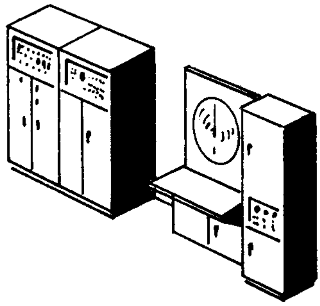

LESSON 6. NIKE HERCULES COMPUTER

MMS Subcourse No 150	**Nike Radars and Computer**
Lesson Objective	**To give you a general knowledge of the purpose, capabilities, sequence of events during prelaunch, initial turn and dive phase, and the basic function of major units in the computer.**
Credit Hours	**Three**

TEXT

1. **PURPOSE.** The Nike Hercules computer system calculates the necessary orders to guide a designated missile from its position on the launcher until it destroys the designated target. The computer calculates these orders from target and missile positions and their relative velocities.

2. **CAPABILITIES.** In improved Nike Hercules systems, the computer is normally programed for surface to air missions; however, circuits are provided for low-altitude and surface to surface missions. In ATBM systems, the computer is also normally programed for surface to air missions, with circuits provided for antimissile and surface to surface missions. The computer programs Nike Hercules missiles equipped with high explosive, nuclear, or cluster warheads and Nike Ajax missiles with high explosive warheads.

3. **SEQUENCE OF EVENTS.**

a. After a target is designated and tracked, the computer provides the prelaunch solution that predicts a burst point. The burst point is a continuously calculated point in space where missile burst is predicted to occur if the missile were fired at the instant of calculation. This information is continuously displayed on the plotting boards.

b. The computer also calculates the azimuth of the predicted burst point during the prelaunch phase. This angle, the gyro azimuth (A_G), is used to preset the roll amount gyroscope in the missile to be fired. The roll amount gyroscope is continuously positioned to the new A_G until "fire." Approximately 2 seconds after fire, but before the missile leaves the launcher, the roll amount gyroscope is uncaged to provide the missile and computer with a common reference plane to which missile steering orders are oriented.

c. Approximately 2 seconds after fire, the missile lifts off the launcher in a near-vertical programmed flight. The computer detects the upward acceleration of the missile and starts a 4-second timer. During this 4 seconds, the booster separates from the missile and the missile rolls about its longitudinal axis because of the setting of the roll amount gyro. This establishes a "belly-down" attitude with respect to the gyro azimuth plane (roll stabilization occurs as shown in figure 1).

d. When the 4-second timed interval expires, the computer assumes that the missile is "roll stabilized" and issues a computed dive order to the missile. The purpose of this dive order (initial dive order) is to bring the missile out of near-vertical flight and direct it along the optimum flightpath to the burst point. The requirements for an initial dive always exist; however, the dive orders may be modified by an initial turn order. The initial turn condition is provided to keep the missile

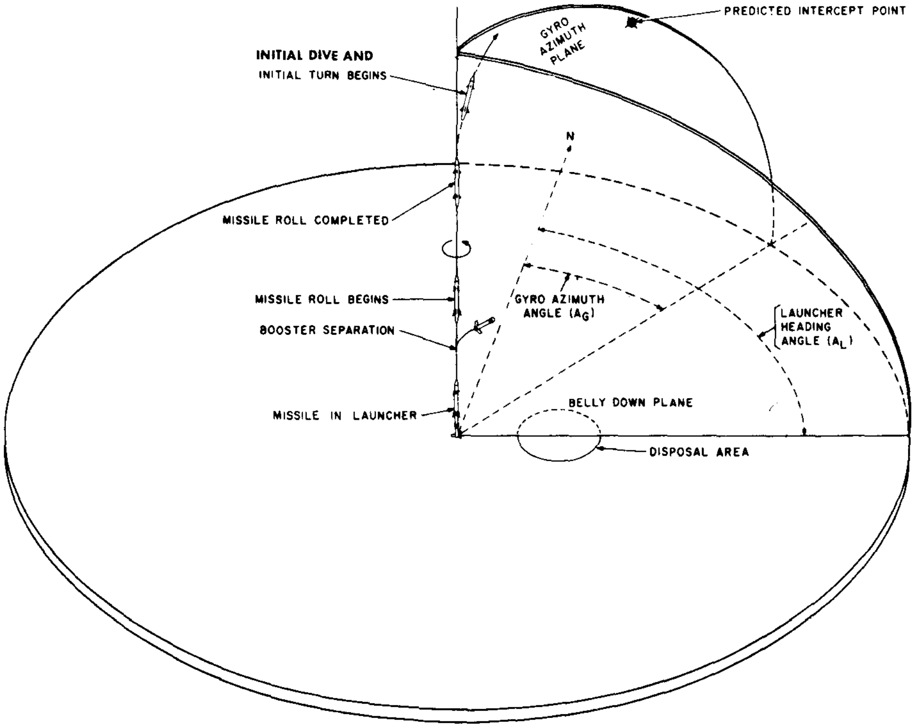

Figure 1. Missile roll stabilization - sequence diagram.

from entering the forbidden zone of the missile track radar. The forbidden zone is an area around the missile track radar through which missile flight would require the MTR to exceed its angular tracking capabilities. When an initial turn condition exists, the initial dive order is modified by a turn order that causes the missile to fly a course skirting the forbidden zone. As soon as the missile passes the missile track radar, "radar cleared" is detected by the computer and the initial turn condition ends. When the missile is headed toward the predicted burst point "on trajectory" occurs.

e. When "on trajectory" occurs, the computer begins to issue corrective guidance orders to the missile by means of the missile track radar. These guidance orders are referenced to the gyro azimuth plane, which was established at "fire" and is common to both the computer and the missile. Throughout the "steering phase," target and missile position information is sent to the computer from the target and missile track radars. The computer uses this information along with preset information to determine the guidance orders that will cause the missile to "intercept" the target. As the time to intercept approaches zero, the computer issues the "burst command."

f. The "burst command" is transmitted from the computer to the missile by means of the missile track radar and is issued at a predetermined time before the target and missile intercept. This advanced burst is used not only to compensate for delays in the burst channel of the computer, missile track radar, and missile, but also to place the burst point so that maximum destruction is obtained from the warhead.

g. Shortly after burst, the computer recycles and returns to a standby condition. The computer is then ready to continue the engagement or begin a new engagement.

4. COMPUTER COMPONENTS AND CIRCUITS.

a. **Analogs**. The computer is a DC analog computer. Physical measurements such as distances, velocities, accelerations, time intervals, and angles are represented in one of two ways: as DC voltages proportional to physical quantities, or as variable resistor shaft positions proportional to physical quantities. Either way, the analog quantity is related to the real quantity by a ratio known as the scale factor. Thus, a distance of 1,000 yards may be indicated by a voltage of ±1 volt, or by a mechanical shaft displacement of ±100 degrees. In the first case, the scale factor is 1 millivolt per yard; in the second case, 0.1 degree per yard.

b. **Computing amplifier.**

(1) General. The computing amplifier is a

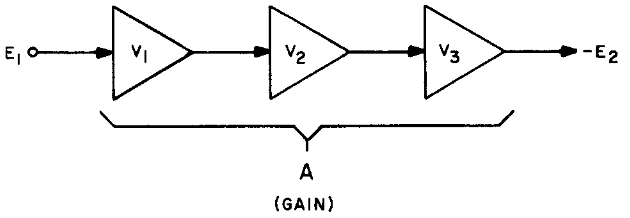

Figure 2. Computing amplifier-without feedback.

basic component of DC analog circuits. Its function is to produce a DC voltage output proportional to a DC voltage applied to the input. The operations performed are amplification, isolation, and polarity inversion. With input networks, mathematical computations are performed. The mathematical computations include multiplication, division, addition, subtraction, differentiation, and weighting.

