) Networks producing this voltage are:

      a) R3/H55,

      b) R4/H55,

      c) R5/H55, and

      d) R6/H55.

INSTRUCTOR'S NOTE: All the above networks are on figure 21-4. This SDC is a "fudge" factor.

f. The quantity X_g applied to the $-X_p$ input network is a correction for parallax.

g. The data from $+\dot{X}_4$ data-smoothing networks (DSN) is applied to the ungrounded side of T10A/H48 through K21 and to the rate meters.

   1) The operation of K21 is controlled by the DATA SMOOTHING switch.

   2) The rate meters are kept on scale by multiplying circuits.

   3) The arm of potentiometer T10A is positioned by the time-of-flight servo.

3. Both data-smoothing networks will produce an output of $36\dot{X}$ which, through the proper positioning of contacts 5, 7, and 8 of K21/H23, can be applied to the ungrounded side of T10A in the linear-prediction operation.

   a. The delay in the $\dot{X}_4$ network is 1.6 seconds.

   b. The delay in the $\dot{X}_8$ network is 3.2 seconds.

4. Tangential prediction.

   a. Tangential prediction will compensate for the delay in the $+\dot{X}_4$ DSN by providing an additional $24\ddot{X}$ prediction voltage at the centertap of T10A. The centertap of T10A corresponds to 15 seconds time of flight.

   b. Tangential prediction will compensate for the delay in the $+\dot{X}_8$ DSN by providing an additional $48\ddot{X}$ prediction voltage at the centertap of T10A.

   c. For optimum accuracy, this type of prediction is limited to a time of flight of less than 15 seconds.

   d. The $+\ddot{X}$ amplifier differentiates rate voltage and produces an acceleration voltage. The output symbol $\ddot{X}$ represents the target acceleration in an east-west direction.

      1) The scale factor of the amplifier is 15; therefore, the output is $225\ddot{X}$.

      2) The input to the $\ddot{X}$ amplifier is determined by a relay K12 in the input network.

      3) The $\ddot{X}$ amplifier has a built-in six-second DSN to reduce false outputs.

   e. In STATIC TEST No. 6, a test (TST) voltage is applied to check out part of the acceleration circuit.

f. The output of the $\ddot{X}$ amplifier is applied to the acceleration meter and relays K23 and K22.

1) Relays R23 and K22 are controlled by the operation of the PREDICTION switch in the rate-indicating panel.

2) Energizing of K22 (tangential selection) provides 24$\ddot{X}$ correction to the fixed 15-second centertap of T10A. This is done by placing an additional voltage divider into the circuit. This voltage divider consists of:

a) R3/H48,

b) R4/H48, and

c) R5/H48.

<u>INSTRUCTOR'S NOTE</u>: This voltage divider is found on figure 21-4, and similar ones exist for Y and H.

3) The voltage at the centertap of T10A is equivalent to 24$\ddot{X}$.

4) Time of flight from 0 seconds up to 15 seconds is used in tangential prediction.

5. Prediction in quadratic selection provides an additional acceleration-voltage connection to a fixed 15-second centertap of T8A. Quadratic prediction is the sum of linear, tangential, and quadratic correction.

a. For optimum accuracy, time of flight is limited to less than 15 seconds.

b. The correction felt at the centertap of T8A/H48 is 112.5$\ddot{X}$ because of a drop through resistor R20/H48.

c. The arm of potentiometer T8A/H48 is positioned by the time-of-flight servo.

d. The centertap of T8A represents 15 seconds time of flight. This potentiometer is wound quadratically from 0 to 15 seconds time of flight.

e. From 15 to 36 seconds time of flight, the amount of quadratic prediction is removed linearly.

6. The system-delay compensation correction at pin 7 of the $-X_p$ network is a compensation voltage for delays resulting from antenna lag and electrical transmission. It is available from the $-\dot{X}$ network (pin 4) when prediction circuits are out.

7. Parallax correction, symbolized by X_g, applied to pin 6 of $-X_p$ network, is a voltage that represents the displacement between radar and guns in the X coordinate.

a. Its input is controlled by the parallax potentiometers located on the correction panel.

b. A maximum correction of $\pm 2\frac{1}{2}$ volts is available.

8. The altitude-limit circuit (fig 21-6) limits the output of the $-H_p$ amplifier to prevent the guns from shooting into obstructions. Minimum altitude is established by the MINIMUM ALTITUDE knob located on the correction panel.

a. The limiting circuit is a voltage divider in the output of the $-H_p$ amplifier.

b. V1/H27 functions to detect unbalance caused by the minimum-altitude circuit. Unequal conduction of V1 causes the MINIMUM ALTITUDE lamp, located at the rate-indicator panel, to flicker.

c. Special consideration should be given to the output stage of the $-H_p$ dc amplifier because of the minimum-altitude circuit (fig 21-6).

> INSTRUCTOR'S NOTE: The material covered was for the X coordinate. The H and Y coordinates are similar. Some thought should be given to polarities in various quadrants, especially output polarity at the $-X_p$, $-Y_p$, and $-H_p$ amplifiers. Give a detailed explanation of the $-H_p$ minimum-altitude circuit (fig 21-6).

SUMMARY:

1. Prediction circuits function only in DYNAMIC, FIRE FOR EFFECT (after the TRACKED button is depressed at the track console) and in part, when STATIC TEST NO. 5 and STATIC TEST NO. 6 are used.

2. In linear prediction, a voltage representing speed of the target is presented at pin 4 of the $-Y_p$ network.

3. In tangential prediction, in addition to the linear-prediction voltage, we have a voltage introduced at the fixed 15-second centertap of T10A to compensate for delay occuring in the data-smoothing network.

   a. For the 4-second DSN, a correction of 1.6-second delay.

   b. For the 8-second DSN, a correction of 3.2-second delay.

4. In quadratic prediction, the sum of three prediction voltages is present: the linear- and tangential-prediction voltages at pin 4 and the quadratic-prediction voltage at pin 5 of the $-X_p$ network.

5. The ACCELERATION and RATE meters monitor the outputs of the $\ddot{X}$ and the $+\dot{X}_4$ or $+\dot{X}_8$ amplifiers, respectively.

6. Present-position voltage X_o is always present at pin 3 of the $-X_p$ network.

7. Parallax corrections at pin 6 of the $-X_p$ network are determined by the setting of the PARALLAX potentiometers located at the correction panel.

8. The system-delay compensation voltage at pin 7 of the $-X_p$ network is a very small correction (0.005X).

9. The minimum-altitude circuit limits the output of the $-H_p$ amplifier.

   a. This limit is determined by the setting of the MINIMUM ALTITUDE knob on the correction panel.

   b. Operation beyond limits is indicated by the flickering of the MINIMUM ALTITUDE lamp at the rate-indicator panel.

PRACTICAL EXERCISE

PREDICTION COORDINATES AND PREDICTED-TARGET COORDINATES

AAFCS M33 SETUP:

Completely deenergized and all computer doors open.

EQUIPMENT NECESSARY:

1. Multimeter,
2. Null-voltage test set, and
3. Check sheet.

PRELIMINARY TROUBLE:

Short terminals 1 and 2 of T4 (fig 2-2).

DEMONSTRATION:

1. Perform a dynamic test using the log book.
2. Explain how STATIC TEST NO. 5 will indicate troubles in the rate circuits.
3. Explain how STATIC TEST NO. 6 will indicate troubles in the acceleration circuits.
4. Demonstrate the use of the check sheet in checking out the correct values of Y_p, K_p, and H_p.
5. By disconnecting terminal 784 in the computer, demonstrate that the first-derivative networks are prime suspects if STATIC TEST NO. 5 is off tolerance.

6. By disconnecting terminal 795, demonstrate that if STATIC TEST NO. 6 is off tolerance, the second-derivative networks are good suspects.

> INSTRUCTOR'S NOTE: Both of the above assumptions can be made, provided that the first four static tests read correctly. Demonstrate the procedure for setting up the computer servos for the null-voltage check.

7. Before the groups are put to work on a trouble, it would be advisable to misadjust all the controls on the power panel and computer control panel. This procedure should be continued until the students have become acquainted with the preliminary check-out procedure.

8. Have the students give the computer a complete static test as well as a tracking test (with plotting boards) at the end of each trouble.

SUGGESTED TROUBLES:

1. Primary.

   a. Open terminal 108 (fig 21-6).

   b. Place a bad tube in $\dot{X}_4$ amplifier (fig 21-4).

   c. Open terminal 792 (fig 21-6).

   d. Open any of the following terminals:

781	788	795	798
784	789	796	799
785	794	797	

   e. Open any of the following terminals:

706	711	722	728
707	712	724	
708	714	726	

2. Review.

a. Open terminal 5 of E45 in the radar cabinet.

b. Open terminal 25 of E45 in the radar cabinet.

c. Loosen the range-input network Z3 till the RANGE handwheel loses control of the range servo.

LESSON PLAN

BALLISTIC SYNTHESIS

OBJECTIVE:

1. To introduce the use of ballistic correction.

2. To acquaint the student with the ballistic unit and its associated components.

3. To develop a logical sequence for troubleshooting the ballistic circuits.

INTRODUCTION:

With the advances in the capabilities of aircraft, the fire control of batteries becomes increasingly complex. Effective rounds must be discharged since there is a limited time of engagement. All standard and nonstandard ballistic conditions are compensated for in the computer. The purpose of the ballistic-synthesis section is to introduce these quantities into the computer.

PRESENTATION:

1. The corrections called ballistics are the fourth step of the air defense problem. It must be added to previous information to hit a target. Ballistic information is a correction voltage for non-standard conditions.

   a. Standard conditions for 90-mm guns are:

      1) Muzzle velocity is 2, 675 feet per second,

      2) Air density is 100 percent,

      3) Powder temperature is 70°F.,

4) Air temperature is 59°F., and

5) Projectile weight is "two squares."

> INSTRUCTOR'S NOTE: Enumerate the standard conditions for the computer used with the 120-mm guns.

b. Correction voltages for the above are developed in potentiometers.

1) These potentiometers are called ballistic-synthesis potentiometers.

2) They are located at the correction panel and in the four servo units.

3) The main source of voltage for these potentiometers is 250 volts dc.

4) The arms of the potentiometer are positioned by one of three servos (az, El, time-of-flight), or by the controls on the correction panel.

c. The compensation voltages picked off the potentiometer arms will correct the trajectory of a projectile so that it will hit a target even though nonstandard conditions exist.

> INSTRUCTOR'S NOTE: Show the various potentiometers in the ballistic unit (figs 21-16 to 21-18). Point out potentiometers on correction panel (fig 21-19). Indicate which potentiometer arms are moved by various servos and which potentiometer arms are moved by the controls on the correction panel.

d. These potentiometers cannot be operated separately since the various servos are interrelated.

e. These potentiometers are empirically wound according to firing tables calculated for the ballistic effects on a projectile.

f. The time-of-flight servo is the main positioning component used for the solution of the ballistic-synthesis problem.

g. Diagram 5 is a block diagram of the ballistic-synthesis solution.

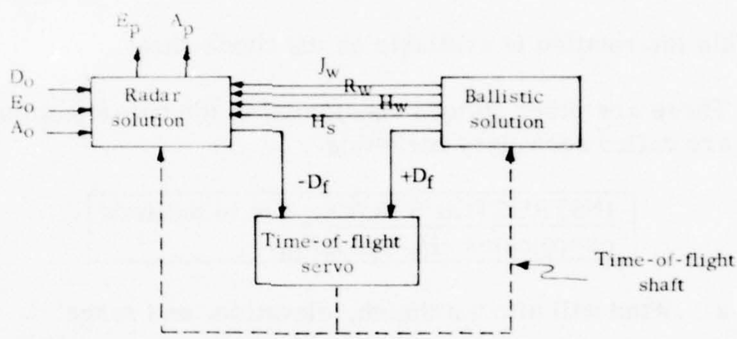

Diagram 5. Ballistic-synthesis solution.

INSTRUCTOR'S NOTE: Review purpose of D_f on the large block. Use illustration to explain the synthesis of D_f. Relate illustration to figure 21-16.

1) When $-D_f = +D_f$, the computer solution to a problem is solved.

2) The $+D_f$ is produced by the ballistic units.

h. The input networks used in ballistic synthesis are similar to the others found throughout the computer.

i. The dc amplifiers are identical to the others found throughout the computer.

j. Amplifiers are used to isolate and produce certain polarity voltages needed.

> INSTRUCTOR'S NOTE: Point out those amplifiers in the ballistic-synthesis system that are used to isolate and produce certain polarities of voltages needed.

k. The voltages used at the input networks are negative, positive, or any combination of the two.

Note: This information is available on the check sheet.

2. There are other factors considered in the ballistic solution. These are called secondary ballistics.

> INSTRUCTOR'S NOTE: Tie in ballistic coordinates $-H_S$ and ΔF_m.

a. Wind will affect azimuth, elevation, and range.

1) Wind affecting range: $-R_W$, a head or tail wind.

2) Wind affecting azimuth: J_W, a cross wind.

3) Wind affecting elevation is $-H_W$.

b. The circuitry for wind corrections is found on figure 21-18.

c. The potentiometer A9/H46 is a sine-cosine potentiometer to determine wind components for azimuth and range.

> INSTRUCTOR'S NOTE: Explain that, to hit a given target with a cross wind, the guns must be aimed into the wind.

d. There are three factors that determine the effects of the wind. These are the inputs to the $+T_W$ network (fig 21-18).

1) Muzzle-velocity correction, V_{1C}.

2) Time-of-flight correction, T_{11B}.

3) Slant range to the virtual target $+D_f$.

e. The voltage $+T_W$ must go through the OPERATION switch S2D/H19 (fig 21-18) for most of the positions of this switch. Exceptions are:

1) In TRACKING TEST, and

2) In DYNAMIC TEST.

f. The only purpose of the $-T_W$ amplifier is to have a negative voltage at the potentiometer A9.

> INSTRUCTOR'S NOTE: Point out to the students the potentiometers (fig 21-18) which are positioned by hand. Correlate with potentiometers on figure 21-19.

g. The outputs of the secondary ballistic circuits are $-J_W$, $-R_W$, and $-H_W$.

1) These are all used in the ballistic-synthesis system only.

2) The polarity of these wind corrections depends on the difference in azimuth of the projectile and the wind.

3) The polarity is automatically adjusted by the sine-cosine potentiometer A9 and the correction-panel potentiometers.

h. Secondary ballistic corrections must be made for muzzle whip and drift.

> INSTRUCTOR'S NOTE: Mention corrections for jump and droop.

1) This correction is called -JD.

2) The magnitude and polarity are variable.

3) The time-of-flight servo is the controlling component unit for adjusting JD.

4) The information JD is fed into the azimuth servo through the OPERATION switch (fig 21-7).

