CHAPTER 3(C)

THEORY OF OPERATION

Section I (C). SYSTEM OPERATION

3-1 (C). General Missile Operation

a. Missile Guidance Set.

(1) The missile guidance set performs three main functions in controlling and detonating the guided missile. First, it controls the missile flight in accordance with guidance commands (coded RF pulses) initiated by the computer and transmitted to the missile by the missile tracking radar (MTR) system. Secondly, it transmits an RF response pulse which enables the MTR to track the missile. Thirdly, it causes detonation of the missile warhead when a burst command is received from the ground guidance equipment. In addition, it initiates detonation of the missile warhead if ground guidance ceases or if a malfunction occurs within the missile.

(2) The missile guidance set consists of four functional groups of circuits: receiving and decoding circuits, transmitting circuits, steering control circuits, and command and fail-safe detonation control circuits. The guidance commands are received, amplified, and decoded by the receiving and decoding circuits. The decoded output of the receiving and decoding circuits is applied to the transmitting circuits and to the steering control circuits. The transmitting circuits produce an RF response pulse each time a guidance command is received and decoded. The steering control circuits, in conjunction with the missile hydraulic system, convert the decoded guidance command into displacement of the missile elevons. Seven flight-control instruments—part of the steering control circuits—aid in maintaining proper trajectory. When a burst command is received and decoded or a malfunction occurs within the missile, ground guidance ceases and the command and fail-safe detonation control circuits cause a burst voltage to be applied to the warhead system, resulting in detonation of the missile warhead.

b. Missile Control Surfaces. Four control surfaces (elevons) control the trajectory of the missile in response to steering orders from the missile guidance set. An actual movement (climb or dive) about the pitch axis is accomplished through both P and Y elevon displacements. The two displacements, when vectorially added, result in a given pitch movement (fig. 3-1). Movements (right or left turn) about the yaw axis are derived in an identical manner. The four missile elevons are paired and designated P and Y, respectively, to avoid confusion with aerodynamic surfaces which act in a single reference plane. All four missile elevons operate simultaneously and differently by pairs to provide roll stabilization of the missile.

3-2 (C). Operating Phases

The operating phases for the two missile missions, surface-to-air mission (fig. 3-2) and surface-to-surface mission (fig. 3-3) are identical in every phase except the controlled flight phase and the burst conditioning phase. The operating phases are discussed in *a* through *h* below.

a. Prelaunch Phase (Fig. 3-2). During the prelaunch phase, the missile is conditioned for flight. Gyro preset data obtained from the computer is used to preset the caged roll amount gyro in the missile guidance set. The roll amount gyro is preset so its outer gimbal lies in the gyro azimuth plane (the vertical plane including the predicted intercept point and the missile). The gyro spin axis is then perpendicular to the gyro azimuth plane. When the