(2) Computing amplifier without feedback. The amplifier contains three stages of amplification and is represented as a triangular block as shown in figure 2. This amplifier is assumed to be an ideal amplifier having the same gain (flat response) for all frequencies including direct current. The input E_1 applied to the computing amplifier results in an output $-E_2$, equal to $-A \times E_1$. The minus sign appears because of the polarity inversion. The gain A is the forward gain of the computing amplifier without feedback. The computing amplifier circuit input impedance is sufficiently high so that only an extremely small drive current is required. Since the computing amplifier must produce zero voltage with a zero voltage input, negative feedback is used. Negative feedback from the plate of the output tube to the grid of the input tube is one of the main requirements for the computing amplifier. The effective input impedance of the computing amplifier with an input network is about 25 ohms. The effective output impedance is about 1 ohm.

(3) Typical computing amplifier. A computing amplifier with the addition of resistors R_{in} and R_F in a feedback voltage-divider network is shown in figure 3. R_F is the feedback resistor and R_{in} is the input resistor. Applying an input voltage E_{in} results in an output $-E_O$. The actual input at the computing amplifier grid, however, must be E_O/A, applying the assumption concerning gain in (2) above. The voltage drop across R_{in} is the difference between E_{in} and E_O/A, thus the current through R_{in} is

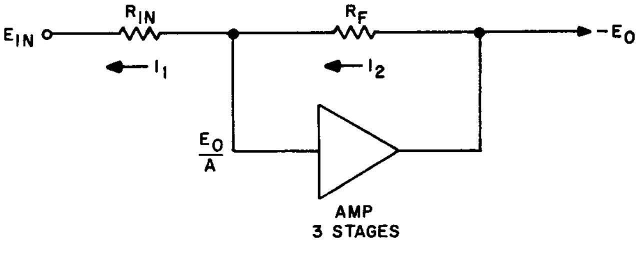

Figure 3. Computing amplifier with feedback.

$$I_1 = \frac{E_{in} - (E_O/A)}{R_{in}}$$

Similarly, The voltage drop across R_F is the difference between $-E_O$ and E_O/A. Thus, current through R_F is

$$I_2 = \frac{(E_O/A) - E_O}{R_F}$$

Since the input grid draws very little current, I_1 and I_2 may be considered as a single current flowing through R_{in} and R_F. Since the voltage drops across R_{in} and R_F depend upon their resistance values, a simple proportion can be established, if A is assumed very large.

$$\frac{-E_O}{E_{in}} = \frac{R_F}{R_{in}}$$

Solving for $-E_O$

$$-E_O R_{in} = E_{in} R_F$$

or

$$-E_O = E_{in} \frac{R_F}{R_{in}}$$

E_O is the voltage output of this circuit with feedback, where the ratio of R_F to R_{in} determines the gain of this circuit. The negative sign appears in the expression because the computing amplifier contains three stages, causing the output to be reversed in polarity with respect to the input.

EXAMPLE:

Find the gain of the amplifier in figure 3 if: $R_F = 5$ megohms and $R_{in} = 2$ megohms.

$$\text{Gain} = \frac{R_F}{R_{in}} = \frac{5 \text{ megohms}}{2 \text{ megohms}} = 2.5$$

(4) Multiplication. The computing ampli-

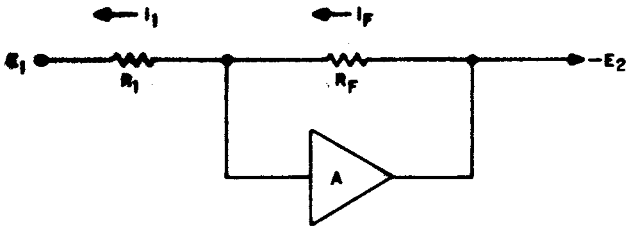

Figure 4. Multiplication or division by a constant.

fier with a single variable input (fig 4) multiplies an input E_1 in accordance with

$$-E_2 = \frac{R_F}{R_1} \times E_1$$

Network resistors R_1 and R_F are selected so that R_F/R_1 equals the desired multiplying constant. For example, find E_2 when: R_F = 5 megohms, R_1 = 2 megohms and E_{in} = 10 millivolts.

$$-E_2 = \frac{5M \times 10mV}{2M}$$

$$E_2 = 25mV$$

(5) Division. The multiplying circuit (fig 4) will divide by a constant. In this case, network resistors are selected to make R_F/R_1 equal to the reciprocal of the constant divisor. If E_1 is to be divided by three, the value of R_1 is made three times that of R_F, then:

$$-E_2 = \frac{R_F}{R_1} \times E_1 \text{ or: } -E_2 = 1/3 \text{ of } E_1.$$

(6) Addition. The process of addition in the computing amplifier makes use of the inherent characteristic of the computing amplifier of maintaining its summing point (input) at near zero potential.

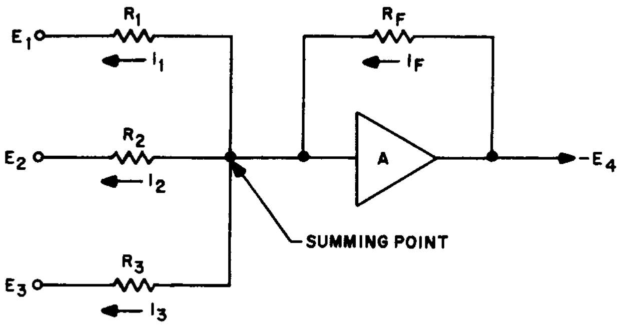

Figure 5. Summing network.

(a) Figure 5 illustrates a simple summing network composed of three input resistors, each having a different applied voltage. If no current is to flow into the amplifier input:

$$I_F = I_1 + I_2 + I_3$$

or

$$\frac{E_1}{R_1} + \frac{E_2}{R_2} + \frac{E_3}{R_3} = \frac{-E_4}{R_F}$$

If all resistors are equal,

$$E_1 + E_2 + E_3 = -E_4$$

the output being the negative sum of the inputs.

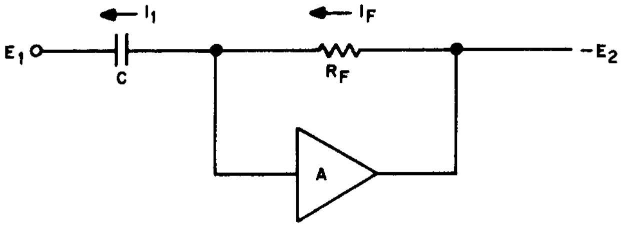

Figure 6. Differentiation circuit.