5) The voltage JD is out in TRACKING TEST and DYNAMIC TEST.

> INSTRUCTOR'S NOTE: A brief explanation of drift and muzzle whip may be needed to explain the need for these voltages.

SUMMARY:

1. The voltage $+D_f$ is a quantity describing the slant range to the virtual target.

2. The voltage $+D_f$ is a comparison voltage to $-D_f$. When the algebraic sum of these two is zero, the computer problem is solved.

3. The scale-factor voltage S (fig 21-19) from air-density potentiometer terminal 16 is used to insure correct plots on the predicted altitude board for varying ballistic factors.

4. The voltage AFM (fig 21-13) is used in the fuze servo to correct the fuze number for the effects of air density.

5. The voltage $-H_s$ (fig 21-17) is used to correct firing elevation deviations due to the pull of gravity.

6. The voltages $-J_w$, $-R_w$, and $-H_w$ (fig 21-18) are used to correct for wind effects on azimuth, range, and elevation, respectively.

7. In TRACKING TEST and DYNAMIC TEST, the voltages H_s, J_w, R_w, and H_w are not used.

8. In other positions of the OPERATION switch, these voltages are placed into the ballistic-coordinate circuit.

9. The remainder of the period will be devoted to a discussion of the block diagram of all the components of the ballistic-synthesis circuits and their associated components.

INSTRUCTOR'S NOTE: As the arms of any of the potentiometers are moved upward, they correspond to a numerical increase of that function.

PRACTICAL EXERCISE

BALLISTIC SYNTHESIS

AAFCS M33 SETUP:

System completely energized and all computer doors open.

EQUIPMENT NECESSARY:

1. Multimeter,
2. Check sheet,
3. Test amplifier, and
4. Null-voltage test set.

PRELIMINARY TROUBLE:

1. Open terminal 88 in the radar cabinet.
2. Remove fuze XF13/A15 and its associated indicator lamp.
3. Open terminal 99 in the radar cabinet (fig 19-20).

> INSTRUCTOR'S NOTE: The instructor's demonstration should not be delayed while the students find the preliminary troubles. It is suggested that the secondary group work on these troubles while the primary group is engaged in troubleshooting the computer.

DEMONSTRATION:

1. Show how the log book used to check the computer ballistic computations.

2. Demonstrate how varying any of the ballistic correction dials alters computer's solution to a given problem. Demonstrate with the static tests.

3. Show students how to aline the correction potentiometers.

4. Show the location of all the components associated with the ballistic-synthesis section.

SUGGESTED TROUBLES:

1. Primary.

   a. Open any of the following terminals:

      1) 734 (fig 21-17),

      2) 737 (fig 21-16), and

      3) 878 (fig 21-17).

   b. Place a bad tube in the $-H_S$ amplifier (fig 21-17).

   c. Open any terminal in the ballistic-synthesis section.

2. Review.

   a. Short the terminating resistor on E12 in the tracking console.

   b. Short the plates of C1 (fig 15-4) with a short piece of wire.

LESSON PLAN

THE SUMMING AMPLIFIER

OBJECTIVE:

To explain, as simply as possible, how the computer transforms the data it has developed into firing information, and to present a brief account of the problems solved by the summing networks in the various servo groups.

INTRODUCTION:

Up to this point in our study of the computer, we have gone to great lengths in explaining how various bits of information regarding present and future position of the target, as well as ballistic corrections, are developed in the computer. We will now undertake to explain how this information is put together and arranged in a form that can be used by the guns.

PRESENTATION:

INSTRUCTOR'S NOTE: Draw a simple block diagram of a closed servo loop on the blackboard.

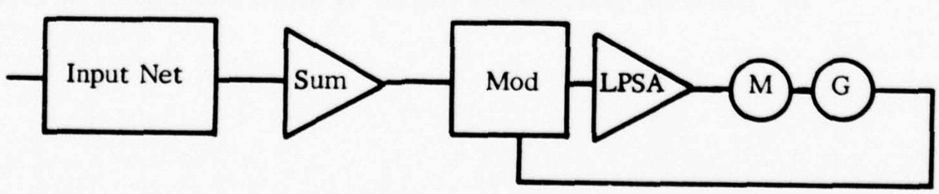

Diagram 6. Closed servo loop.

1. For the servomotor in diagram 6 to come to rest, it is obvious that the input to the input network must be removed.

2. In the case of the azimuth servo, some means must be devised whereby the azimuth servomotor comes to rest when the value of firing azimuth A_f is correct.

3. If two inputs, equal in potential but of opposite polarities, are sent to the above input network, the effective input to the summing amplifier is zero, and the motor comes to rest.

4. In the computer, a pair of potentiometers solve a similar problem. This problem yields both negative and positive answers which are sent to the input network of the summing amplifiers. The circuits are arranged so that, when the value of A_f is correct, the answers to the problem involved are equal and of opposite polarity. In this case, the azimuth servo comes to rest. If the two answers are not equal, the azimuth servomotor turns until it finds a point where there is no input or where the two answers equal each other.

5. We will now demonstrate the solution for the angle A_f.

   a. *Assuming that the projectile travels a perfectly flat trajectory* and is unaffected by atmospheric conditions, the guns can be positioned in azimuth by the values of X_p and Y_p (diag 7). The guns will be positioned at angle A_f to hit a target at the intercept point.

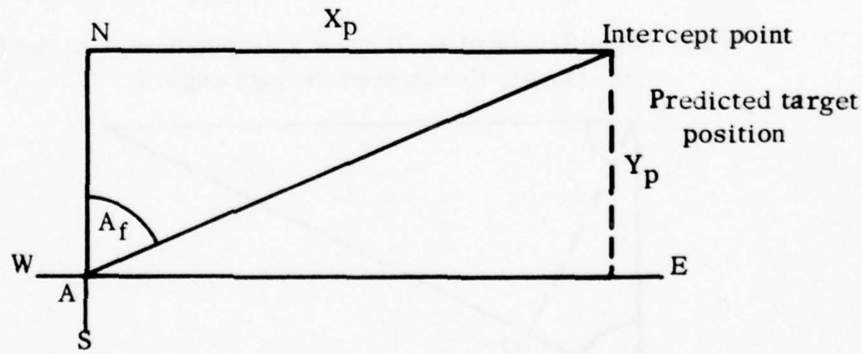

Diagram 7. Solution for A_f.

b. The values of X_p and Y_p have been determined by the predicted-target coordinates section of the computer. The only unanswered question is, "What is the value of A_f?"

c. Forgetting, for a moment, the purpose of the computer, let us examine a right triangle (diag 8) that is congruent to the triangle shown in diagram 7.

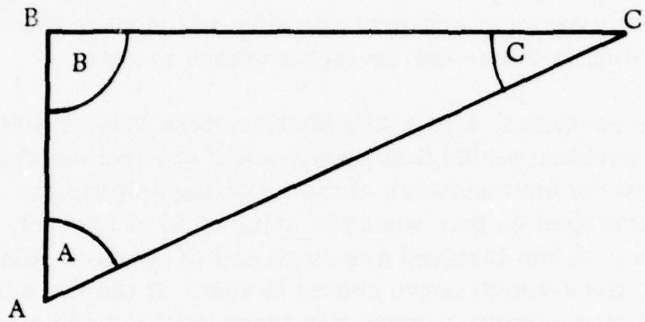

Diagram 8. Triangle congruent to triangle in diagram 7.

1) $\angle B = 90°$.

2) $\angle A + \angle C = 90°$.

3) $\angle A + \angle B + \angle C = 180°$.

4) The line AC is the hypotenuse of the triangle.

d. We will now (diag 9) draw a perpendicular to the hypotenuse of the triangle that passes through angle B.

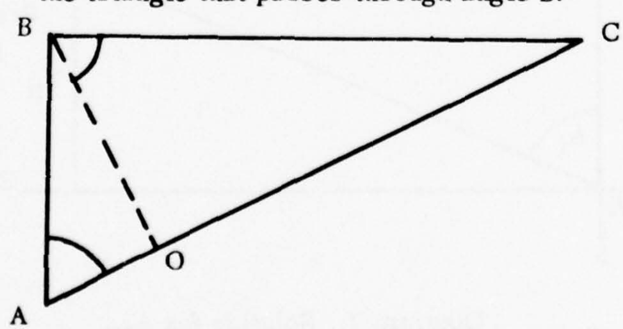

Diagram 9. Drawing a perpendicular to line AC of diagram 8.

e. We will call the perpendicular OB.

f. If we had to, we could easily prove that ∠OAB is equal to ∠OBC, but for now let us just take it for granted.

g. If we wanted to find the value of the line OB, we could use the formula: AB sin ∠OAB = OB.

> INSTRUCTOR'S NOTE: This formula might raise a little commotion with the class, but it should not be too hard to clear up this confusion with a brief explanation.

h. Since ∠OAB is equal to ∠OBC, we could also solve, in the following manner, BC sin ∠OBC = OB.

> INSTRUCTOR'S NOTE: If you can get these two formulas across, the rest of this class should proceed with ease. It might be well to spend a few minutes to make sure the students have absorbed the two formulas as well as to reiterate that the same principles are involved in solving for E_f and fuze.

i. Returning now to the block diagram of the azimuth servo, we will be able to use the information we have just discussed in learning how the computer solves for A_f. The values X_p, $-X_p$, Y_p, and $-Y_p$ are sent to a pair of quadrant switches. The quadrant switches are used for nothing more than to make the values of X_p and Y_p conform to the system of coordinates that is used in the computer.

> INSTRUCTOR'S NOTE: Review how the coordinate polarity varies for each of the four quadrants.

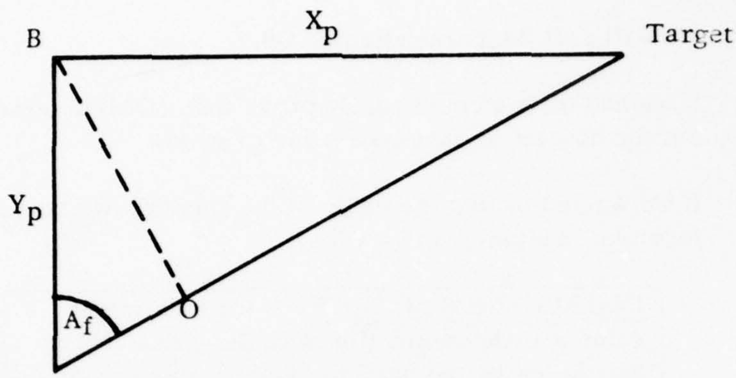

Diagram 10. Target in the first quadrant.

j. Potentiometer A_{11} is arranged in such a manner that, when the azimuth servo positions the wiper arm, it solves for the value of line OB (diag 10) by using the formula X_p cosine A_f. A negative voltage representing the solution for the value of OB is sent to the azimuth-sum input network.

k. Potentiometer A_{10} yields a positive solution for OB by using the formula Y_p sine A_f which is also sent to the input network.

l. The servo loop will drive until a point is reached where $(Y_p \sin A_f) - (X_p \cos A_f) = 0$. At this point, the input to the input network is zero, and the motor comes to rest.

m. The fine and coarse synchros that are driven by the azimuth servomotor will then develop the data regarding A_f that is sent to the guns.

n. Positive values representing wind and drift corrections are also sent to the input network, adding to the positive value of $+(Y_p \sin A_f)$. This means that for the amplifier input to remain at zero we must position A_{11} so that a larger value of $-(Y_p \cos A_f)$ is obtained. The azimuth servomotor will continue to move the arm of A_{11} until $+(Y_p \sin A_f) + (A_d) + (J_w) - (Y_p \cos A_f) = 0$. When this point is reached, the servo comes to rest, and the gun information has been corrected for wind and drift.

INSTRUCTOR'S NOTE: Turn to figure 21-7 and spend a while going over the operation and function of components.

6. We will now cover the solution for firing elevation.

a. The solution for firing elevation is very similar to the solution for firing azimuth (diag 11).

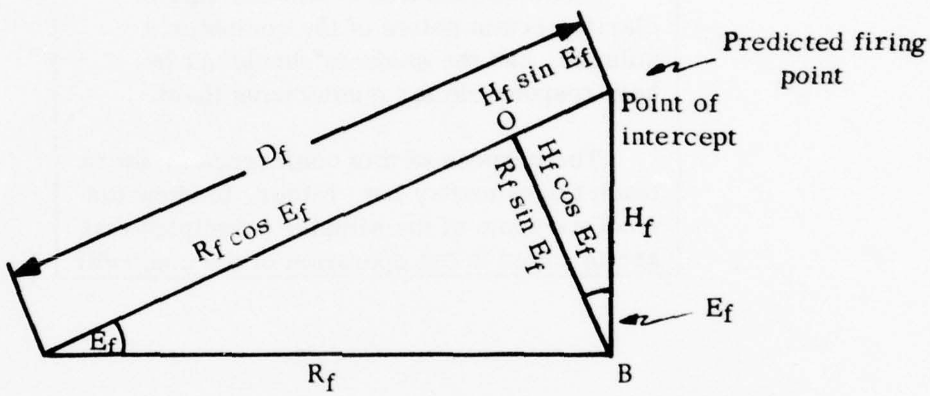

Diagram 11. Servo solution for firing elevation.

b. The value of line OB is again solved by two different equations, and the answers are given two polarities. The answers cancel each other when the firing elevation is correct.

INSTRUCTOR'S NOTE: Place a block diagram drawing of the elevation servo group on the board.

c. The values that are sent to the input network are $-(R_f \sin E_f)$ and $+(H_f \cos E_f)$. Any corrections necessary to compensate for the trajectory of the projectile are also sent to the network as positive voltages, thereby changing the servo position at which zero input is attained. When the servo comes to rest, the firing elevation has been corrected by amounts proportional to the correction voltages introduced to the input network.

7. The time-of-flight servo uses the values $-(R_f \cos E_f)$ and $-(H_f \sin E_f)$ to compare with $+D_f$. It can be seen that both values represent the hypotenuse of the same triangle. When the equal but opposite solutions cancel at the time-of-flight input network, the time of flight has been solved.

> INSTRUCTOR'S NOTE: Explain how fuze can now be determined and start a little review.
>
> The formulas are to be used only to clarify certain points of the computer's solution, and the students should not be held responsible for memorizing them.
>
> The purpose of this conference is not to teach trigonometry but, rather, to show the students some of the simpler principles that are involved in the operation of the computer.

PRACTICAL EXERCISE

SERVO GROUPS

AAFCS M33 SETUP:

Completely deenergized with all computer corrections misadjusted.

EQUIPMENT NECESSARY:

1. Null-voltage test set,
2. Multimeter, and
3. Check sheet.

PRELIMINARY TROUBLE:

Terminal 107 (fig 21-6) removed.