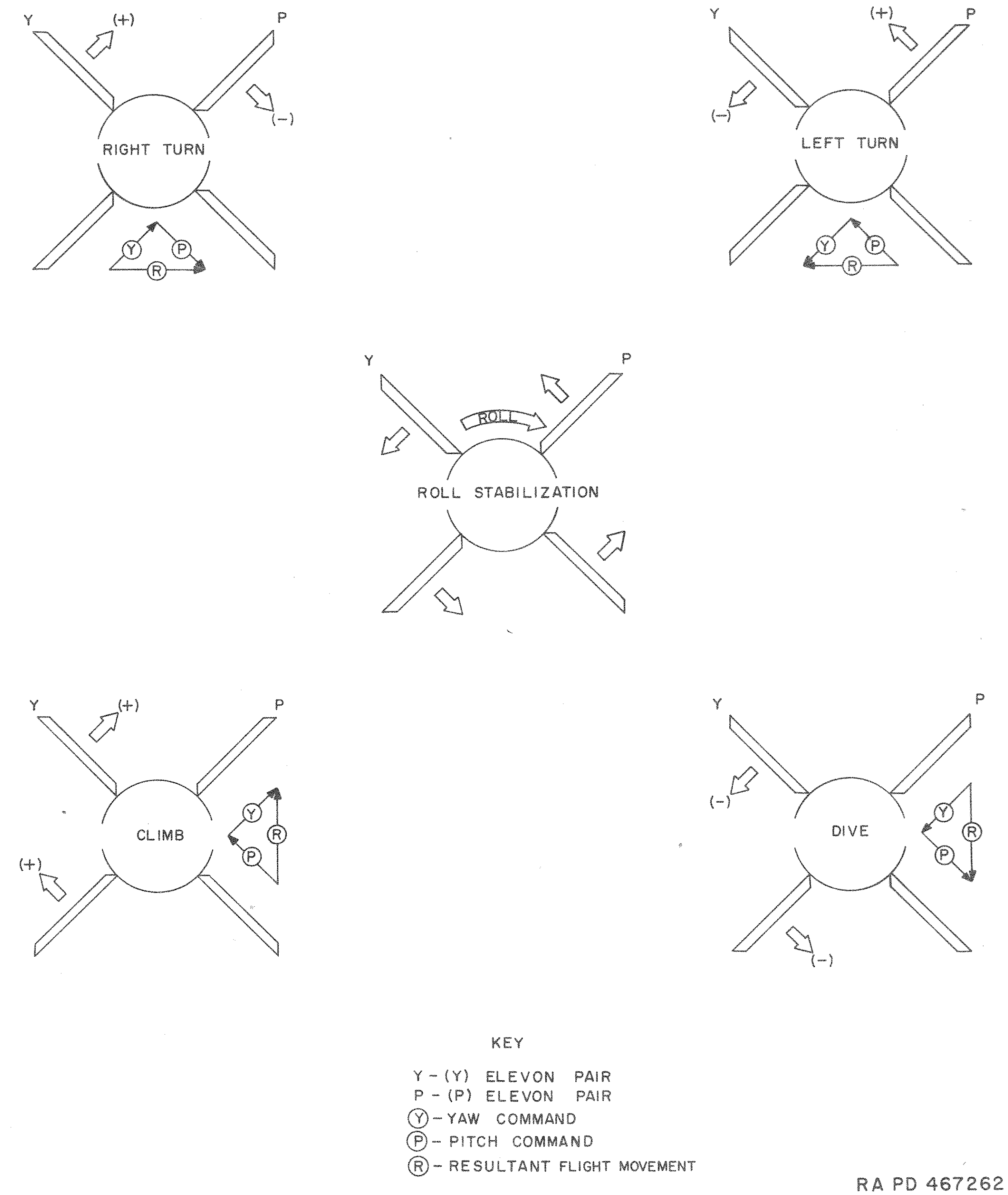

Figure 3-1 (U). Elevon displacement and resulting flight movement (U).

fire command is given, the computer sends a constant value of gyro preset data, thereby allowing the gyro preset servo system to stabilize. Simultaneously, the guidance set transfer relay switches the power source for the missile guidance set from the launcher control-indicator to the missile guidance set battery, and the accessory power supply (APS) or hydraulic pumping unit (HPU) is started.

b. Launch Phase (Fig. 3–2). The missile launch order follows 2 seconds after the fire command and causes the roll amount gyro to be freed (uncaged) so that it can maintain its position relative to the gyro azimuth plane. The rocket motor cluster is ignited 0.25 second after the launch order. As the missile body and the rocket motor cluster move along the launching-handling rail, the missile umbilical assembly is sheared. The launching-handling rail release, which secures the missile to the rail, pivots downward and provides a clear path for the missile body and the rocket motor cluster.

c. Boost Phase (Fig. 3–2). During the boost phase, the rocket motor cluster accelerates the missile in a near vertical launch to supersonic speed, the elevons are mechanically locked, and the computer sends 0G guidance commands. When the rocket motor cluster thrust is expended, the higher drag on the rocket motor cluster separates it from the missile. At separation, the rocket motor cluster releases the missile elevons and pulls the propulsion arming lanyard, thereby activating the missile thermal batteries that supply the voltages for igniting the missile rocket motor.

d. Roll Stabilization Phase (Fig. 3–2). During the roll stabilization phase, the roll control servo system positions the missile elevons so that the belly of the missile is pointed toward the predicted intercept point as established by the preset position of the roll amount gyro. The total time of the boost and roll stabilization phases is approximately 5 seconds.

e. Controlled Flight Phase for Surface-to-Air Missions (Fig. 3–2). At the end of the roll stabilization phase, the missile tracking radar transmits a dive command and then sends steering commands. Roll orientation of the missile is maintained during the controlled flight phase. The missile accelerates during this phase and reaches a maximum velocity of 3,700 feet per second at missile rocket motor burnout.