(b) A weighted sum includes one or more terms that are multiplied by a coefficient before addition. For example, R_F (fig 5) is 500,000 ohms. Assuming input E_1 to be a voltage not to be multiplied by a coefficient, the value of R_1 will be selected to be equal to R_F. Assuming input E_2 to be multiplied by a coefficient of 2, R_2 will be 250,000 ohms, since $R_F/R_2 = 2$. Assuming input E_3 to be multiplied by a coefficient of 1/3, R_3 will be 1.5 megohms, since $R_F/R_3 = 1/3$. Solving the equation,

$$E_1 + 2E_2 + 1/3E_3 = -E_4$$

For example, if E_1, E_2, and E_3 in figure 5 were each 10 volts, $-E_4$ would be:

$$-E_4 = 10 + 2 \times 10 + \frac{10}{3}$$

$$-E_4 = 33.3 \text{ volts.}$$

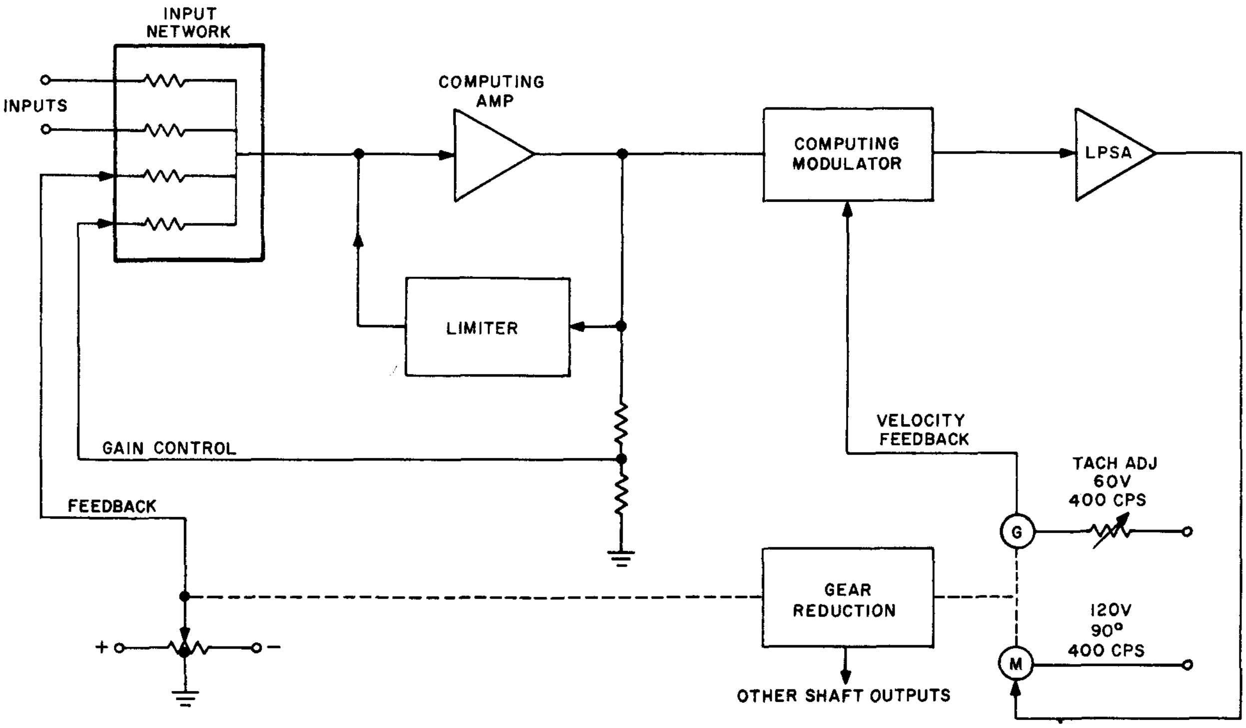

Figure 7. Typical positioning circuit - block diagram.

(7) Subtraction. For subtraction, the functions to be subtracted are applied to the summing network with reverse polarity. Weighting may be accomplished as described in (6)(b) above.

(8) Differentiation. This process involves detecting or recognizing a change in voltage. The circuit in figure 6 can detect the rate of change of the input voltage. The current into the capacitor is equal to the capacitance times the rate of change of the voltage across the capacitor. Thus,

$$I_1 = C\dot{E}_1$$

where $\dot{E}_1$ is the rate of change of the input voltage and C is the capacitance. Also,

$$I_F = \frac{E_2}{R_F}$$

Since I_1 is equal to I_F, $C\dot{E}_1$ can be substituted for I_F giving:

$$C\dot{E}_1 = \frac{E_2}{R_F} \quad \text{solving for } E_2,\ E_2 = R_F C\dot{E}_1$$

E_1, the input voltage to the differentiator represents target position. The rate of change of this voltage, $\dot{E}_1$, represents target velocity. Therefore, E_2 is target velocity if component values are picked so R_FC is one. If target position is changing at a constant rate, target velocity will be a constant. If target position is not changing, target velocity will be zero. Another differentiation of $\dot{E}_1$, would yield target acceleration.

(9) Stabilization. Each amplifier chassis in the computer contains two separate computing amplifier channels, each using one section of a common output tube. Internal disturbances, such as noise or voltage fluctuation, are compensated for by a negative feedback circuit, a high frequency bypass circuit, and by automatic zero-setting to provide high stability and essentially constant amplification. Automatic zero-setting compensates for drift in the amplifier by adjusting the summing point voltage to approximately zero when the output voltage is zero. The accuracy of the computing amplifier depends on the accuracy of the automatic zero-set circuit in holding the summing voltage at approximately zero level. Certain operations in the computer will tolerate some error in computing amplifiers. These amplifiers use semiprecision automatic zero-setting. Other operations demanding a higher degree of amplifier accuracy, use precision automatic zero-setting.

c. **Basic servo.**

(1) General. The Nike Hercules computer

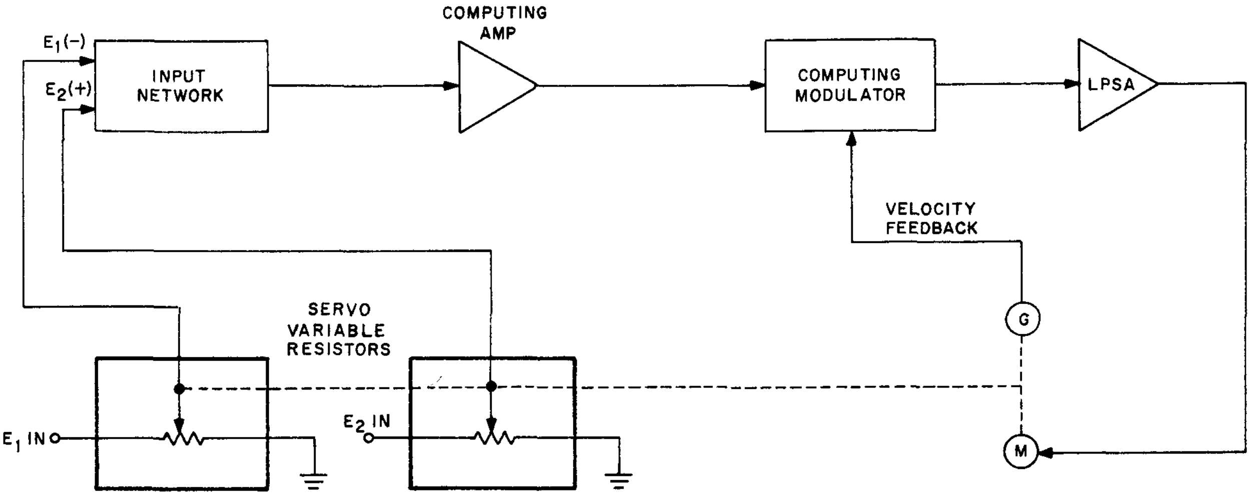

Figure 8. Typical computing servo-block diagram.

servos operate in two different ways: as a servo positioning circuit and as a servo computing circuit. The servo positioning circuit is described in (2) below, and the servo computing circuit is described in (3) below.