DEMONSTRATION:

1. On the azimuth summing amplifier input network, demonstrate how the inputs on pins 3 and 4 approximate each other in voltage but are of opposite polarity.
2. Point out and discuss the purpose of the quadrant switches.
3. At the elevation input network, demonstrate how the inputs at 3 and 4 cancel each other. Use static tests and leave 270V DC POWER switch OFF.
4. Point out the quadrant switches associated with the elevation servo. Mention why only two quadrants are necessary in elevation as opposed to four in azimuth.

5. With the 270V DC POWER switch OFF, set up the servos for STATIC TEST NO. 2. Measure inputs to terminals 3 and 4 of the azimuth input network. Move the azimuth dial about 200 mils in either direction. Re-measure the inputs on terminals 3 and 4. Explain what happened.

6. Enter into a review discussion of the computer as so far covered. Do not forget to mention that if the solution for firing azimuth is wrong, elevation, time of flight, and fuze will also be in error. If only elevation is wrong, time of flight and fuze will be in error, with azimuth slightly off, etc.

SUGGESTED TROUBLES:

1. Remove any of the following terminals and replace with dummy leads.

706	713	724
707	714	726
709	721	727
711	722	728
712	723	729

2. Remove the springs from any of the quadrant switches.

3. Remove terminal 11 of E75.

4. Use any of the troubles previously listed in the computer practical exercises.

LESSON PLAN

TRIAL FIRE INDICATOR AND TIME-TO-BURST INTEGRATOR

OBJECTIVE:

To discuss and explain:

1. The function and purpose of the trial fire indicator and time-to-burst integrator,

2. The various channels of the trial fire indicator,

3. The operation of the time-to-burst integrator, and

4. The velocity fire problem.

INTRODUCTION:

The trial fire indicator (TFI) is used, in conjunction with the time-to-burst integrator (TBI) circuits of the computer, to determine the muzzle velocity (MV) of air defense guns. Distance and time are the basic factors affecting the determination of valid firing data. Both of these factors are determined by velocity fire using the trial fire indicator and the time-to-burst integrator. The time-to-burst integrator is the device used for computing the time element. The indicator gives a display of action around a predetermined point. If a correction for range is to be made, the muzzle-velocity potentiometer is used to correct the error. The new position of the MUZZLE VELOCITY dial is the developed MV of the gun that is shooting, and this is what we are trying to determine. Therefore, we have a "large stopwatch" which is used to measure projectile time of flight to a definite range, determined range, or velocity. These "stopwatch" components, actually electronic circuits, start a timing action which begins when the gun is fired and ends when the projectile explodes. The student should know both unit operations.

PRESENTATION:

1. The trial fire indicator is located in the extreme upper right corner of the tracking console.

2. The trial fire indicator is made up of four channels. They are the:

   a. Sweep channel,

   b. Video channel,

   c. Signal-selector channel, and

   d. Bias channel.

INSTRUCTOR'S NOTE: Present block diagram with general statements of each channel (fig 18-1).

   1) The sweep channel produces two three-microsecond saw-tooth waveforms for the horizontal deflection coils. Sweep generator circuit is shown in diagram 12.

      a) *This sweep channel consists of:*

         1. Expansion amplifier V2,

         2. Paraphase amplifier V3A,

         3. Sweep generator V3B,

         4. Amplifier V4,

         5. Sweep amplifier V5 and V6, and

         6. Transformers T2 and T3.

      b) The sweep channel produces a signal to be used in the selector channel.

      c) The sweep channel also produces a signal to be used in the unblanking on the TFI.

INSTRUCTOR'S NOTE: A detailed operation of each tube is not needed. However, a short review on sweep generation is necessary. All inputs and outputs should be presented.

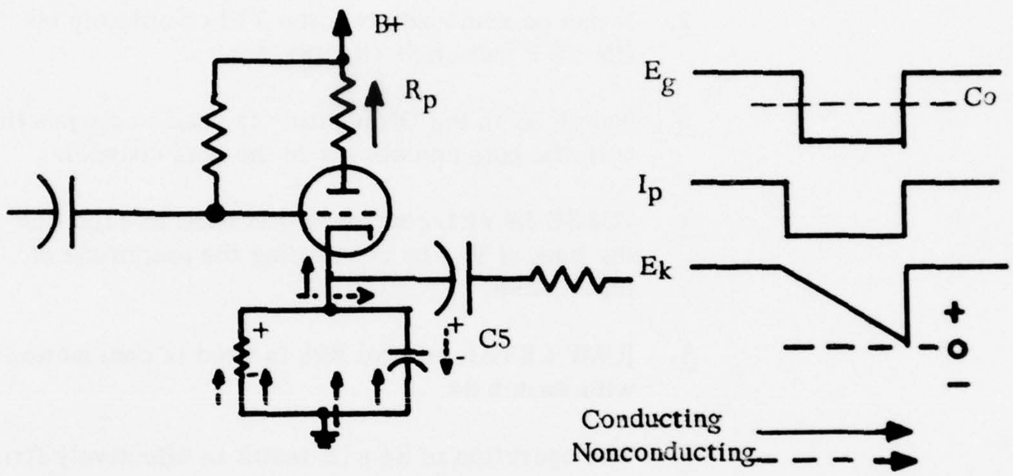

Diagram 12. Simple sweep generator circuit.

2) The video channel produces the presentation of video on the trial fire indicator by applying the video to the bottom vertical deflection plate.

a) The video channel consists of:

1. Video amplifier V7,

2. Video amplifier V8, and

3. Pulse amplifier V19.

b) The video channel produces two other signals:

1. One for the bias circuit, and

2. One for the signal-selector circuit.

c) The input to the pulse amplifier V19 (fig 18-2) is the acquisition range mark.

1. The output of V19 can be used in all three channels of the TFI.

2. It can be removed from the TFI completely by ON-OFF switch S5 (fig 18-2).

3. Switch S5 in the ON position is used in conjunction with the bias adjustment in the bias channel.

4. PULSE LEVEL control R94 is used in adjusting the bias of V11 by controlling the amplitude of input pulse.

5. JUMP LEVEL control R96 is used in conjunction with switch S4.

6. The operation of S4 will result in effectively firing V11 and stopping the time-to-burst integrator.

> INSTRUCTOR'S NOTE: Use pictorial explanation for adjustments above.

3) The signal-selector channel is similar to a gating circuit in that it is operated properly only when the coincidence tube V9 conducts.

a) Video and expansion pulse in coincidence causes V9 to conduct.

b) Tube V9 will conduct only for length of expansion pulse (three microseconds).

c) Tube V10 amplifies and inverts the three-μsec video pulse.

d) Tube V17B, a cathode follower, is for isolation.

e) The pulse stretcher is CR1 and its associated components.

f) The operation of the pulse stretcher is shown in diagram 13.

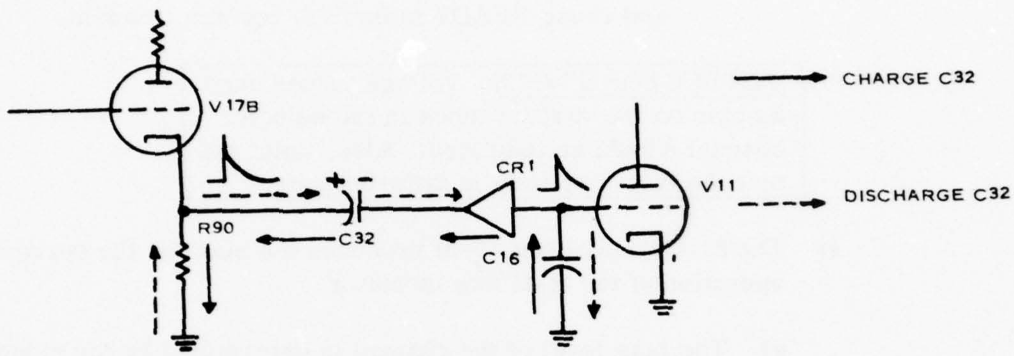

Diagram 13. Simplified pulse stretcher.

1. Capacitor C32 charges when the cathode of V17B goes positive.

2. As C32 charges, the charge on capacitor C16 rises, and causes the grid of V11 to become positive; hence, V11 conducts.

3. Because of the action of CR1, the grid of V11 remains positive for a longer period of time than the duration of the three-μsec video pulse.

INSTRUCTOR'S NOTE: Explain, in detail, diagram 13 and the operation of CR1.

g) When the thyratron-switch tube V11 conducts, it stops the time-to-burst integrator.

1. Tube V11 is normally cut off by the bias channel.

2. The conduction of tube V11 extinguishes READY lamp I3 and energizes relay K30 (fig 21-13).

3. READY lamp I3 is normally lit.

4. When relay K30 is energized, it stops the dial at the fuze servo.

5. RESET button S2 will cause V11 to cease conducting and cause READY lamp I3 to become lit again.

INSTRUCTOR'S NOTE: Voltage values used as bias on the various tubes in the selector channel should be indicated. Also, point out how the bias may vary in different sets.

4) The bias channel (fig 18-3) produces the bias for the correct operation of the trial fire indicator.

a) The bias level of the channel is determined by the video and noise from the receiver.

b) The bias selector tube V12 will not conduct unless video and the TRGA (30 microseconds in duration) are in coincidence.

c) The amplifier V13 inverts and amplifies the input signals.

d) The integrator V14A will maintain a certain level of conduction depending upon the noise level.

INSTRUCTOR'S NOTE: Point out to students that the newer sets have a different type of hookup.

1. With no signal into V14A, the grid may be varied from ground to +11.4 volts by the MIN BIAS adjustment R80.

2. This adjustment determines the conduction of V14A which in turn develops the dc level output.

3. As video and noise grow stronger, the dc level becomes more positive.

4. The MAX BIAS adjustment R86 varies the input-signal amplitude (video and TRGA).

5. The tube V14A is normally conducting.

6. Cathode follower V14B is controlled by the dc input to its grid.

7. The coupling tubes V15 and V16 are gas-filled VR tubes. They have a -174v drop and couple the voltage to the grid of V17A.

8. The tube V17A is a dc bias amplifier. It inverts and amplifies the negative signal output from tube V17A and keeps V11 cut off until video from the selector channel overcomes the bias.

9. The tube V18 is a voltage-regulator tube that keeps a steady -150 volts on the cathode of V17A.

Note: The proper adjustments for the MAX BIAS R86 and the MIN BIAS R80 are given in the log book.

10. Firing of the switch tube V11 energizes K30 and stops the time-to-burst integrator.

3. The time-to-burst integrator circuit is used to check over-all accuracy of the computer and fuze servo (fig 21-13).

4. This network is used in conjunction with the fuze servo and trial fire indicator.

5. The time-to-burst amplifier is located at the extreme right of group 3 of the dc amplifier.

6. The network consists of:

   a. Relays K1 and K2 and associated resistors,

   b. Relay K29, and

   c. Relay K30.

7. The simple block diagram of the time-to-burst integrator is shown in diagram 14.

INSTRUCTOR'S NOTE: Present operation of the network on block diagram level (diag 14) at this point.

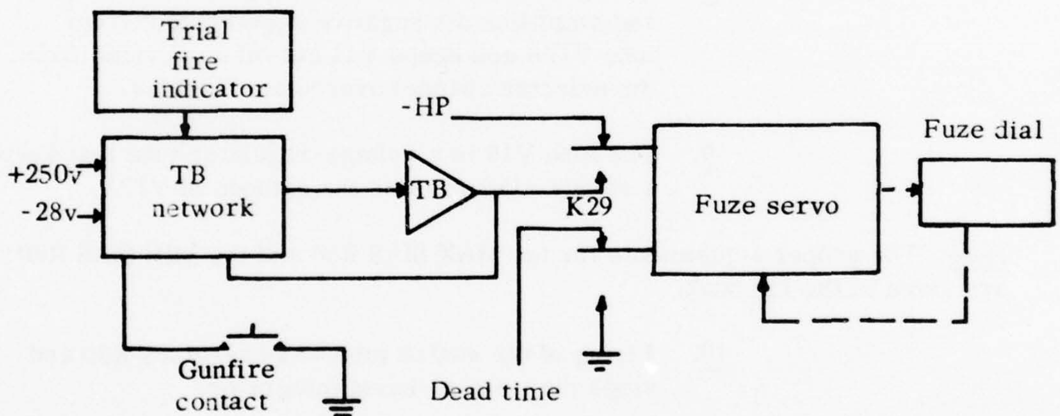

Diagram 14. Time-to-burst integrator.

8. The controls associated with time-to-burst integrator are:

   a. OPERATION switch,

   b. RESET buttons, and

   c. INPUT DATA switch.

INSTRUCTOR'S NOTE: Present the positions of above switches and their functions during velocity fire.

9. The time-to-burst integrator is operated by a negative voltage which increases linearly in time.

   a. The integration of a square wave accomplishes this.

   b. The output of the -TB amplifier is a linearly decreasing voltage whose leading edge represents the firing of the gun and whose trailing edge represents the burst point of the projectile.

INSTRUCTOR'S NOTE: An explanation of integration may be necessary to get the idea across. Show voltage at input to the -TB amplifier and show the output waveforms.

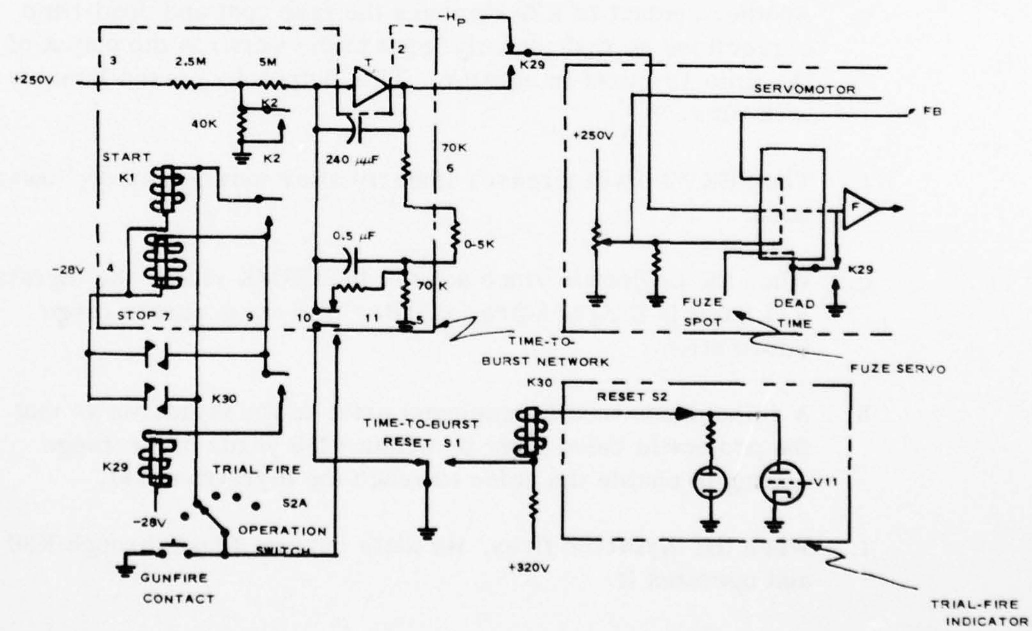

Diagram 15. Time-to-burst integrator simplified schematic diagram.