f. Burst Conditioning Phase for Surface-to-Air Missions (Fig. 3–3). At approximately 0.5 second before intercept, the controlled flight phase ends and the burst conditioning phase begins. During the burst conditioning phase, no corrective steering orders are generated. A sequence of 25 consecutive conditioning signals, 0G P commands at the 500-pulse groups per second rate with no Y commands, enables the missile for burst. At a predetermined time before intercept, the missile warhead is detonated by a burst command from the ground guidance equipment.

g. Controlled Flight Phase for Surface-to-Surface Missions (Fig. 3–3). In the controlled flight phase, the missile is steered toward an initial aiming point directly above the target. The target coordinates are set into the ground equipment from known target position data, and the missile steering orders are based upon this data. As the missile dives vertically toward the target, the missile altitude decreases until the MTR cannot maintain contact with the missile.

h. Burst Conditioning Phase for Surface-to-Surface Missions (Fig. 3–3). While the missile is still under control of the ground guidance equipment, burst conditioning orders are sent to the missile to begin the burst conditioning phase. During the burst conditioning phase, the missile is conditioned not for burst but for unguided flight to the target. Just prior to the loss of ground guidance control, the MTR transmits a burst command. The burst command disables the receiving and decoding circuits of the missile guidance set, so that the course of the missile cannot be changed by enemy jamming. The burst command also causes the missile to roll 3,200 angular mils or to flip over. This flipover distributes the drift error, minimizing drift and improving accuracy. The missile is detonated by a barometric fuse or crush rings.

3–3 (C). Command Coding

a. General. The orders received from the missile tracking radar system are pulse groups of RF energy occurring at 2,000-microsecond intervals (500-pulse groups per second). There are three possible types of orders received by the missile. The types are the P command (A, fig. 3–4), the Y command (B), and the burst command (C). The P and Y commands, called steering commands, are composed of groups of four pulses. The pulses for the P and Y commands are numbered (No. 1, No. 2, No. 3, and No. 4) in sequence of occurrence. The P and Y steering commands are transmitted alternately during the command guidance or steering phase. During the burst conditioning phase starting 0.5 second before intercept, only 0G P commands are received. The burst command consists of pulse groups of five pulses and is received only when the missile is to be detonated. On surface-to-surface firings (para 3–2), the burst command does not detonate the missile but conditions it for an unguided flight phase after which the missile is detonated by a barometric fuse or crush rings. The arrangement and numbering of the pulses are the same as for a 0G P command except for the fifth pulse, called the No. 5 pulse or burst pulse which occurs 1.58 microseconds after the No. 2 pulse in the stovepipe guidance set or 1.5 microseconds after the No. 2 pulse in the mushroom guidance set.

b. Steering Commands. The time interval between the No. 1 pulse and the No. 2 pulse (A, B, and C) is equal to the missile code time, and the command is accepted only by missiles equipped to receive that code (*d* below). The time interval between the No. 3 and No. 4 pulse indicates whether the order is a P command (A and C) or a Y command (B). If the time interval is equal to the missile code plus 1 microsecond, the order is a P command. If the time interval is equal to the missile code plus 2 microseconds, the order is a Y command. During the steering phase of flight, the P and Y commands are received alternately. During the last 0.5 second of flight, when the missile is to be conditioned for burst (*c* below), only 0G P commands are received. The time interval between the No. 2 pulse and the No. 4 pulse varies and is related to the magnitude and direction of the maneuver to be performed. This time interval varies linearly from 52.5 microseconds for a −8.5G order in the mushroom guidance set or a −7G order in the stovepipe guidance set to 122.5 microseconds for a +8.5G order in the mushroom guidance set or a +7G order in the stovepipe guidance set.

c. Burst Command. The five pulses of a burst command (C) are the same as for a 0G P order with the additional pulse occurring 1.58 microseconds after the No. 2 pulse in the stovepipe guidance set or 1.5 microseconds after the No. 2 pulse in the mushroom guidance set. This additional pulse is called the No. 5 pulse or burst pulse. A series of ten pulse groups containing the burst pulse is required to detonate the missile. The burst command will not be effective unless the missile has been conditioned for burst by special steering orders. This conditioning requires at least 25 consecutive P command pulse groups at 2,000-microsecond intervals (500-pulse groups per second) with no Y command pulse groups. Transmission of the conditioning signals begins 0.5 second before intercept. About 90 milliseconds before intercept, the computer in the ground guidance equipment initiates the burst command. Eighteen to 20 milliseconds of this time is needed to transmit the burst command and about 2 milliseconds is for detonation of the missile. The remainder of the time allows for delays in the computer and missile tracking radar system.