(2) Positioning servo circuit. A typical positioning circuit is illustrated in figure 7. Signals are applied to the input network and are compared with the electrical feedback analog of the servomotor shaft position. The difference between the signal and the feedback analog voltage is an error signal. The error signal is amplified by the computing amplifier, which has a limiter to prevent overloads. The DC output of the amplifier is used to modulate an AC error voltage in the computing modulator. The AC error is then applied to the low power servoamplifier. The low power servoamplifier output drives the servomotor which positions the variable feedback resistor to nullify the error signal at the input network. This is how the seven plotting board servos, the transit time servo, and the velocity correction servo in the computer operate. To eliminate servo hunting (oscillations), an AC generator is mounted on the servomotor shaft. The output of the generator is proportional to the speed of the servomotor. The output of the generator (velocity feedback) opposes the output of the computing modulator and counteracts rapid changes in the error signal. This eliminates both servo overshooting and servo hunting. A large error in servomotor shaft position would cause the servomotor to run at high speed and overshoot its desired position. The opposite velocity feedback voltage causes the motor to slow down as its shaft approaches the desired position, thus preventing overshooting.

(3) Computing servo circuit. Another application of the computer servo is to balance two voltages, each derived from variable resistors on the servoshaft. This arrangement is shown in simplified form in figure 8. The variable resistors are fed with voltages of opposite polarity and are arranged so that when one brush voltage is increased by rotating the shaft, the other brush voltage is decreased. In other words, the servo operates by detecting and correcting the error between two voltages. This error voltage provides a driving signal to the servo. The gyro azimuth, ballistics, climb angle, turn angle, and time servos operate in this manner.

d. Nonlinear resistors.

(1) Card-shaping is used in the computer to allow the variable resistor to develop output voltage values which change according to a desired nonlinear

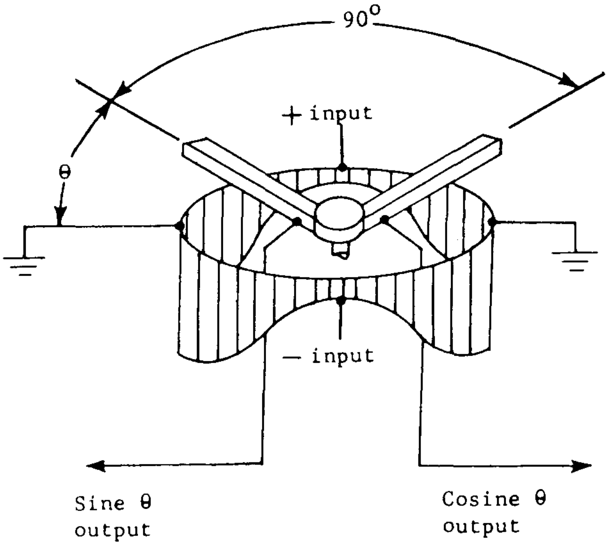

Figure 9. Sine-cosine variable resistors.

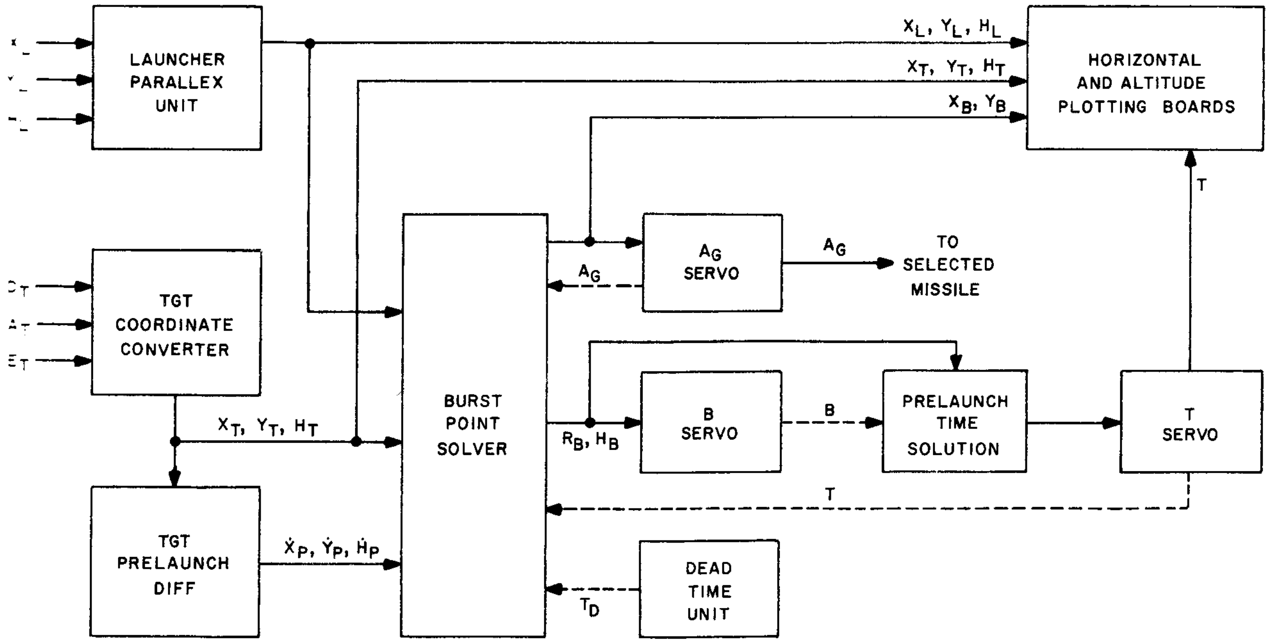

Figure 10. Prelaunch phase of computer operation-block diagram.

characteristic. Card-shaping involves the use of a card of nonuniform width as an insulator. One edge of the card is straight to accommodate the brush arm. The other edge is contoured so that the width of the card and, hence, its resistance per turn will cause the brush-arm voltage to follow the changes in the required function.

(2) One type of nonlinear card is that used in the sine-cosine variable resistors. The contoured edge of the card causes voltage output to vary as the sine or cosine of the angle of resistor shaft rotation. Physical appearance of a sine-cosine card is shown in figure 9. The zero position of the sine brush arm coincides with zero voltage output. Since the cosine function has the same shape as the sine function, the same card may generate a cosine function if another brush arm is displaced 90 degrees from the first. More simply, at zero position the cosine brush arm coincides with the maximum output.

5. GUIDANCE PROBLEM.

a. A surface to air guided missile is intended to achieve a one-round kill; consequently, accuracy is a prime consideration in system design. Guided missile accuracy depends upon the ability of the missile to counter target maneuvers with timely, effective trajectory corrections. As the design and performance characteristics of airborne targets become more sophisticated, guidance techniques must also improve to meet the new threat. The guided missile problem consists of such factors as target maneuverability, tactical application of target vehicles, and increased range of the bomb release point.

b. The Nike Hercules system utilizes command guidance. Therefore, both the guided missile problem and its solution depend on effective computer functioning. The computer is supplied with target and missile position information and uses this data to derive trajectory corrections that will bring the missile and the target into coincidence at some point in space. The computer also calculates when intercept will occur and at this crucial moment initiates a burst command.

c. Target maneuvering tactics, meterological conditions, and differences in the flight characteristics of individual missiles are a few of the important factors affecting the trajectory required for a given engagement. The successful solution of the guided missile problem depends upon the ability of the computer to make immediate, accurate trajectory corrections in response to the above conditions.

d. The computer system solves all the equations required to solve the guided missile problem. It uses these solutions to generate the guidance commands sent to the missile. Each equation in the computer is so arranged that for given inputs only one correct answer is possible. Each mechanization of an equation is characterized by a closed loop that can be viewed as a constraint by which the computing amplifier forces the system to simulate the equation and forces the response of the system to satisfy the equation. The solutions for