10. The operation of the time-to-burst integrator follows. By referring to diagram 15, the entire operation may be seen from start to finish.

    a. With S2A of the OPERATION switch in the TRIAL FIRE position, as shown, the closing of the gun-fire contact at the instant of recoil will place a momentary ground on K29 and K1 and activate these relays.

    b. One contact of K29 removes $-H_p$ from the fuze servo and applies the output of the time-to-burst integrator.

    c. One contact of K1 provides a holding circuit for itself and for K29 through the spring-loaded TIME TO BURST RESET push-button S1.

    d. The other contact removes the 10,000-ohm shunt resistance and sets the integrator into action.

    e. Another contact of K29 removes the fuze spot and dead-time corrections so that the only input to the servo is the output of the time-to-burst integrator. This output decreases linearly with time.

    f. The SERVO dial increases linearly after moving rapidly toward zero.

    g. When the projectile video adds to the QRMK video, the thyratron V11 fires in the trial fire indicator if given accurate range information.

    h. A coincidence tube is employed prior to the thyratron so that the projectile video must be within +250 yards of the range setting to enable the pulse to reach the thyratron grid.

    i. When the thyratron fires, its plate current flows through K30 and operates it.

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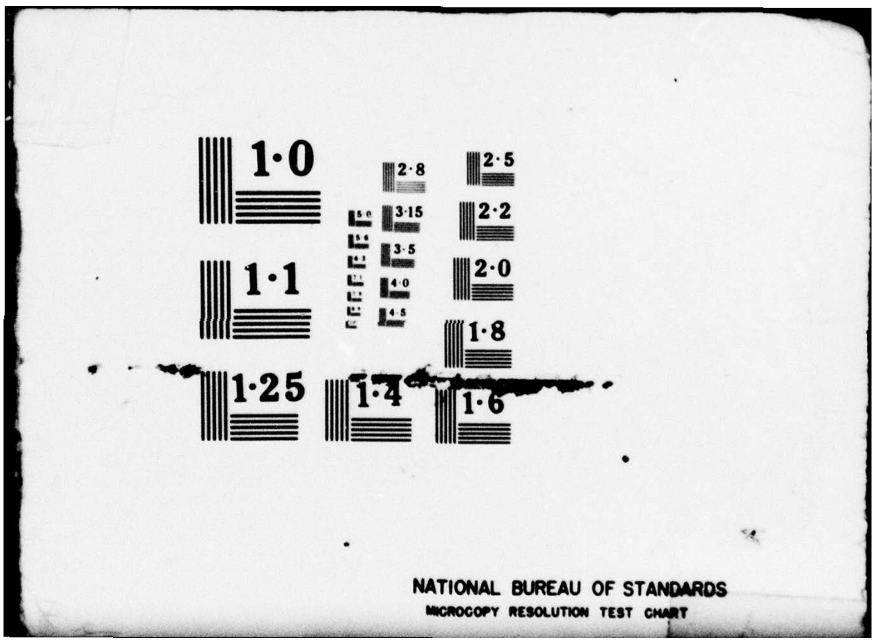
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NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

j. The lone contact of K30 places a ground on K2 whose contact, in turn, terminates the square-wave input by grounding this point. This acts to hold the output constant at the value it has when K2 operated.

k. The other contact of K2 provides its own holding circuit through the same path used to obtain ground for K29 and K1. This insures that K2 will remain energized even though K30 may be deenergized as a result of operating the RESET pushbutton S2 on the trial fire indicator.

l. The fuze servo will turn as a result of the negative voltage input from the TBI, but it stops when the feedback equals the final output value of the TBI.

m. The FUZE SERVO dial will continue to hold the reading of the exact time of flight in seconds.

n. As a final step, to return the circuit to its quiescent state, the TIME TO BURST RESET pushbutton is pressed to deactivate K1, K2, and K30 and to stop conduction of V11 by removing B+. The normal data are then applied to the fuze servo, and the dial again reads the fuze of the trial point.

11. Velocity fire is used to determine the actual time of flight for each gun under standard conditions.

a. The actual time of flight is found through the combined use of the trial fire indicator and the time-to-burst integrator.

b. In a velocity fire problem, six valid rounds are fired from each gun in a battery, and each round is timed from muzzle to a predetermined firing point.

1) An average is taken from the six rounds, and the muzzle-velocity potentiometer is adjusted to this average.

2) The fuze servo measurement of the time of flight of each round is cut off by the video burst signal.

c. When all guns have been through the velocity fire problem, an average of all guns in the battery is taken.

1) This new average is set in on the muzzle velocity potentiometer.

2) Although the setting of the muzzle velocity potentiometer may not be correct for any one gun, the target will be in the center of the combined burst area.

PRACTICAL EXERCISE

TRIAL FIRE INDICATOR AND TIME-TO-BURST INTEGRATOR

AAFCS M33 SETUP:

Fully energized including computer.

> INSTRUCTOR'S NOTE: It will be the instructor's responsibility to see that his trial fire indicator and time-to-burst integrator are adjusted and working properly. Otherwise, very little will be accomplished during this exercise.

EQUIPMENT NECESSARY:

1. Test amplifier,
2. Multimeter,
3. Null-voltage test set, and
4. Check sheet.

PRELIMINARY TROUBLES: None.

DEMONSTRATION:

1. Demonstrate the trial fire bias adjustments.

> INSTRUCTOR'S NOTE: The sweeps should be vertically and horizontally centered before the class arrives.

2. Press the RESET button at the trial fire indicator and turn off the READY lamp.

3. Open the two large doors on the computer and check the interlocks.

4. Place the INPUT DATA switch in LOCAL and the OPERATION switch in TRIAL FIRE.

5. Open the dc amplifier bay and short terminal 75 of the computer or terminal 7 of the -TB network to ground.

6. Explain that in actual use, terminal 75 is shorted to ground by a switch at the guns and that the fuze servo is now reading time of flight in seconds. Use figure 21-13 to show this momentary ground.

7. At some time before 30 seconds time of flight, trigger the time-of-flight indicator and point out the reading on the fuze servo.

8. Press the TIME TO BURST RESET pushbutton and point out the fuze servo which now reads the fuze number that it was indicating before terminal 75 was shorted.

9. Point out the following components:

   a. TB amplifier,

   b. Integrator-input network, and

   c. Relays K29, K30, K1, and K2.

> INSTRUCTOR'S NOTE: Let the students set the TFI bias and start and stop the trial fire measurement for themselves.

SUGGESTED TROUBLES:

1. Primary.

   a. Remove terminal 169 in the radar cabinet (fig 18-3).

   b. Replace V11 with a bad tube (fig 18-3).

   c. Replace V10 with a bad tube (fig 18-3).

d. Replace any of the tubes in the video or sweep channels with bad tubes.

2. <u>Review.</u>

a. Interchange the spade lugs going to terminals 773 and 774 at the computer.

b. Remove terminal 715 (fig 23-13).

c. Disconnect the retaining spring on one of the azimuth quadrant switches.

LESSON PLAN

PREOPERATIONAL CHECKS

OBJECTIVE:

1. To present a procedure for systematically checking the computer which will aid in locating malfunctions.

2. To explain the purpose of each test and how it insures accuracy of firing.

3. To review briefly the complete computer operation.

INTRODUCTION:

The AAFCS M33 system is a complex unit with many electronic components. Some method must be devised to check the operation and accuracy of the system. This check is to be done efficiently and in as short a period of time as possible. The preoperational check accomplishes this task.

PRESENTATION:

1. The log book is the most important record of the system's past performance and of what present maintenance is needed.

   a. It consists of test sheets for the preoperational check.

      1) White sheets are daily tests.

      2) Pink sheets are weekly tests.

      3) Blue, yellow, and green sheets are monthly tests.

   b. An explanation of each test is at the front of the book.

c. A place for comments is included in the rear of the book. Comment should be placed here.

INSTRUCTOR'S NOTE: Knowledge of the need for records and how to keep them is one of the weak points of present maintenance men. Log book procedure cannot be overstressed.

2. Daily preoperational checks.

INSTRUCTOR'S NOTE: Incorporate a brief description as each check is covered.

a. Voltage check.

b. Tracking test with guns in REMOTE.

c. The use of the log-sheet static test under standard conditions.

1) Use static checks to check entire computer without corrections or spots.

a) Use check sheet in conjunction with static-test checks.

b) TM 9-6092-1 contains the check sheet.

2) Explain use of static checks under nonstandard conditions to check entire computer with corrections or spots.

a) Use the check sheet in conjunction with the static-test check.

b) Voltages must be within tolerances.

d. Check guns and gun dials against computer dials.

Note: Normally static tests (1 through 6) are used. Tests 1 through 4 check ballistics while 5 and 6 check prediction.

1) Use a test aircraft for complete computer check.

2) Use a ground aiming point or a celestial body to check present position data.

3. Weekly preoperational checks.

INSTRUCTOR'S NOTE: Incorporate a brief description as each check is covered.

The plotting-board test checks the orientation of the automatic plotting-board pens.

a. OPERATION switch in the STATIC TEST position.

b. INPUT DATA switch in the LOCAL position.

c. Set information, as prescribed by the log sheet, into the tracking console.

d. Set plotting controls to OPERATE and then to PLOT.

1) Tests 1 and 2 check the horizontal board.

2) Test 3 checks the present altitude board.

3) Test 4 checks the predicted altitude board.

Note: All pens must plot within 1/8-inch of designated point. Check the designated point with log sheet.

4. Monthly preoperational checks.

INSTRUCTOR'S NOTE: Incorporate a brief description as each check is covered.

a. The horizontal prediction test is used to check the validity of the prediction circuits in the horizontal plane. The information for the proper check is obtained from the log book.

1) Follow log sheet instructions for correct placement of computer switches and radar switches.

2) The radius of each circle must be within tolerance.

> INSTURCTOR'S NOTE: Using the log book, point out the various positions of the switches in the computer.

b. The parallax-correction test is used to check the accuracy of the three correction circuits.

1) OPERATION and INPUT DATA switches are in TRACKING TEST and LOCAL, respectively.

2) Data are placed into the tracking console prescribed by the log sheet.

3) Results are observed on the firing AZIMUTH and ELEVATION dials.

> INSTRUCTOR'S NOTE: Use log book instructions to place correction knobs at correct setting for each problem. Show how readings of the servos and the log book are used.

c. The wind-azimuth correction test checks the wind-azimuth correction circuit.

1) Use STATIC TEST NO. 2.

2) Set WIND VELOCITY dial at 50 mph.

3) Turn WIND AZIMUTH dial according to log book, observing AZIMUTH, ELEVATION, and FUZE SERVO dials at their limits.

d. The computer dynamic operation test determines the accuracy of computer prediction and of the prediction pens at the plotting boards.

1) Place radar and computer switches to proper positions according to log book.

2) At the target-rate indicator, place:

   a) HORIZONTAL PREDICTION to LINEAR,

   b) ALTITUDE PREDICTION to LINEAR,

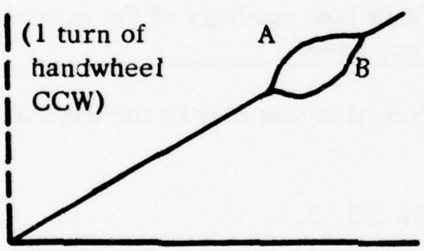
   c) PLOTTING CONTROL to PLOT,

   d) HORIZONTAL DATA SMOOTHING to 4 seconds,

   e) ALTITUDE DATA SMOOTHING to 8 seconds.

3) Turn RANGE handwheel, slowly, one turn counter-clockwise to set in a range rate of 120 yards per second.

4) The predicted altitude pen should plot the figures shown in diagram 16.



Curve	Prediction
A	X-Y Lin -4 sec Alt Lin -8 sec
B	X-Y Lin -8 sec Alt Lin -4 sec

Diagram 16. Computer prediction response versus predicted-altitude pen plot.

5) The predicted position pen on the horizontal plotting board should plot a straight line toward the origin of the coordinates.

6) The next five tests must be made with the pens at their proper starting position.

7) The positions of switches for additional tests are prescribed in the log book.

8) The proper figures to be plotted for the various tests can be found in the log book.

INSTRUCTOR'S NOTE: Show on log book or on the board the figures of the various tests.

e. The target-rate test is used to check the validity of rate circuits in the horizontal and vertical planes.

1) Follow the setting prescribed by the log book.

2) Set up multimeter for dc voltage operation.

3) Connect the multimeter between terminals in TCC (listed in log book sheet 7) and, after 10 seconds, it should indicate less than 0.5v dc.

4) All predicted pens should plot a straight line toward the origin of the plotting boards.

f. The dead-time test is used to check the validity of the dead-time circuits.

Note: A stopwatch is needed to perform this test successfully.

1) Set DEAD TIME dial to 4 seconds.

2) Set computer and radar dials to the correct setting shown in the log book.

3) Turn RANGE handwheel counterclockwise two turns.

4) The FUZE SERVO dial decreases with range. At a chosen reading, start the watch and turn DEAD TIME dial to 0.

5) Watch the FUZE SERVO dial and when it returns to chosen number, stop the watch.

6) The elapsed time should be 4 ±0.4 seconds.

7) This test must be repeated and an average taken.

INSTRUCTOR'S NOTE: Explain momentary increase in fuze number when DEAD TIME knob is turned to 0.

g. The altitude-limit test checks the operation of the minimum-altitude circuits in conjunction with the PREDICTED ALTITUDE LIMIT lamp.

1) Computer AIR SURFACE switch is in SURFACE position.

2) TARGET lamp it lit.

3) Turn MINIMUM ALTITUDE knob up slowly.

4) PREDICTED ALTITUDE LIMIT lamp flickers at a setting of 50 ±100 yards on dial.

5) Check log book for tolerances.

h. The ballistic test is used to check out the ballistic-synthesis circuits.

1) The standard ballistic-conditions check has 19 problems.

a) The problems are set in at the tracking console according to the log book.

b) Answers are recorded and compared with the log book.

2) The nonstandard ballistic-conditions check has 18 problems.

a) The problems are set in at the tracking console according to the log book.

b) Answers are recorded and compared with the log book.

c) If an out-of-tolerance condition occurs, a correction should be made immediately.

> INSTRUCTOR'S NOTE: Explain how the check sheet is used to find an out-of-tolerance condition. For the proper class period, work sheets should be obtained to give students actual practice in recording in log books. The problem is to be worked out by the instructor prior to class period.