d. Decoded Pulse. The received command (A, B, or C) is passed through a delay circuit which delays each pulse by a time interval corresponding to the missile code time. In the resulting delayed signal (D), the delayed No. 1 pulse corresponds to the undelayed No. 2 pulse of the received order (A, B, or C). The coincidence of these two pulses produces an output in the amplifier-decoder called the decoded pulse (E). This decoded pulse in turn controls the generation of three signals (F, G, and H). All missile control depends upon these three signals. Therefore, if the No. 1 and No. 2 pulse spacing is not equal to the missile code time, the received RF energy pulses will not be effective. The three signals controlled by the decoded pulse are the burst enable pulse (F), the 80-microsecond enable pulse (G), and the slope voltage (H). The burst enable pulse (F), a 2- to 4-microsecond pulse, begins coincident with the No. 2 pulse and enables operation of the burst command detection circuit of the missile. The 80-microsecond enable pulse (G) is 80 microseconds in duration and begins about 50 microseconds after the No. 2 pulse. The 80-microsecond enable pulse enables the steering circuits during the time interval in which the No.

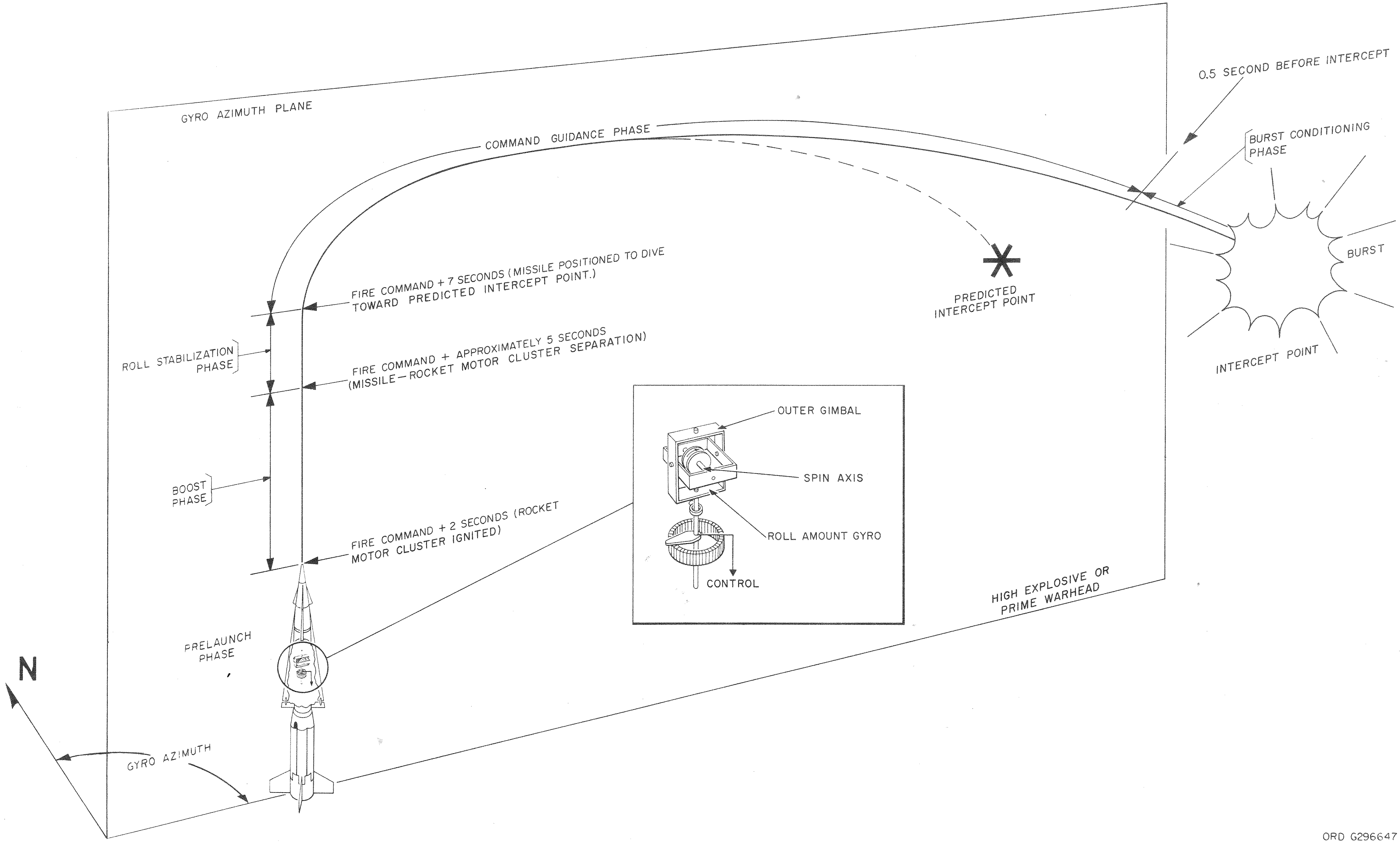

Figure 3–2 (C). Phases of surface–to–air mission (U).

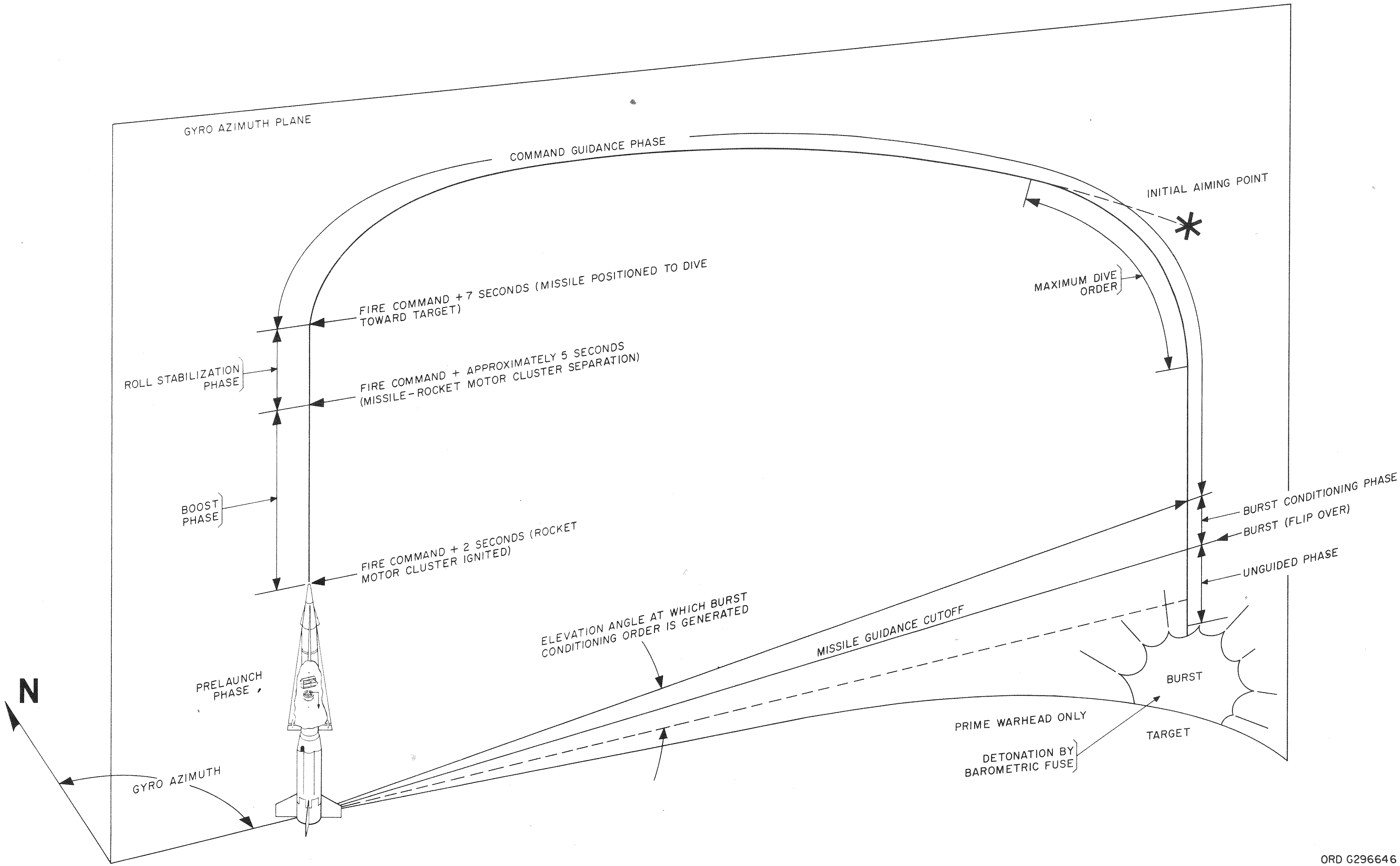

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Figure 3-3 (C). Phases of surface-to-surface mission (U).