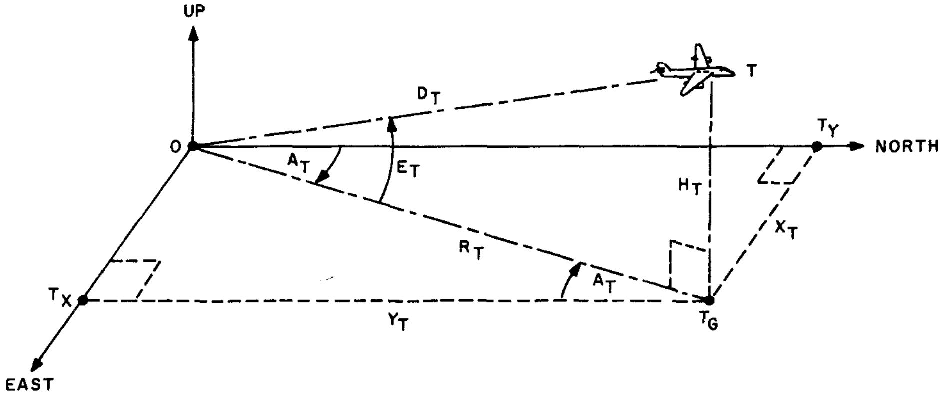

Figure 11. Target position in spherical and rectangular coordinates.

the guided missile problem are always derived from an error signal. The error signal is always generated by the network which sums the various terms in the equation. In solving the guided missile problem, each equation is designated to generate an unknown quantity. A computing amplifier and an input network with a closed loop are provided for each equation. The equation loops are appropriately interconnected with each other to simulate the guided missile problem.

6. FUNCTION OF MAJOR UNITS.

a. Prelaunch.

(1) General. During prelaunch, major units of the computer (fig 10) predict the burst point position and missile time of flight, based on an immediate missile launch. The computer uses present target position, target velocity, launching area center position, and built-in missile-ballistic characteristics data to make the prediction. The computer determines the gyro azimuth angle (A_G) of the predicted burst point referenced from the center of the launching area. The A_G signal is applied by the gyro azimuth transmission system to the roll amount gyroscope in the missile. Determination of A_G is a function of time (T), missile-ballistic characteristics pertaining to T, and predicted burst-point position.

(2) Target coordinate conversion. The position information from the target track radar (TTR) is in spherical coordinates of azimuth angle (A_T), angular height (E_T), and slant range (D_T). The subscript denotes target quantities. The target coordinate converter in the computer (fig 10) converts the spherical position data into corresponding rectangular position data (X_T, Y_T, and H_T).

(a) Spherical coordinates. Figure 11 illustrates spherical and rectangular coordinates of target position with respect to the target track antenna, the origin of both systems. Spherical coordinates of the target are azimuth angle (A_T), angular height (E_T), and slant range (D_T). Slant range is the straight line distance from the target track antenna to the target. Point T_G is the point in the ground plane directly beneath the target. (The ground plane is a horizontal plane at target track antenna height.) Azimuth angle (A_T) is the angle that exists between true north and the line from 0 to T_G in the ground plane. A_T is measured in a clockwise direction from true north. Elevation angle (E_T) is the angle formed between lines OT_G and OT in the vertical plane. Elevation angle (E_T) is positive when T is above T_G. In exceptional cases E_T is negative, indicating that the target track antenna is in a ground plane above the target.

(b) Rectangular coordinates. The position of the target in rectangular coordinates is specified in terms of east-west distance (X_T), north-south distance (Y_T), and height (H_T). The conversion to these coordinates involves right triangle OTT_G (fig 11). Knowing the hypotenuse D_T and angle E_T, the sides R_T and H_T can be solved as shown below.

$$R_T = D_T \cos E_T \qquad (1)$$

$$H_T = D_T \sin E_T \qquad (2)$$

The next conversion is in the ground plane and involves parallelogram $OT_XT_GT_Y$. The diagonal R_T and angle A_T are known. Sides X_T and Y_T are

$$X_T = R_T \sin A_T \qquad (3)$$

$$Y_T = R_T \cos A_T \qquad (4)$$

The quantities X_T, Y_T, and H_T specify the target

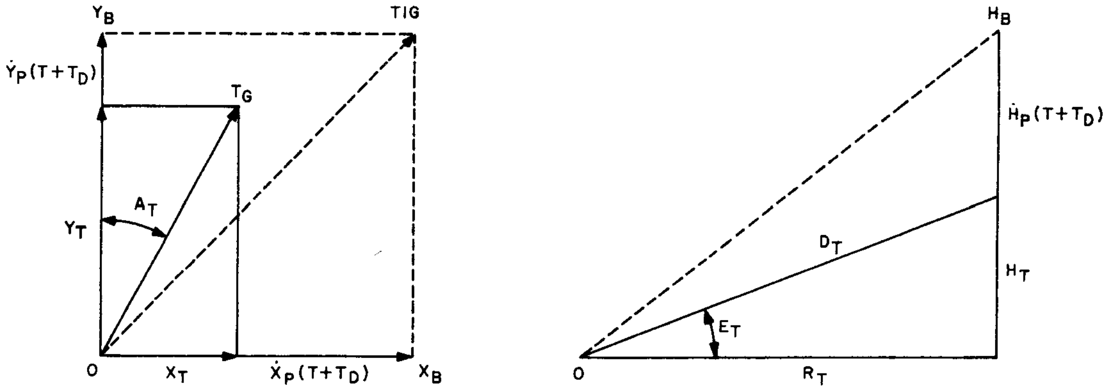

Figure 12. Predicted burst point coordinates - referenced to target track radar.

position in earth's rectangular coordinates.

(3) Missile coordinate conversion. Conversion from spherical to rectangular coordinates must also be performed for missile position. With the exception of the origin, which is the missile track antenna, the conversion equations are analogous to the target equations.

$$R_M = D_M \cos E_M \qquad (5)$$

$$H_M = D_M \sin E_M \qquad (6)$$

$$X_M = R_M \sin A_M \qquad (7)$$

$$Y_M = R_M \cos A_M \qquad (8)$$

The quantities X_M, Y_M, and H_M specify the missile position in earth's rectangular coordinates.

(4) Burst point prediction.

(a) After "target tracked" occurs, the target track radar supplies the computer with spherical coordinates of target position. These coordinates vary with target movement. The computer differentiating circuits determine the rate of change in target position and 4 seconds after "target tracked," the computer begins to compute a continuous "burst point" prediction. The lead distance between the target and the burst point is a function of target and missile velocities and the distance between the missile and the target.

(b) Total prediction time is the time interval between operation of the FIRE switch and arrival of the missile at the burst point. This time includes 7.3 seconds known as dead time (T_D). During T_D the missile is launched, completes boost, and is roll stabilized. Time of flight (T) is measured from the completion of roll stabilization, just before the beginning of the steering phase. Therefore, total prediction time is $T + T_D$.

(c) When the FIRE switch is operated, T_D decreases from 7.3 seconds to zero. When $T_D = 0$, T begins to run down. Figure 12 shows the development of the burst point coordinates by applying a simple formula, distance = rate X time in equations (9), (10), and (11).

$$X_B = X_T + \dot{X}_P (T + T_D) \qquad (9)$$

$$Y_B = Y_T + \dot{Y}_P (T + T_D) \qquad (10)$$

$$H_B = H_T + \dot{H}_P (T + T_D) \qquad (11)$$

The subscript B denotes burst coordinates, the dot represents rate of change in target position, and the subscript P denotes prelaunch. The prelaunch differentiators calculate $\dot{X}_P$, $\dot{Y}_P$, and $\dot{H}_P$.