PRACTICAL EXERCISE

PEROPERATIONAL CHECKS

AAFCS M33 SETUP: Completely energized and all computer doors open.

EQUIPMENT NECESSARY:

1. Test amplifier,

2. Multimeter, and

3. Null-voltage test set.

PRELIMINARY TROUBLES: None.

DEMONSTRATION:

1. Explain the various methods of computer testing such as:

   a. Tracking test (explain exactly what circuits are being tested).

   b. Dynamic test (use the curves in the log book).

   > INSTRUCTOR'S NOTE: Have each man perform at least one dynamic test.

2. It is assumed, optimistically perhaps, that the students are by now familiar with the purpose of the static tests. Therefore, as little time as possible will be devoted to this subject.

3. Show the use of the log book as it applies to the preoperational checks on the computer.

4. Explain the method used in setting in the correction for parallax (bring the guns to the computer).

5. Have the students complete the log book for the daily, weekly, and monthly checks.

> INSTRUCTOR'S NOTE: Divide the class into two groups.

SUGGESTED TROUBLES:

> INSTRUCTOR'S NOTE: Insert troubles that will be found during the course of performing the specified checks listed in the log book.

	Symptoms	Trouble
1.	Azimuth is unaffected when a cross wind of varying velocity is set in.	Disconnect terminal 22 on the wind-velocity potentiometer.
2.	Parallax does not affect elevation servo reading.	Remove terminal 3 of the H-parallax potentiometer.

> INSTRUCTOR'S NOTE: This is the last practical exercise on the computer proper before the beginning of the study of the plotting boards. Therefore, it might be wise for the instructor to review all the troubleshooting procedures used so far in the computer.

LESSON PLAN

PLOTTING BOARDS BLOCK DIAGRAM AND ASSOCIATED CIRCUITS

OBJECTIVES:

1. To discuss the purpose of all plotting boards.

2. To present circuits associated with plotting boards.

3. To discuss the operation of plotting boards on a block diagram level.

4. To present the characteristics of each board.

5. To discuss control circuits in general.

INTRODUCTION:

It is desired by the commander that some record of engagements be kept. It is because of this that plotting boards were designed. The items of equipment that supply this record are the horizontal, present altitude, and predicted altitude plotting boards. These greatly increase the firing effectiveness of the unit. From the plotting boards, valid information can be produced for future engagements.

PRESENTATION:

1. Four plotting boards are used in the AAFCS M33: three automatic boards and one manual board. The three automatic boards are as follows.

   a. The horizontal plotting board is used to show horizontal distance traveled by a target. It utilizes the values of X_o and Y_o on one arm and X_p and Y_p on the other. This board records:

      1) Present information, and

      2) Predicted information.

b. The present altitude board is used to record the present altitude position of the target.

c. The predicted altitude board is used to record the predicted altitude of the target against its horizontal travel.

d. The early warning board is used to plot the course of the incoming target by information sent from higher channels. The plots on this board are done manually.

2. The plotting controls consist of a five-position switch and two pushbuttons to guide and control all plotting pens.

a. The five positions of the PLOTTING CONTROL switch are:

1) REFERENCE MARK,

2) STAND-BY,

3) OPERATE,

4) PLOT, and

5) TEST.

INSTRUCTOR'S NOTE: Explain the operation of the pens in each position.

b. The two pushbuttons of the plotting controls are:

1) PLOTTING CONTROL PEN INTERCHANGE, and

2) PLOTTING CONTROL PEN LIFT.

INSTRUCTOR'S NOTE: Explain operation of pens under both conditions.

3. The mark circuits display certain types of marks on the plotting boards. These different marks give indications of various actions going on during operation. These marks are:

   a. Timing,

   b. Fire, and

   c. Cease-fire marks.

Note: These marks will be discussed in a later conference.

4. The over-all block diagram of the plotting boards is shown in diagram 17.

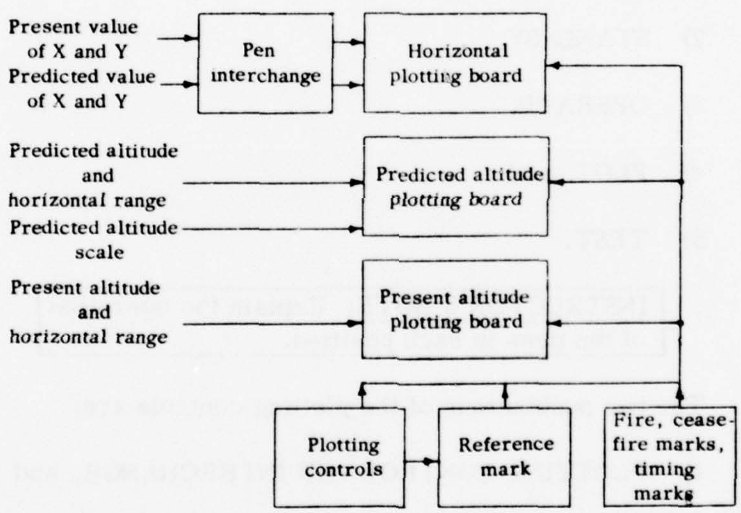


Diagram 17. Plotting boards.

INSTRUCTOR'S NOTE: The trigonometric values of the inputs to various boards are not necessary. Mention of the voltage symbol is all that is necessary. That is as shown in diagram 17.

a. The <u>horizontal plotting board</u> contains two pens. The inputs driving the pens are X and Y information.

1) There are two motors controlling each pen.

a) X_L and Y_L motors control the left pen.

b) X_R and Y_R motors control the right pen.

c) The X motors control horizontal movement of the pens.

d) The Y motors control vertical movement of the pens.

2) One pen is plotting present information while the other plots predicted information.

<u>INSTRUCTOR'S NOTE</u>: Figure 22-1 is a good schematic for showing inputs to each motor and which pen is plotting present, or predicted, information.

3) The plotting-pen circuits are servo loops. The pens will come to rest when feedbacks from the respective servos are opposite in polarity and equal in amplitude to the input signal.

4) The servomotor tachometers are not interchangeable as are the other servos on the computer. This is due to the gear-reduction box.

5) Another feature of the horizontal board is the <u>pen-interchange</u> system.

a) This feature is incorporated to prevent pen interference when plotting present and predicted information.

b) Because of this system, the pens will exchange their plotting information rather than interfere with each other.

c) Two lamps are associated with each pen to indicate its plotting data. These lamps are:

1. PREDICTED, and

2. PRESENT.

6) General information about the horizontal board.

a) The horizontal plotting board consists of a sheet of translucent material approximately 29 inches square. A reference system is provided by a series of concentric range circles at intervals of 5, 000 yards and radial azimuth lines that are engraved on the board. The center of the board represents the gun-directing point. A sheet of tracing paper is placed over the plotting board and arranged so that lights shining behind the board illuminate the range circles and azimuth lines. Two pens plot the present and predicted positions of the target upon the paper and trace the path of the aircraft being tracked.

b) The scale of the horizontal board is 1:100, 000. This allows use of military maps for making overlays.

b. The present altitude board is operated by the input information representing R_0 and H_0.

1) There is a servo for each of these inputs. Their operation is the same as that of the horizontal board.

2) The R_0 input to the present altitude board will drive the system from 0 yards to a position representing 40, 000 yards.

3) The H_0 input to the present altitude board will drive the system from a minimum altitude of -500 yards to a maximum altitude of +20, 000 yards. With no voltage input, the pen is at zero altitude.

4) General information concerning the present altitude board.

a) The present altitude plotting board plots a continuous record of the present altitude position of the target.

b) The present altitude plotting board plot is approximately 14 inches by 7 inches.

c) It is marked by slant-range circles every 5, 000 yards and altitude lines every 2, 000 yards. The range circles extend from zero to 40, 000 yards, and the altitude lines extend from -500 to +20, 000 yards.

d) The board provides a continuous recording of the present target altitude against its horizontal range at a scale of 1:100, 000.

e) The complete plots may be removed as in the horizontal plotting board; clean paper is advanced into position by a hand-operated roller.

f) The origin of the coordinates corresponds to the tracking antenna.

c. The <u>predicted altitude</u> board is operated by the input information representing R_p and H_p.

1) The operation of the unit is the same as that of previous servos.

2) The R_p input will drive the system horizontally from 0 yards to 14, 400 yards. Two inputs make up the R_p input. They are voltages representing a value for X and one for Y.

> INSTRUCTOR'S NOTE: The exact formula or nomenclature of this voltage is not necessary for maintenance, and the student should be held responsible for the names only.

3) The H_p will drive the system from -500 yards in altitude to +14, 260 yards in altitude.

4) The voltages (+s) and (-s) are received from the ballistic circuits for trajectory corrections.

   a) These voltages are used in the feedback circuits of the two servos.

   b) The voltage -0339S is used to establish the lower limit of pen operation at -500 yards.

5) General information concerning the predicted altitude board.

   a) The predicted altitude plotting board plots a continuous record of the predicted altitude of the target against its predicted horizontal range.

   b) The plot is about 14 inches square, and the 90-mm gun-trajectory chart for standard conditions of muzzle velocity and air density is engraved upon it.

   c) It uses a scale of 1, 000 yards per inch which varies with the computer muzzle velocity and air density to keep the gun-trajectory chart very nearly correct.

   d) If the system is to be used with another type of gun, a new plotting surface, engraved with the appropriate gun-trajectory chart, is required for proper operation.

   e) The predicted altitude board shows a range of 14, 400 yards and an altitude from -500 to +14, 260 yards.

   f) Its origin of coordinates corresponds to the battery gun-directing point.

   g) The scale of this board is approximately one-third that of the other boards for standard ballistic conditions.

5. The plotting-control circuits are used to develop the various marks on the plotting boards at the computer operator's console. The five positions of the plotting control appear as in diagram 18.

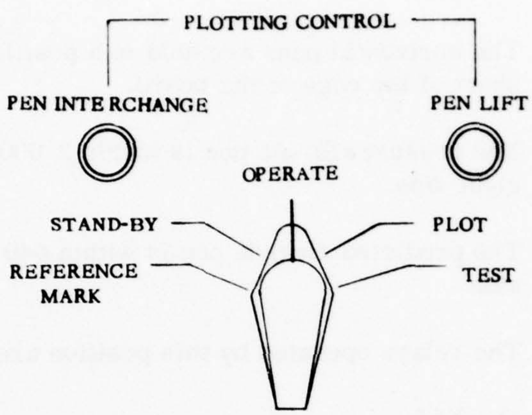


Diagram 18. Plotting control positions.

a. In the REFERENCE MARK position, the relays that are operated are:

1) K61,

2) K62,

3) K71,

4) K45,

5) K63, and

6) K67.

7) The pens plot to the origin of the coordinates of each board.

Note: Point out that on the horizontal board only the right pen moves.

8) With the switch placed in STAND-BY, the pens make a little mark and return to the STAND-BY position.

b. In the STAND-BY position, the pens are ready to go into operation.

1) The horizontal pens are held in a position 2,000 yards short of the edge of the board.

2) The present altitude pen is within 2,000 yards from the right side.

3) The predicted altitude pen is within 640 yards of the right side.

4) The relays operated by this position are:

a) K63,

b) K64,

c) K65,

d) K66, and

e) K67.

c. In the OPERATE position, all pens move into operation and function according to their input data but do not plot.

d. In the PLOT position with prediction in, the pens actually begin to plot the target's course.

e. In the TEST position, a test for proper operation of the pens can be made.

<u>INSTRUCTOR'S NOTE</u>: All relays energized in the first two positions of the switch are deenergized by the positions OPERATE and PLOT.

SUMMARY:

1. There are three automatic plotting boards and an early warning plotting board. The automatic boards are:

   a. Horizontal,

   b. Present altitude, and

   c. Predicted altitude.

2. The plotting controls are operated by a five-position switch. The positions of the switch are:

   a. REFERENCE MARK,

   b. STAND-BY,

   c. OPERATE,

   d. PLOT, and

   e. TEST.

SUGGESTED TROUBLES:

	Symptom	Probable Cause
1.	No pen operation or partial pen operation.	Check input and output plugs on prediction-control panel in computer.
2.	No pen interchange or separation of pens.	Dirty contacts of pen-interchange relays.

PRACTICAL EXERCISE

PLOTTING BOARDS BLOCK DIAGRAM AND ASSOCIATED CIRCUITS

AAFCS M33 SETUP: Fully energized.

EQUIPMENT NECESSARY: Null-voltage test set and multimeter.

PRELIMINARY TROUBLE: None.

DEMONSTRATION:

1. If possible, have the tracking radar tracking a target and the plotting boards plotting the path of the target.

2. Set in clean paper at the horizontal plotting board.

3. While the pens are in operation, demonstrate the following:

   a. Plotting boards in STAND-BY (pens move to the sides of the plotting board).

   b. Plotting board in OPERATE (pens go to the designated position but do not touch the paper).

   c. Plotting boards in PLOT (present pen plots the target path, and, if prediction is in, the predicted pen plots predicted information). The pen on the predicted altitude board plots only when the predicted pen on the horizontal plotting board is plotting.

   d. Plotting boards in TEST (all pens are on the paper).

4. Demonstrate the pen-interference interchange by shorting the two pens on the horizontal plotting boards with a screwdriver.

5. Demonstrate the arm-interference interchange by moving the arms together.

6. Push the manual pen interchange (with prediction out), and have students note the effect.

7. Have the students note the timing marks. Explain that they form arrows pointing in a northeast direction, whereas the fire and cease-fire marks form arrows pointing in a southwest direction.

8. Explain and demonstrate the use of the reference marks.

9. Locate the relays associated with the plotting boards. Take the cover off the relays that produce the timing, fire, and cease-fire marks.

10. Locate the modulators and LPSA associated with the plotting boards.

11. Open the horizontal plotting board and point out the motor tachometers that drive the right and left pens in the X and Y directions. Do the same for the other two boards.

12. Point out the arm-interference relay.

13. Demonstrate the zeroing of the plotting-board potentiometers. Have each student zero at least one potentiometer.

> INSTRUCTOR'S NOTE: If possible, have a pen-servicing kit on hand, and put some of the students to work on cleaning and filling the pens.

14. Demonstrate the procedure used in changing rolls of paper on the plotting board.

> INSTRUCTOR'S NOTE: At the end of this exercise, your plotting boards should be in perfect working order. Check all marks and potentiometer zero adjustments as well as paper and ink supplies. Be sure that the following exercises can be devoted to troubleshooting only with no interruptions for purposes of maintenance and repair.

15. Spend the rest of the period reviewing the components used in the operation of the plotting boards. Plot a few aerial targets if possible.