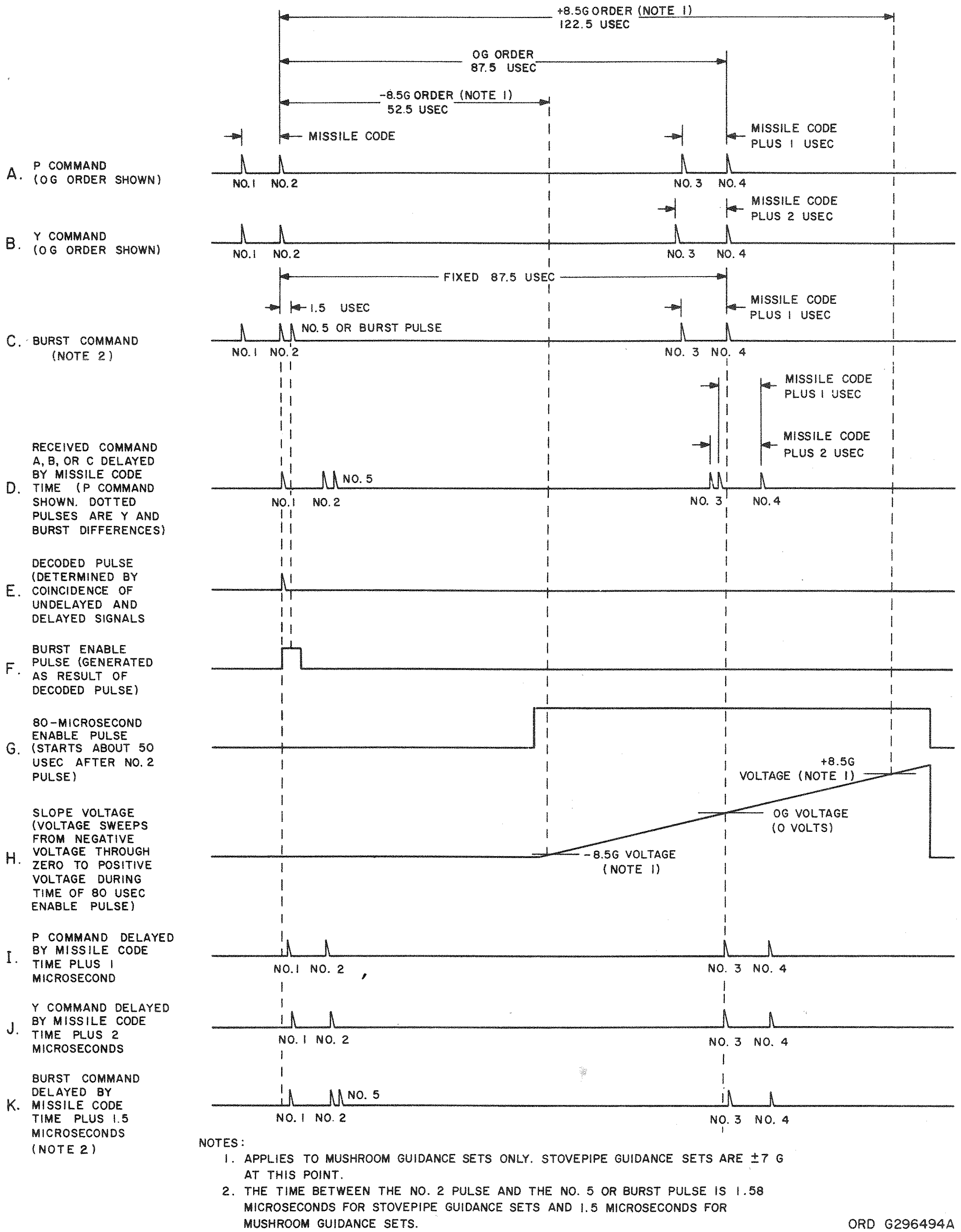

Figure 3–4 (C). Signals for steering and burst orders (U).