(d) The burst point position is required to determine gyro azimuth (A_G) and time (T). Because both of these data are referenced to the launching area center, it is necessary to shift the coordinates of equations (9), (10), and (11) (referenced from the target track antenna) to the launching area center. The parallax coordinates involved are X_L, Y_L, and H_L, which represent the east-west, north-south, and up-down distances, respectively, to the launching area center from the target track antenna. These distances are subtracted from burst point coordinates by the burst point solver and result in equations (12, (13), and (14).

$$X_B = X_T - X_L + \dot{X}_P (T + T_D) \qquad (12)$$

$$Y_B = Y_T - Y_L + Y_P (T + T_D) \qquad (13)$$

$$H_B = H_T - H_L + \dot{H}_P (T + T_D) \qquad (14)$$

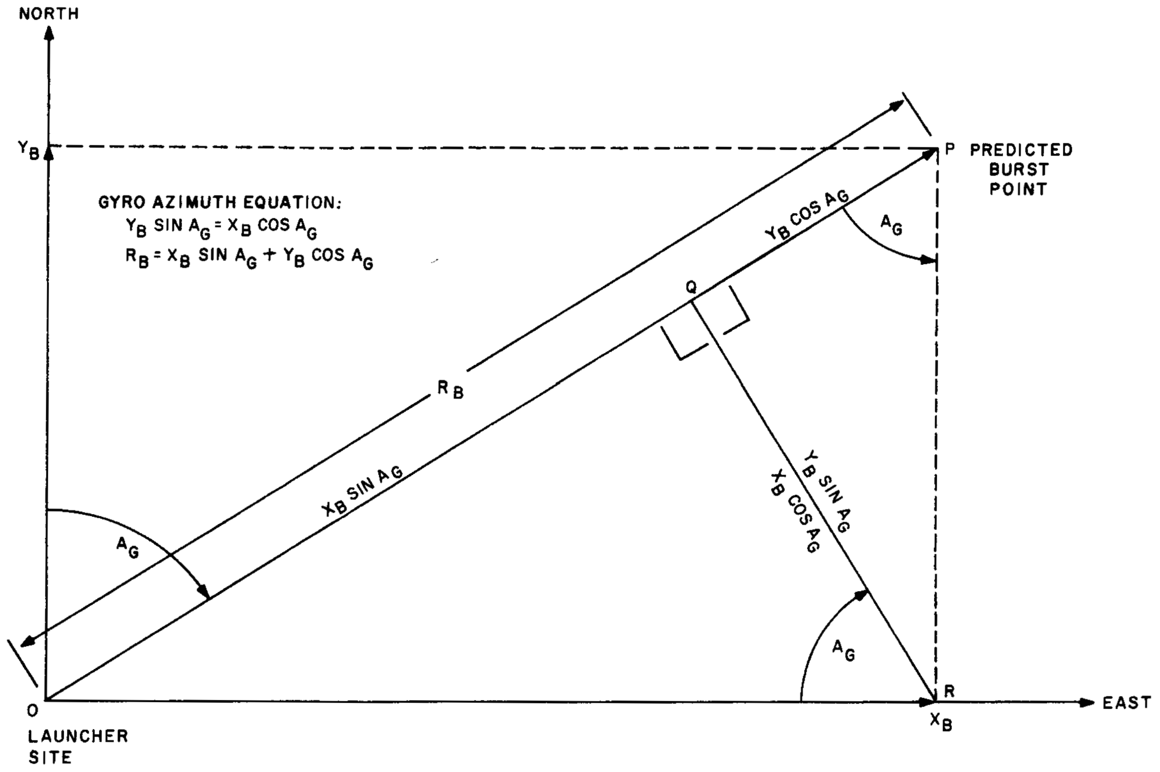

Figure 13. Derivation of gyro azimuth and ground range.

(5) Gyro azimuth and ground range solution.

(a) General. Using the parallax corrected burst point coordinates, it is now possible to determine the gyro azimuth (A_G) of the predicted burst point. The A_G signal from the computer alines the roll amount gyroscope in the missile. With A_G, it is possible to compute the ground range of the burst point (R_B), which is essential to the computation of T. The computations of A_G and R_B are described in (b) and (c) below.

(b) Gyro azimuth. The derivation of the equation governing A_G is shown in figure 13. The angle at R corresponds to A_G, therefore QR = X_B cos A_G. The angle at P is also A_G, therefore QR = Y_B sin A_G. Since both equations are equal, A_G is correct for the given X_B and Y_B values when

$$Y_B \sin A_G = X_B \cos A_G \qquad (15)$$

Equation (15) is solved electro-mechanically by representing A_G as the shaft position of the servo shown in figure 8. Inputs at E_1 and E_2 of the servo variable resistors are the Y_B and X_B analog voltages and the variable resistors are sine and cosine potentiometers. This arrangement causes the $-E_1$ and $+E_2$ inputs to the input network of the A_G servo to be the electrical equivalent of equation 15. The error signal which drives the servo is the difference in these signals. When $-E_1$ equals $+E_2$ there is no error and equation 15 is solved. The result is that the correct A_G is on the servo shaft.

(c) Ground range. To calculate T, it is necessary to know R_B, the ground range to the burst point. The derivation of the equation governing R_B is shown in figure 13.

$$R_B = X_B \sin A_G + Y_B \cos A_G \qquad (16)$$

This is the solution for ground range at burst point and is calculated by the burst point solver (fig 10).

(6) Ballistic elevation angle solution. The computer is programed to develop the equation for time of flight in terms of the predicted burst point if the ballistic elevation angle (B) is known. Angle B (fig 14) is the angle from the predicted burst point to the ground plane with the launching area center as origin. From the figure, it is obvious that for any given R_B and H_B, the B angle is correct when equation (17) is balanced.