LESSON PLAN

PEN-INTERCHANGE, REFERENCE-MARK, AND TIMING-MARK CIRCUITS

OBJECTIVE:

1. To explain the purpose and operation of the interchange circuits in the various modes of operation.
2. To discuss the reference marks and their associated circuits.
3. To discuss the timing marks and their associated circuits.
4. To present a logical sequence for troubleshooting these circuits.

INTRODUCTION:

The data displayed on the plotting boards are a very valuable source of information. This information must be continuous. Because the system of pen interchange is used, interference of the pens on the horizontal plotting board is prevented. In order to read the plots recorded on the board, some type of key or symbols must be used. From these symbols or marks, information concerning tactics, altitude, direction, and capabilities of an attack can be predetermined. The efficiency of the battery will be improved by the use of these marks.

PRESENTATION:

1. General information.
   a. Pen interchange exists only at the horizontal plotting board.
   b. Timing marks are made every twenty seconds.
   c. Reference marks are made on all three boards.

2. The data flow and sequence of events of the pen-interchange circuit are shown in the block diagram (diag 19).

<u>INSTRUCTOR'S NOTE</u>: Take students through the data flow and sequence of operation of the block diagram. The slow-release relays and the time interval of operation should be presented here.

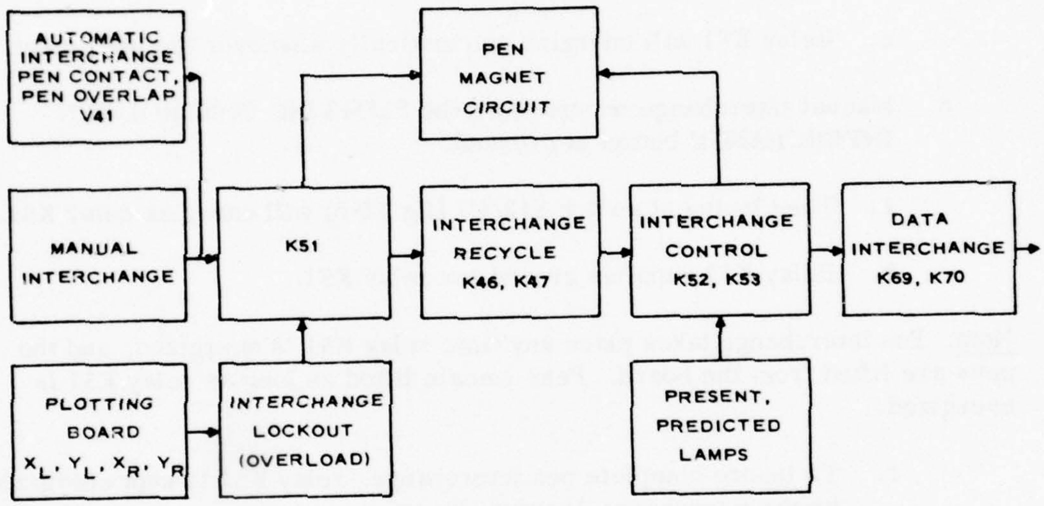


Diagram 19. Block diagram of the plotting control pen interchange.

3. The pen interchange in the horizontal board will eliminate any interference between pens during an engagement or in testing.

4. Automatic interchange occurs when pen holders or pens come into contact with each other. The resulting action will:

   a. Lift pens,

   b. Interchange data, and

   c. Await settling of servos before dropping pens to boards.

5. PEN CONTACT or PEN OVERLAP switch initiates the interchange by grounding the grid of V41.

   a. Tube V41 conducts, energizing relay K51 and reversing pen operation.

   b. Pens will change from present to predicted plots.

Note: One of the pens will be plotting present information and, upon contact, will change its plotting to predicted information.

   c. Relay K51 will energize automatically whenever the pens meet.

6. Manual interchange occurs when the PLOTTING CONTROL PEN INTERCHANGE button is pressed.

   a. The closing of switch S12/C1 (fig 22-6) will energize relay K51.

   b. Relay K12 supplies ground for relay K51.

Note: Pen interchange takes place any time relay K51 is energized, and the pens are lifted from the board. Pens remain lifted as long as relay K51 is energized.

   c. To insure complete pen interchange, relay K51 is kept energized by the interchange-lockout circuit.

7. The interchange-lockout circuit is a holding circuit for the relay K51.

   a. Relay K51 is kept energized until the pens assume their respective new positions.

   b. When the information in the pen dc amplifiers is zero, the interchange-lockout circuits will let relay K51 deenergize.

   c. The interchange lockout will hold the pens out of operation, using the tubes V42, V43, V44, V45, and their associated relays, until pen interchange is over.

8. The following is the sequence of relay operation.

   a. Relay K51 energizes, operating the pen magnets and lifting the pens from the paper.

   b. Relay K51 energizes relays K46 and K47.

   c. Relays K46 and K47 control the recycling of the pen.

      1) One or the other of these relays is energized during interchange.

      2) The relays are both energized or both deenergized between interchange.

   d. Relays K52 and K53 are energized by relay K46.

      1) Relays K52 and K53 are the control relays for the pen changeover.

      2) They operate in such a manner that X data are interchanged before Y data.

      3) These relays also operate the proper interchange of the lights at the bottom of the horizontal plotting board.

      4) Data-interchange relays K69 and K70 are energized by relays K52 and K53.

         a) Data relay K69 operates the X data in the horizontal board amplifier.

         b) Data relay K70 operates the Y data in the horizontal board amplifier.

         c) Both relays are energized or deenergized during plotting of the pens.

         d) When both relays are energized, the predicted position is plotted by the left pen.

e) When both relays are deenergized, the present position is plotted by the left pen.

> INSTRUCTOR'S NOTE: The contacts associated with the relays mentioned above should be covered here.

9. On the first interchange, relays that are energized are:

   a. K46,

   b. K47,

   c. K52,

   d. K69, and

   e. K70.

> INSTRUCTOR'S NOTE: The function of each relay above is necessary here as a review of major components.

10. Diagram 20 is a block diagram of the timing-mark circuit.

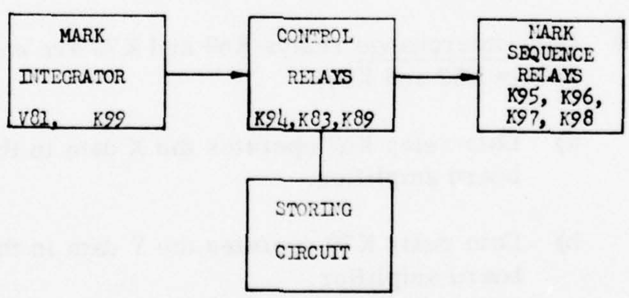


Diagram 20. Timing-mark circuit.

11. The timing marks that appear at the plotting board are shown in diagram 21.

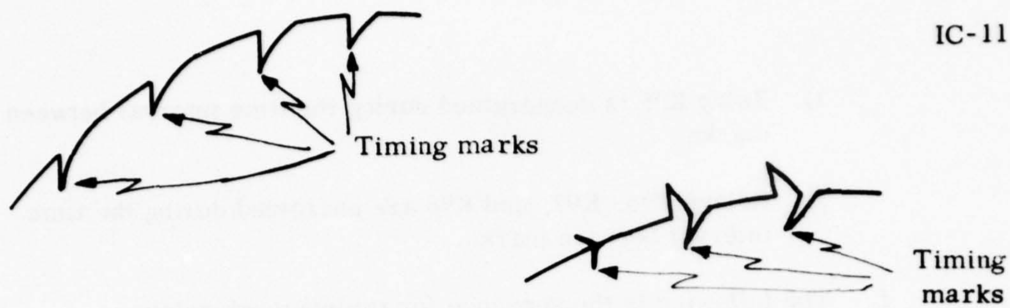


Diagram 21. Timing marks.

12. These timing marks are initiated by the mark integrator V81 (fig 22-7) every 20 seconds.

13. The timing interval between marks is established by the setting of the potentiometer arm of resistor R83.

14. The A section of V81 energizes relay K99 at the end of each time interval.

    a. Relay K99 energizes relay K94, and

    b. Grounds the grid of V81, the B section.

15. The mark-sequence relay K94 energizes relays K82 and K84.

    a. No marks are produced by these relays. Their function is to get the circuit ready for timing-mark voltages.

    b. Relays K83 and K94 provide a ground for K95 and energize it.

    c. Relay K95 keeps relays K83 and K84 energized through its contacts.

    d. The application or removal of timing marks on the plotting boards is done by the energizing and deenergizing of relay K95.

    e. The relays making the timing marks are K95, K96, K97, and K98.

1) Relay K95 is deenergized during the time interval between marks.

2) Relays K96, K97, and K98 are energized during the time interval between marks.

f. The following is the sequence for timing-mark relays.

	K99	K94	K83	K84	K95	K96	K97	K98
t0 (0 sec) (Start sequence)	D	D	D	D	D	E	E	E
t1 (18.4 sec)	E/D	E	E	E	E	E/D	E	E
t2 (18.8 sec)	D	E/D	E	E	E	D	E/D	D
t3 (19.2 sec)	D	D	E	E	E	D	D	E/D
t4 (19.6 sec)	D	D	E	E	E/D	D	D	D
t5 (20.0 sec)	D	D	D	D	D	E	E	E

E - Energized.
D - Deenergized.
E/D - Excitation is removed from coil, but the contacts remain closed for 0.4 sec.

> INSTRUCTOR'S NOTE: For proper explanation of relays K95, K96, K97, and K98, their contacts (figs 22-2, 22-5, and 22-7) should be presented in conjunction with each one's function.

16. The storingcircuit prevents the fire and timing marks from interfering with each other in the event they both occur at the same time.

a. The storing circuits are made up of relays K94, K81, K83, and K84.

b. Relays K94 and K81 store or delay the timing marks.

c. Relays K93 and K83 store or delay the firing mark.

INSTURCTOR'S NOTE: A brief explanation of the operation of the above relays should be presented here.

17. The sequence of operation of the various relays studied in this lesson is shown in diagram 22.

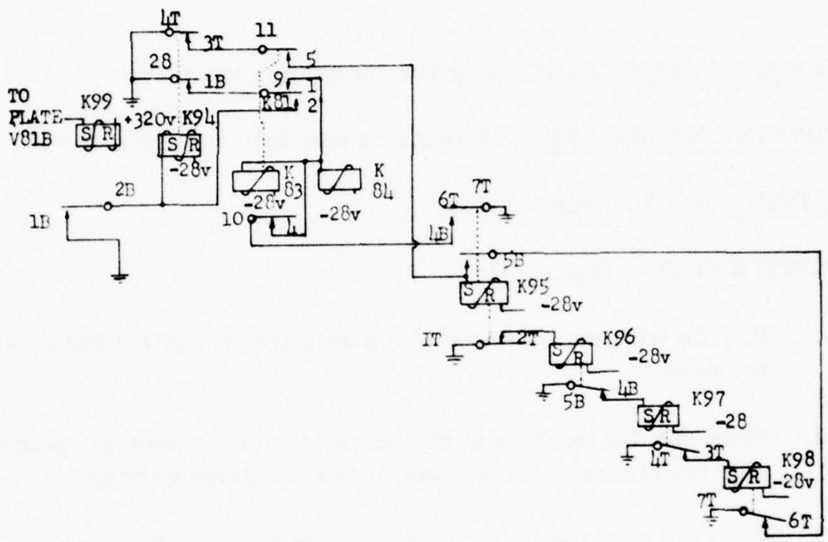


Diagram 22. Control and mark-sequence relays.

Note: The abbreviation SR indicates slow release relays.

PRACTICAL EXERCISE

PEN INTERCHANGE, REFERENCE MARK, AND TIMING MARKS

AAFCS M33 SETUP: Fully energized including computer.

EQUIPMENT NECESSARY: Multimeter and null-voltage test set.

PRELIMINARY TROUBLE: None.

DEMONSTRATION: (fig 22-1)

1. Review with the students which amplifiers control the movement of the pens.

2. Point out the location of the pen motor tachometers, potentiometers, pen-interference microswitch, and the drive cabling.

3. Point out that the voltages necessary to cause the pens to form the marks agree perfectly with the polarity of the coordinates in all four quadrants. For example, in order to form the downward stroke of the timing mark, a negative voltage must be sent to the Y amplifiers; therefore, K84 and K95 (fig 22-1) must be energized. To get the pen to move back up, the negative voltage is taken off, and a ground is used in its place. K82 is energized.

> INSTRUCTOR'S NOTE: If the student thinks in terms of what voltage is necessary to produce the different parts of the timing marks, he may find it easier to grasp the sequence of timing-mark relay operation. The same can be done for the fire and cease-fire marks and the reference marks.

4. Show the location of the time and fire-mark relays and the reference and interchange relays.

> INSTRUCTOR'S NOTE: Show the students how to count the contacts on the SR relays.

5. Point out the mark integrator and stages 41, 42, 43, 44, and 45.

6. Inspect one of the pen magnets.

7. Time the interval between timing marks and make the appropriate adjustment of R83 for 20 seconds.

8. Demonstrate that the timing-mark sequence can be started by pushing K99 with your finger. This can be used as a check to localize a trouble to V81.

SUGGESTED TROUBLES:

1. Primary.

   a. Replace V1 in the X_R LPSA with a bad tube.

   b. Replace terminal 131 in the computer with a dummy lead (fig 22-4).

   c. Open terminal 151 (fig 22-4).

   d. Loosen J2 on the horizontal plotting board till the right pen does not move in the Y direction.

   e. Open terminal 118 in the computer (fig 22-6).

   f. Open terminals 158 and 157 in the computer.

   g, Replace V81 with a bad tube (fig 22-7).

   h. Place paper between any of the contacts of K91, K92, K93, or K99.

   i. Misadjust the balance control on one of the pen modulators. This will cause one of the stages, V42, V41, V43, or V44 (fig 22-6), to conduct and energize its associated relay with the result that the interchange circuit works only once.

2. <u>Review.</u>

   a. Replace V3 5, 000-yard multivibrator in the track-range computer with a bad tube.

   b. Have students perform the track AFC adjustment.

LESSON PLAN

FIRE AND CEASE-FIRE MARKS

OBJECTIVE:

To present and discuss:

1. The purpose and the operation of the fire- and cease-fire mark channel.
2. The circuits associated with the fire- and cease-fire mark channel.
3. A logical sequence of troubleshooting this circuit.

INTRODUCTION:

The last part of all military operation is a critique. To analyze an encounter in which the battery has engaged rapidly, fire and cease-fire marks are used. These marks are superimposed on the target plot. With this information, the battery commander has control over further battery action. This will enable him to have a better percentage of kill.

PRESENTATION:

1. General information.

INSTRUCTOR'S NOTE: Begin with a review of the timing-mark circuits. The review will serve as an excellent tie-in for this lesson.

a. In normal tracking operation, fire and cease-fire marks may be made only when the following buttons have been pushed.

1) TRACKED,

2) COMPUTER READY, and

3) HOSTILE.

b. The above conditions imply:

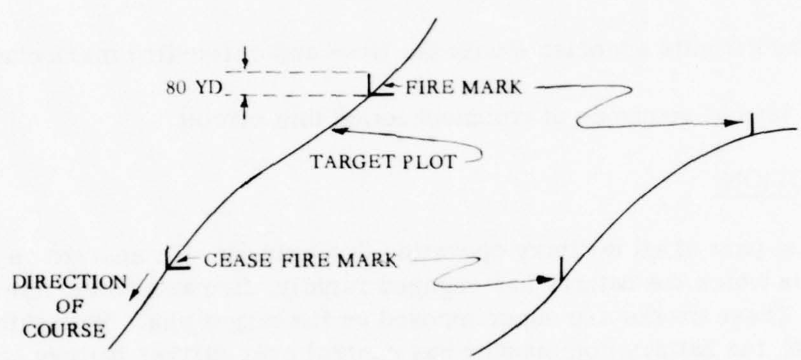
1) Smooth tracking by radar,

2) Smooth prediction by the computer, and

3) Target within fuze range.

INSTRUCTOR'S NOTE: Take students through the sequence of events initiated by TRACKED, COMPUTER READY, and HOSTILE buttons.

2. Fire and cease-fire marks are presented in diagram 23.



(1) Horizontal board (2) Altitude board

Diagram 23. Fire and cease-fire marks.

3. The control of these marks is accomplished by relay K11.

Note: Relay K11 is deenergized between engagements (fig 22-7).

a. During the standby period, relay K11 keeps relay K92 energized.

b. Relay K92 provides a ground path for starting the firing marks.

c. Depressing the FIRE button S8A energizes relay K11.

d. Relay K11, when energized, applies ground to K91 and energizes K91.

e. Relay K91 energizes relay K93 through the contacts of relay K92.

f. Relay K93 energizes relays K81 and K82.

g. Ground is applied to relay K95 through the contacts of K81 and K82.

h. Relay K95 is now energized, and the sequence of marks is started.

> INSTRUCTOR'S NOTE: For proper evaluation of the relays, figures 22-2 and 22-5 should be used in conjunction with figure 22-7.

i. The voltage sources for making these marks come from the voltage dividers R92, R93, R94, and R95 (fig 22-2).

j. The sequence for fire and cease-fire relays is as follows:

> INSTRUCTOR'S NOTE: Show the students that relays K96, K97, and K 98 are energized during the time interval between marks.

k. The voltage used for the fire and cease-fire marks is similar to the voltage used for timing marks except for the polarity. Positive voltage is used here.

Note: Marks do not appear every 20 seconds like the time marks, but only when the FIRE button or CEASE-FIRE button is pressed. There is one mark for each button.

l. When relays K96, K97, and K98 have completed their action, the fire mark is made.

m. Relay K98 terminates all action, and the circuit returns to normal.

4. The pressing of CEASE FIRE button S7 (fig 22-7) will deenergize relay K91 and energize relay K92.

   a. The whole sequence of relay operation is started again through the slow-release contacts of relay K91.

   b. The sequence is the same as that mentioned above for the fire-mark presentation.

> INSTRUCTOR'S NOTE: Show students that contacts of relays K81 and K83 are in opposite channels. Explain why this is so. Also present the fact that the contacts of relays K91 and K92 operate the horn relay panel.

5. The function of each of the various relays studied in this lesson is shown opposite each of the relays listed below.

K92 or K91	Initiator
K82	Voltage selector
K83	Block
K93	Storage

K95	X_L, Y_R, H_o, H_p
K96	Ground
K97	X_L, X_R
K98	Ground

> INSTRUCTOR'S NOTE: A detailed explanation of the material in paragraph 5 should be given here. A short explanation of the Hayden timer should also be given at this time.

PRACTICAL EXERCISE

FIRE AND CEASE-FIRE MARKS

AAFCS M33 SETUP: Fully energized.

EQUIPMENT NECESSARY: Multimeter and null-voltage test set.

PRELIMINARY TROUBLE: None.

DEMONSTRATION:

> INSTRUCTOR'S NOTE: Since the subject of fire and cease-fire marks entails very little additional troubleshooting over what was covered in the previous practical exercise, it will be found that today's subject matter will not cover the full time available. It is suggested that, after the students are sufficiently familiar with the marks, they be given a review of all that has been covered in the plotting boards. The instructor will place troubles anywhere in the plotting-board system using previous practical exercises for his list of troubles.

LESSON PLAN

REVIEW OF AAFCS M33 COMPUTER

OBJECTIVE:

To review the complete operation of the computer in the solution of the air defense problem.

INTRODUCTION:

The purpose of this lesson is to review the over-all computer operations. The student now has studied the individual parts of the computer and the completion of the picture is necessary. This will also clear up and bring back to mind parts of the computer that are very vague to him.

PRESENTATION:

> INSTRUCTOR'S NOTE: This lesson will refresh the student's mind on the subjects presented during this portion of the course. The main purpose is to develop troubleshooting techniques, and the class should be conducted along this line. The student should fill in the following block diagrams with the instructor.

1. Simple complete block (diag 24).

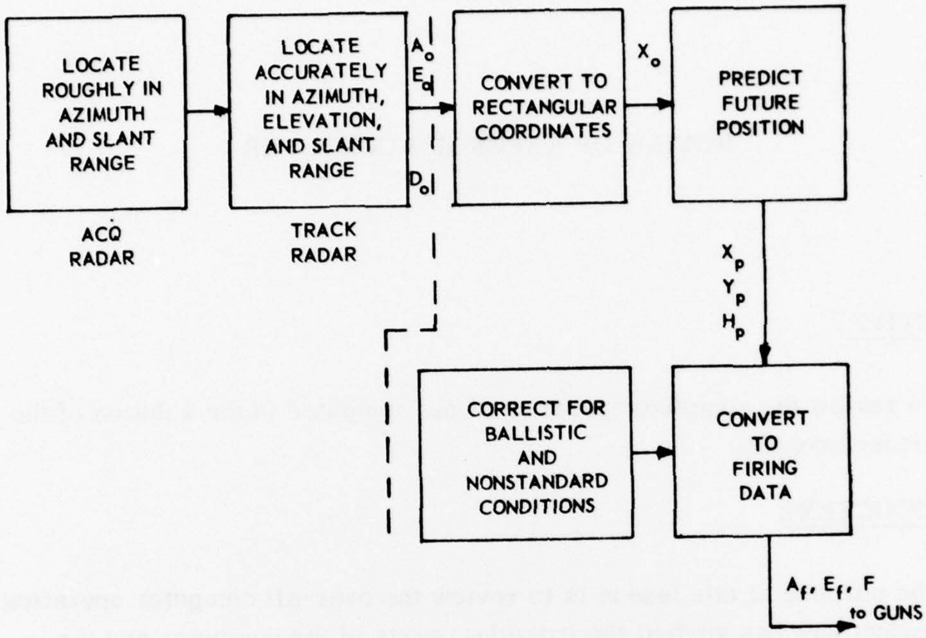


Diagram 24. Simple complete block diagram.

2. Block diagram of observed-target coordinates section (diag 25).

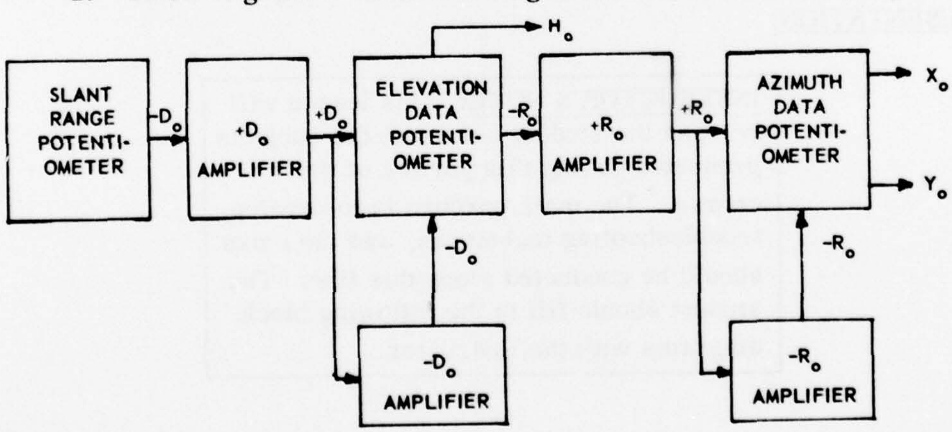


Diagram 25. Block diagram of observed-target coordinates section.

a. One volt is equal to 160 yards at the input to the D_O amplifiers.

b. One volt is equal to 400 yards at the input to the elevation-data potentiometer.

c. The outputs of this section are rectangular coordinates and are sent to the prediction circuits and the plotting boards.

3. Prediction coordinates section (diag 26).

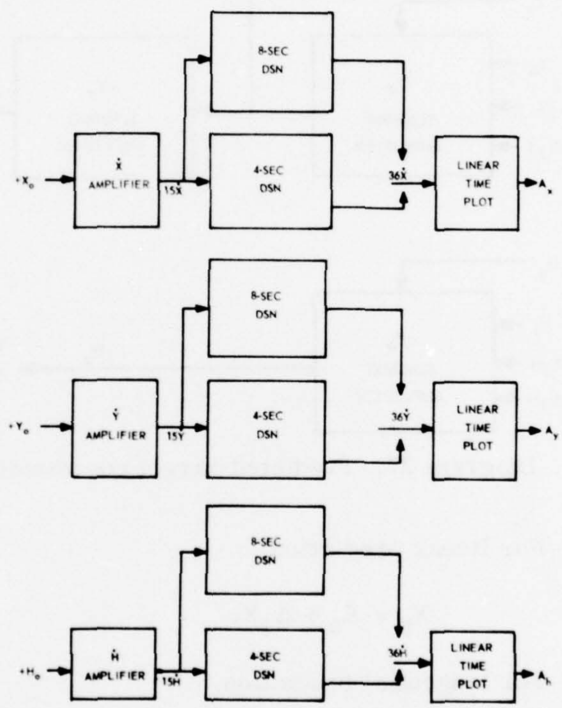


Diagram 26. Prediction coordinates section.

a. The data-smoothing networks are continually operating.

b. The data-smoothing networks are used to smooth erratic voltages.

c. The outputs represent a rate of change in each coordinate.

4. **Predicted target coordinates block diagram (diag 27).**

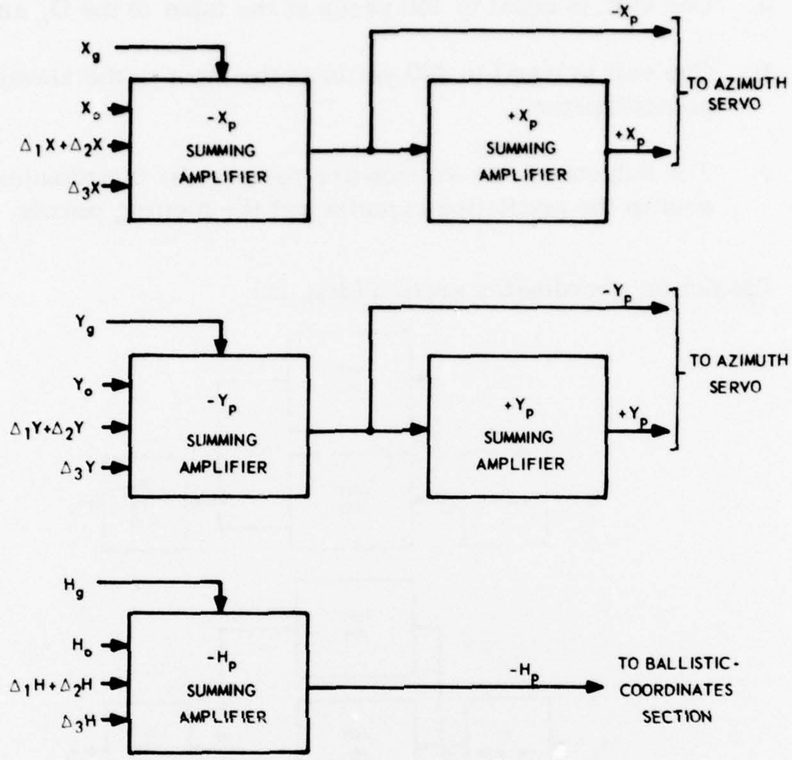


Diagram 27. Predicted-target coordinates block diagram.

a. For linear prediction,

$$X_p = X_o + \Delta_1 X.$$

b. For tangential prediction,

$$X_p = X_o + \Delta_1 X + \Delta_2 X, \text{ and}$$

c. For quadratic prediction,

$$X_p = X_o + \Delta_1 X + \Delta_2 X + \Delta_3 X.$$

5. The azimuth servo (diag 28).

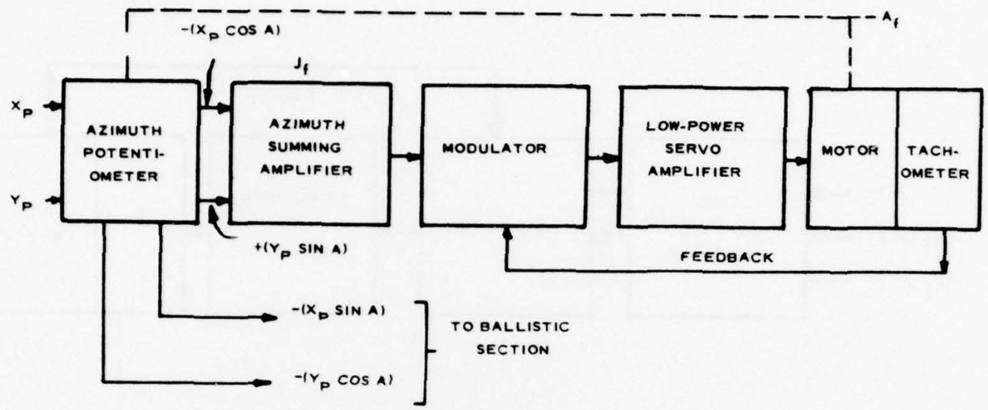


Diagram 28. Azimuth servo.