$$R_B \sin B = H_B \cos B \qquad (17)$$

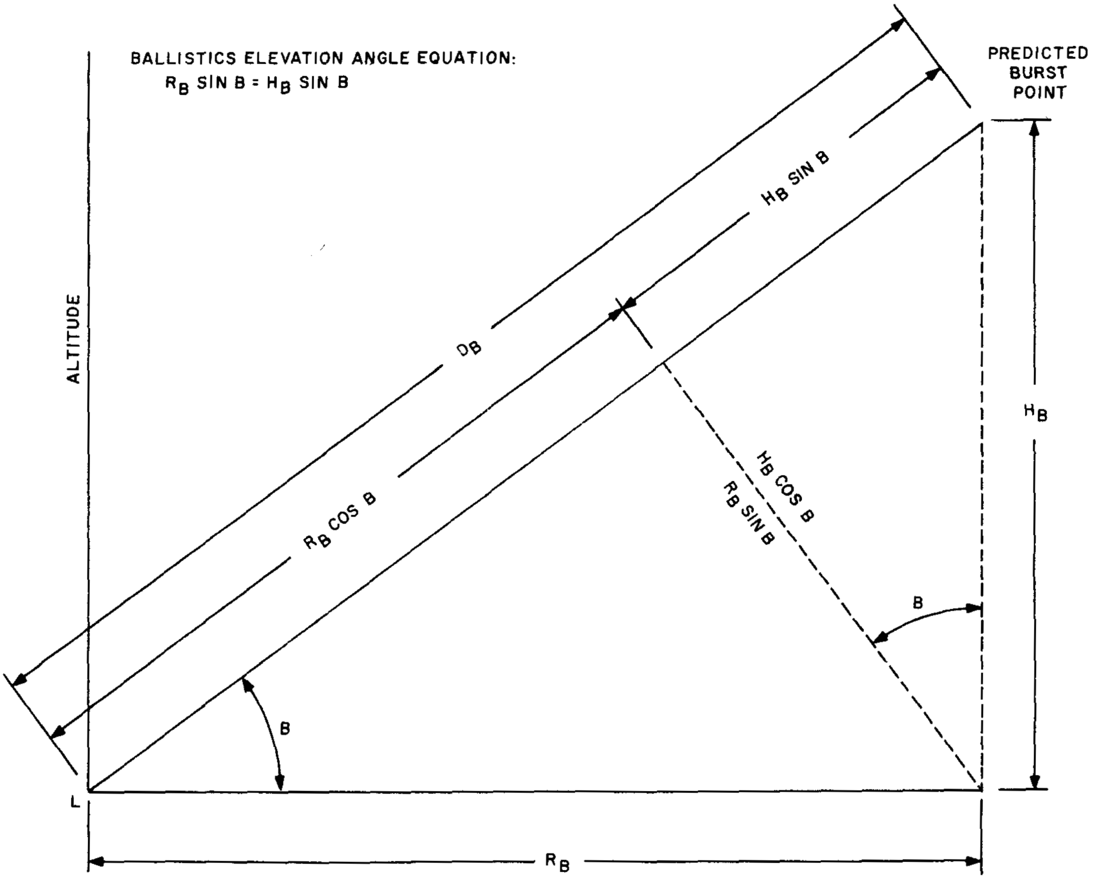

Figure 14. Solution for ballistic elevation angle.

The B servo (fig 10), using a computing amplifier similar to that shown in figure 8, solves this equation by positioning a shaft representing B until equation (17) is balanced.

(7) Time of flight prediction.

(a) The prelaunch equation for time of flight (T) is derived from the same quantities used to determine ballistic elevation angle (B) and ballistic data (D_B). The geometry of T is shown in figure 15. A circular arc is shown intersected by a typical ballistic curve at the critical angle of elevation. The circular arc may be defined as an area of constant time of flight, that is, the missile would theoretically arrive at any point on the arc for a given time of flight. The intersecting ballistic curve shown is the circular arc corrected to include missile ballistics. The intersection of the two arcs is the critical angle, and the time of flight to the two arcs is equal to this point. For Nike Hercules missiles, the critical angle is 32 degrees. For any other elevation angle, the circular arc must be corrected according to missile ballistics, so that time of flight becomes D (T) plus or minus the ballistic correction E (B, T). The

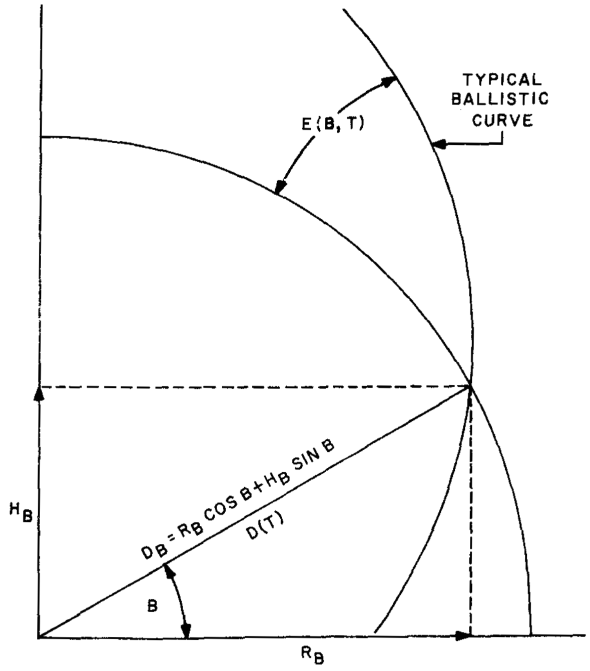

Figure 15. Solution for time of flight.

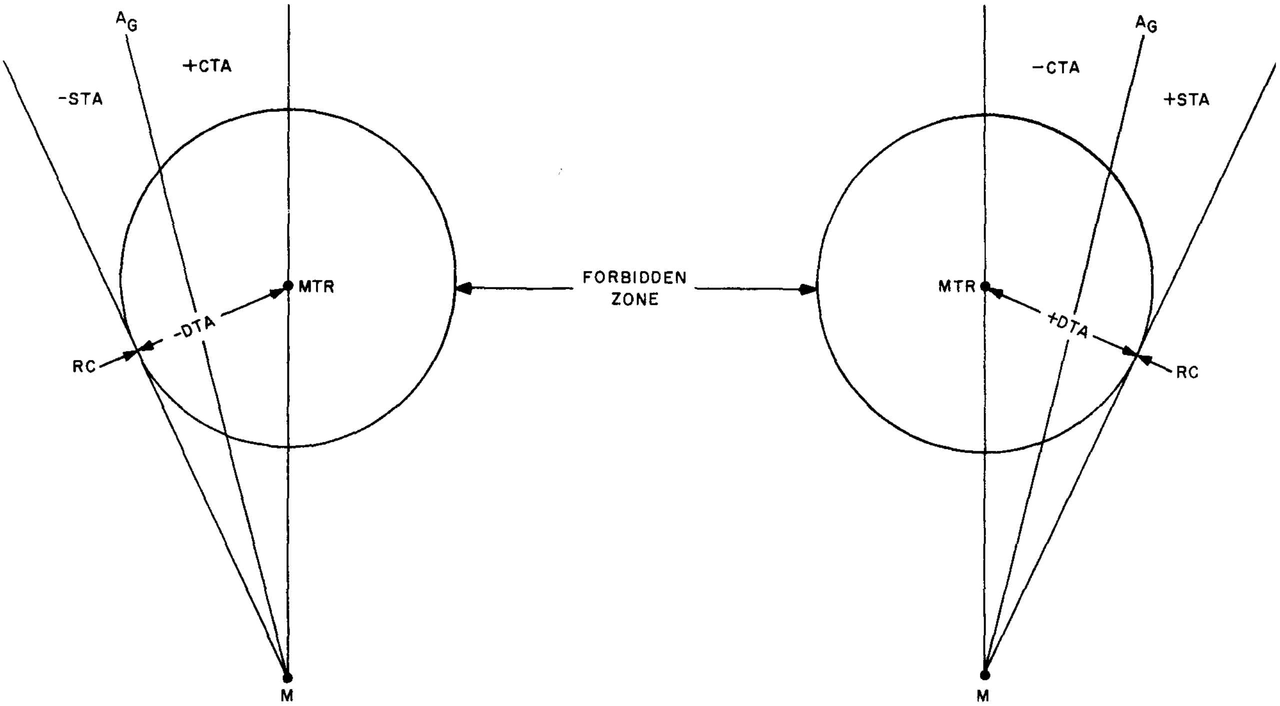

Figure 16. Computation of initial turn angles.

ballistic correction factors are built into the computer prelaunch circuits in the form of voltage divider outputs and nonlinear variable resistor functions. The equation for T is balanced and a solution obtained for the given input values when

$$R_B \cos B + H_B \sin B = D(T) + E(B,T). \qquad (18)$$

(b) While T does not appear explicitly in the left side of the equation, terms in both sides of the equation are ballistic functions of T.

b. Initial dive and turn circuits.