6. The elevation servo (diag 29).

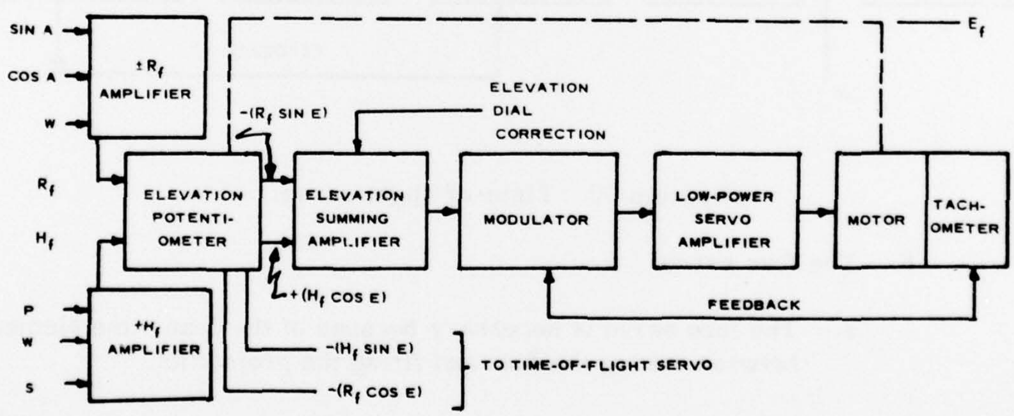


Diagram 29. Elevation servo.

7. The time-of-flight servo (diag 30).

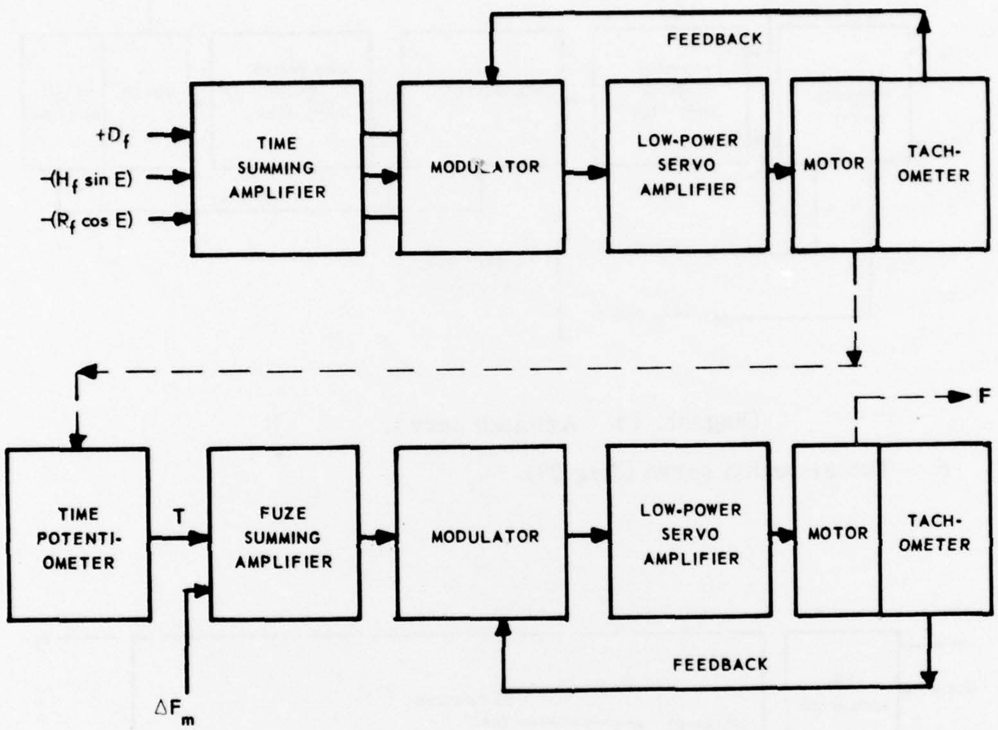


Diagram 30. Time-of-flight servo.

8. The fuze servo.

a. The fuze servo is necessary because of the dead-time element between cutting the fuze and firing the projectile.

b. The fuze number is usually larger than the time-of-flight number but may be smaller.

c. The system comes to rest when $F-T-F_m = 0$.

d. FM is a correction for air density, muzzle velocity, and time-of-flight effects on the fuze.

9. Ballistic synthesis section (diag 31).

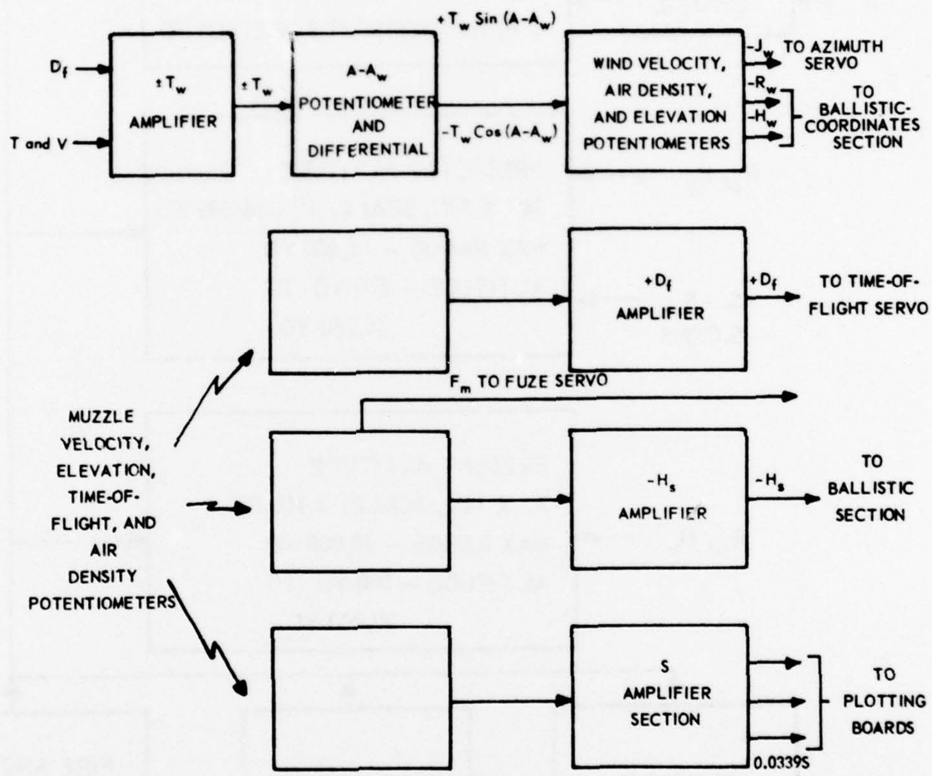


Diagram 31. Ballistic-synthesis section.

10. The plotting boards (diag 32).

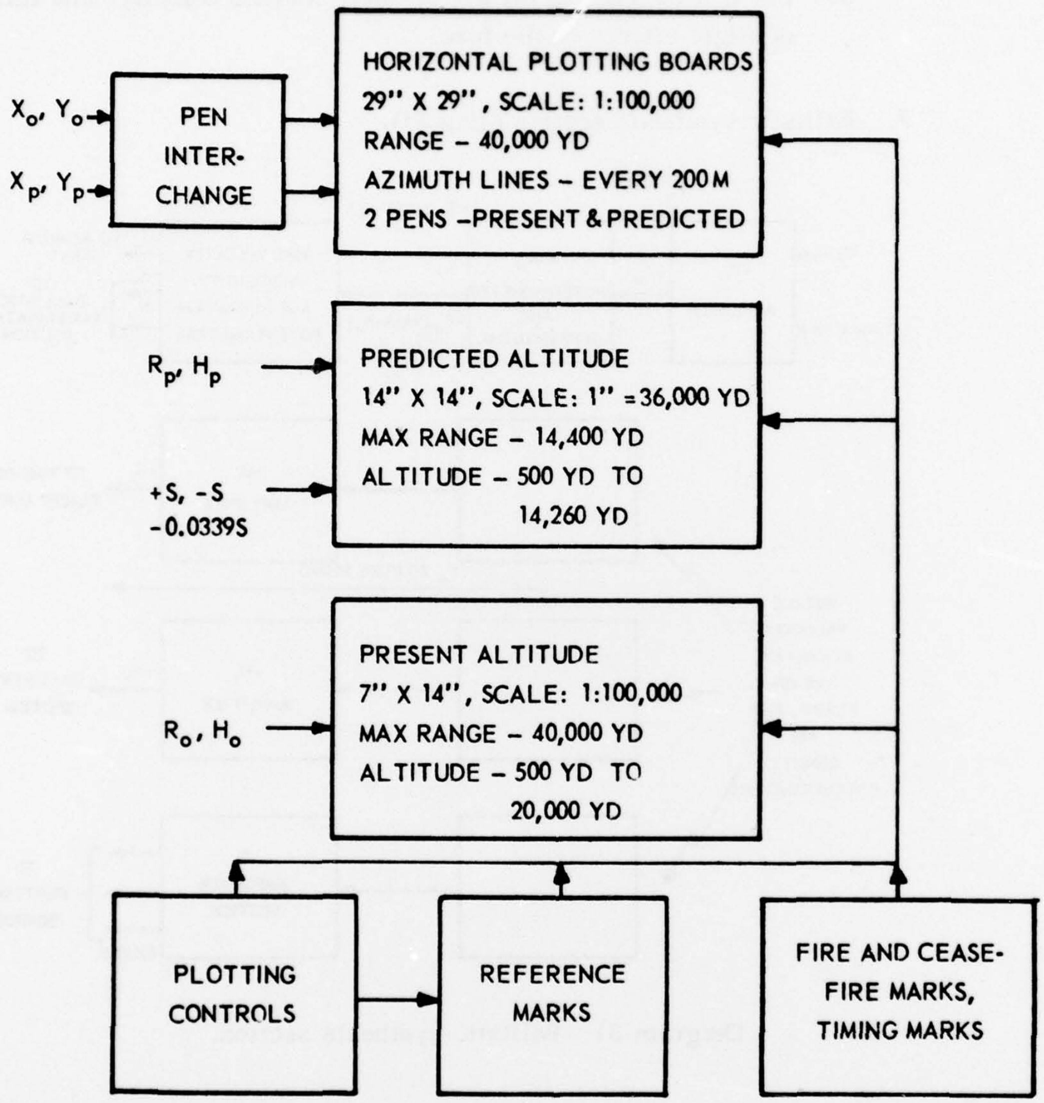


Diagram 32. Plotting boards (M33C).

a. Plotting board controls:

1) PLOTTING CONTROL PEN INTERCHANGE pushbutton,

2) PLOTTING CONTROL PEN LIFT pushbutton, and

3) OPERATION switch:

a) REFERENCE MARK,

b) STAND-BY,

c) OPERATE,

d) PLOT, and

e) TEST.

INSTRUCTOR'S NOTE: Review complete block diagram and point out corresponding units at the computer (diag 33).

Troubles should be simulated in the system, symptoms should be given, and students should troubleshoot to right channel and unit. Troubles are up to your discretion. Diagram 33 should be completed with correction-voltage data running throughout the computer.

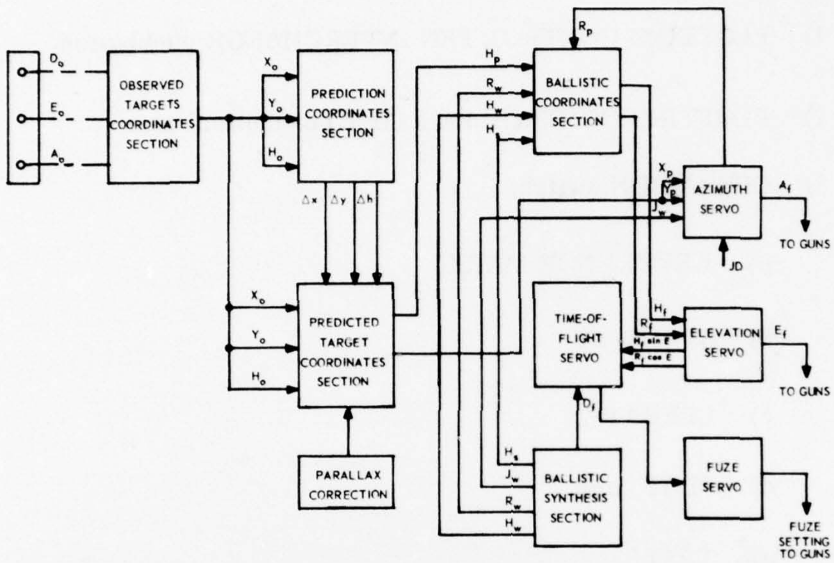


Diagram 33. Complete block diagram with units contained in computer.

PRACTICAL EXERCISE

COMPUTER REVIEW

AAFCS M33 SETUP: Fully energized.

EQUIPMENT NECESSARY: Multimeter and null-voltage test set.

PRELIMINARY TROUBLE: None.

DEMONSTRATION:

> INSTRUCTOR'S NOTE: This exercise will demand more than the usual amount of preparation by the instructor for its proper presentation.
>
> The following is an outline that is suggested for the presentation of this class and should be adhered to only insofar as group and instructor variations permit.

1. At the radar cabinet, monitor the D_o output of the range computer for a range of 20, 000 yards. Ask any relevant questions, such as, "What happens to D_o after 40, 000 yards?" and "How many yards does one volt equal at terminal 172."

2. At the computer, monitor both the input and the output of the $+D_o$ amplifier.

   a. Why do we read 50, 000 yards in and 20, 000 yards out?

   b. What is the purpose of the positive and negative D_o amplifiers?

3. Discuss the method whereby the elevation-data converter solves for the unknown sides of the triangle whose known side is D_o and whose known angle is E_o. Why is a certain amount of $+D_o$ sent to the $-R_o$ potentiometer?

4. Discuss how R_o and A_o are used to form the values X_o and Y_o. Make sure the students know where to measure these values.

5. Since the values of H_o, Y_o, and X_o have been determined, the computer has positioned the target to a certain portion of space. Discuss the means by which the computer goes about finding where the target will be by the time a projectile reaches it. Explain the effects of the ballistic corrections on the computer's answer for any one problem. Be sure to point out check points and the location of hardware.

6. Explain that, since X_o, Y_o, and H_o are known, it is only necessary to find the values of ΔX, ΔY, and ΔH in order to find the values of K_p, Y_p, and H_p.

7. Since the values X_p, Y_p, and H_p are rectangular coordinates, it remains necessary to devise a method of converting these coordinates to firing data in order to point the guns to the predicted target position. This is done in the summing amplifiers by sending to their input networks two opposing answers to a given trigonometric problem. When the answers are exactly equal and opposite, the summing amplifier will have no input and, therefore, yield no output. Since the summing amplifier has no output, the servo that it controls will come to rest. Resolvers, which are driven by the servo, will inform the guns where the servo came to rest or where to point in order to hit the predicted target position.

> INSTRUCTOR'S NOTE: Once the main ideas of the computer's solution are presented and absorbed by the students, the instructor can go on to the purpose of the static tests, timing marks, fire and cease-fire marks, plotting boards, etc. Be sure the students know where everything is. Review any troubleshooting procedures they may have forgotten.

8. For the remainder of the class, the instructor can insert troubles from any previous computer practical exercise.

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