(1) After the fire command is issued, the missile lifts off the launcher in a near-vertical programed flight. Approximately 4 seconds later, the booster separates and the missile roll stabilizes. Prior to roll stabilization the missile receives no steering commands. After roll stabilization, dive orders are issued causing the missile to fly an optimum trajectory toward the predicted burst point. To achieve maximum range, it is desirable to program missile flight at the highest possible altitude to keep aerodynamic drag on the missile low. This permits greater missile ranges than would be possible if the missile flew at lower altitudes where the air is denser. For engagements where the range to the burst point is short, the missile must be brought out of the near-vertical flight as quickly as possible to prevent overshooting the target. The rate at which the missile is ordered to dive is made a function of the range and height of the predicted burst point. Upon receipt of the target tracked signal by the computer, the initial dive order is computed. The coordinates of the predicted burst point, height of burst (H_B), and ground range of burst (R_B) are combined with a fixed voltage to obtain the magnitude of this dive order. Although the initial dive order is computed during prelaunch, it is not applied to the missile until after roll stabilization. The order continues from roll stabilization until "on trajectory" (OT).

(2) The requirements for an initial dive (ID) always exist; however, these requirements may be modified by generation of an initial turn (IT) order. The initial turn (over-the-shoulder) condition exists only when the forbidden zone of the missile track radar (MTR) lies between the launcher and the predicted burst point. The forbidden zone is an area about the MTR through which missile flight would require the MTR to exceed its angular tracking capabilities. When an initial turn condition exists, the computer issues turn orders, causing the missile to skirt the forbidden zone. The initial turn orders are computed during the prelaunch phase of operation if an initial turn is necessary. These turn orders cause the missile to fly a skirting turn angle (STA) (fig 16). The magnitude and polarity of the STA

are determined by an indirect method involving the computations of the critical turn angle (CTA) and difference turn angle (DTA). The DTA angle is computed in both polarities. The computer obtains the correct STA by solving the equation: STA = CTA - DTA if CTA is positive. If the missile is to the right of the MTR at roll stabilization, the computer solves the equation: STA = CTA + DTA if CTA is negative. The magnitude of the initial turn order is greatest at roll stabilization and continuously decreases until the missile is flying the turn angle equal to STA. The missile continues along this path until it passes the forbidden zone. Radar cleared (RC) occurs as soon as the missile passes the MTR. At this time initial turn orders are removed and steering turn orders are applied to bring the missile on trajectory and begin the steering phase.

MMS SUBCOURSE NUMBER 150, NIKE RADARS AND COMPUTER

EXERCISES FOR LESSON 6

1. If 40 volts represents 40,000 yards, what is the scale factor in volts per yard?

    A. 0.004
    B. 0.003
    [✓ C.] 0.002
    D. 0.001

2. Which operations are performed by the computing amplifier?

    A. Amplification, isolation, and zero setting
    B. Isolation, phase shift, and zero setting
    C. Amplification, isolation, and polarity inversion
    D. Amplification, phase shift, and polarity inversion

3. What data (from which trajectory corrections are derived) is supplied to the computer?

    A. Target and missile position
    B. Burst point and time to intercept
    C. Target and missile velocity
    D. Target and missile acceleration

4. When is the roll amount gyro uncaged?

    A. Fire
    B. Fire + 2 seconds
    C. Booster separation
    D. Roll stabilization

5. What is the purpose of the Nike computer?

    A. Guide the missile
    B. Detect the target
    C. Challenge the target
    D. Fire the missile

6. What does the time servo calculate during prelaunch?

    A. Time of liftoff
    B. Time of flight
    C. Dead time
    D. Burst time

7. What is the first derivative of distance?

    A. Acceleration
    B. Direction
    C. Time
    D. Velocity

8. In the prelaunch solution, what does the A_G servo determine by using the junction of X_B and Y_B?

    A. Angle A_G and ground range R_B
    B. Angles A_G and B
    C. Angle A_B and D_B
    D. Distances X_B, Y_B, and H_B

9. Which causes avoidance of the forbidden zone?

    A. Role stabilization
    B. Initial dive
    C. Initial turn
    D. Radar cleared

10. What does the Nike computer utilize to represent real quantities such as distance, velocity, and acceleration?

A. Inductance
B. Voltage
C. Trigonometric equation
D. Capacitance

11. What type of computer is used in the Nike system?

A. AC analog
B. DC analog
C. AC digital
D. DC digital

12. Which event is detected to start the 4-second timer?

A. Missile liftoff
B. Booster separation
C. Missile upward acceleration
D. Roll stabilization

13. What is determined during the prelaunch phase of the Nike computer?

A. Gyro azimuth and time of flight
B. Initial dive and turn angle
C. Initial turn and climb angle
D. Steering orders in climb and turn

14. What is the main requirement of a DC amplifier?

A. High output impedance
B. Low input impedance
C. Positive feedback
D. Negative feedback

15. What is the formula for the voltage output of a DC amplifier which has three stages of amplification?

A. $E_O = E_{in} \times \frac{R_F}{R_{in}}$

B. $E_O = -E_{in} \times \frac{R_{in}}{R_F}$

C. $-E_O = E_{in} \times \frac{R_{in}}{RF}$

D. $-E_O = E_{in} \times \frac{R_F}{R_{in}}$

16. What is positioned by the A_G signal during prelaunch?

A. MTR to the designated missile
B. TTR to the predicted burst point
C. Roll amount gyro to the burst point azimuth
D. TTR to the designated target

17. Which major unit of the computer determines target velocity?

A. Missile coordinate converter
B. Prelaunch differentiators
C. Burst point solver
D. A_G servo

18. When does the steering phase begin if the MTR lies between the launcher and the predicted burst point?

A. Roll stabilization
B. Liftoff
C. Radar cleared
D. Target tracked

19. What major unit of the computer is used to determine X, Y, and H distances to the target?

A. Target coordinate converter
B. Burst point solver
C. Ballistics servo
D. A_G servo

20. What is used to prevent servo hunting?

A. Regenerative feedback
B. Gain control
C. Error signal
D. Velocity feedback

21. A differentiator employing a 2-microfarad capacitor and a 5-megohm feedback resistor has an input which is changing at a rate of minus 2 volts per second. What will be the output voltage?

A. 1 volt
B. 5 volts
C. 10 volts
[✓ D.] 20 volts

22. What is the purpose of zero setting the DC amplifiers in the computer?

A. Establish negative feedback
B. Reduce high frequency distortion
C. Hold the summing point to zero
D. Compensate for drift

23. What is the output, in volts, of the circuit in figure 1?

A. 123.3
B. 36
C. 30
D. 10

24. Which resistor, in figure 1, contributes the most weight in determining the output?

A. R_1
B. R_2
C. R_3
D. R_4

25. What mathematical function is performed by the circuit in figure 2, when R_1 = 3 megohms and R_2 = 1 megohm?

Multiplication
B. Division
C. Differentiation
D. Weighting

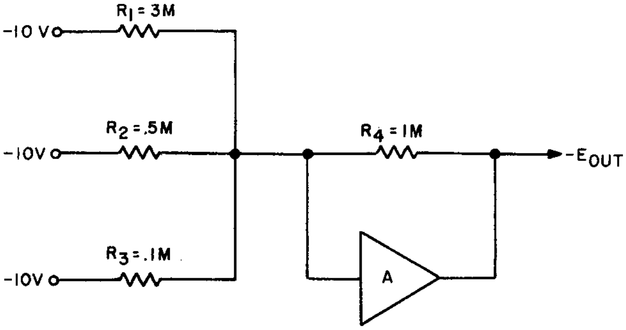

Figure 1.

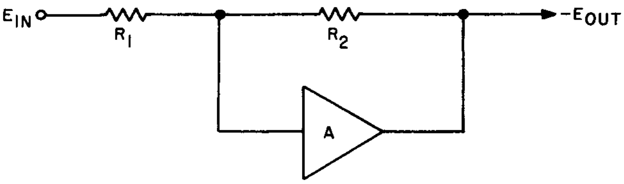

Figure 2.