4 pulse occurs. The slope voltage (H) is generated at the same time as the 80-microsecond enable pulse and sweeps from a negative voltage to a positive voltage. The voltage sweep starts about 50 microseconds after the No. 2 pulse. At 52.5 microseconds after the No. 2 pulse, the slope voltage is a negative voltage which represents a −8.5G command in the mushroom guidance set or a −7G command in the stovepipe guidance set. At 87.5 microseconds after the No. 2 pulse, the slope voltage is zero and represents a 0G command. At 122.5 microseconds after the No. 2 pulse, the slope voltage is a positive voltage which represents a +8.5G command in the mushroom guidance set or a +7G command in the stovepipe guidance set. Intermediate points represent other commands.

e. P, Y, and Burst Delays. All delay signals (D) are delayed by additional amounts; however, only specific delays are important to a given signal. A received P command (A) delayed by the missile code delay time (D) is effective in generation of a P command in the missile only when delayed by an additional microsecond (I). In the delayed command (I), the No. 3 pulse is in coincidence with the No. 4 pulse of the received command (A). The No. 3 pulse of a Y command with the same delays will not be in coincidence with the No. 4 pulse. The generation of a P command voltage from the available pulses and voltages is discussed in *f* below. A received Y command (B) delayed by the missile code time (D with dotted line for No. 3 pulse) is effective in generation of a Y command in the missile only when delayed by an additional 2 microseconds (J). In the delayed command (J), the No. 3 pulse is in coincidence with the undelayed No. 4 pulse of the received command (B). The No. 3 pulse of a P command with the same delays will not be in coincidence with the No. 4 pulse. The generation of a Y command voltage from the available pulses and voltages is discussed in *g* below. A received burst command (C) delayed by the missile code time (D with dotted line for No. 5 or burst pulse) is effective in generating the burst command in the missile only when delayed by 1.58 additional microseconds in the stovepipe guidance set and 1.5 microseconds in the mushroom guidance set (K). In the delayed command (K), the No. 1 pulse is in coincidence with the undelayed No. 5 pulse of the received burst command (C). The generation of a burst signal from the available pulses is discussed in *h* below.

f. P Order Determination. The P order is determined from the P command (A), the 80-microsecond enable pulse (G), the P command delayed by the missile code time plus an additional microsecond (I), and the slope voltage (H). Figure 3—5 shows these pulses in time sequence. Letters A, G, I, and H on figure 3—5 refer to corresponding signals on figure 3—4. Signal AGI on figure 3—5 is a signal resulting from coincidence of signals A, G, and I. The No. 4 pulse of the received P command (A) and the No. 3 pulse of the delayed P command (I) are in time coincidence during the presence of the 80-microsecond enable pulse (G). Coincidence of these three signals produces a resultant P order pulse (AGI) in time coincidence with the No. 4 received pulse (A). The P order pulse (AGI) causes a sample of the slope voltage (H) to be made. The polarity and amplitude of the slope voltage at this instant indicates the direction and magnitude of the received P command. As the time position of the P order pulse changes, the sampled voltage becomes more positive or more negative. This P command voltage is applied to the P control servo system which controls the missile elevons for P maneuvers.

g. Y Order Determination. The Y order is determined from the Y command (B, figure 3—4), the 80-microsecond enable pulse (G), the Y command delayed by the missile code time plus an additional 2 microseconds (J), and the slope voltage (H). Figure 3—6 shows these pulses in time sequence. Letters B, G, J, and H on figure 3—6 refer to corresponding signals on figure 3—4. Signal BGJ on figure 3—6 is a signal resulting from coincidence of signals B, G, and J. The No. 4 pulse of the received Y command (B) and the No. 3 pulse of the delayed Y command (J) are in time coincidence during the presence of the 80-microsecond enable pulse (G). Coincidence of these three signals produces a resultant Y order pulse (BGJ) in time coincidence with the No. 4 received pulse (B). The Y order pulse (BGJ) causes a sample of the slope voltage (H) to be made. The polarity and amplitude of the slope voltage at this instant indicates the direction and magnitude of the received Y command. As the time position of the P order changes, the sampled voltage becomes more

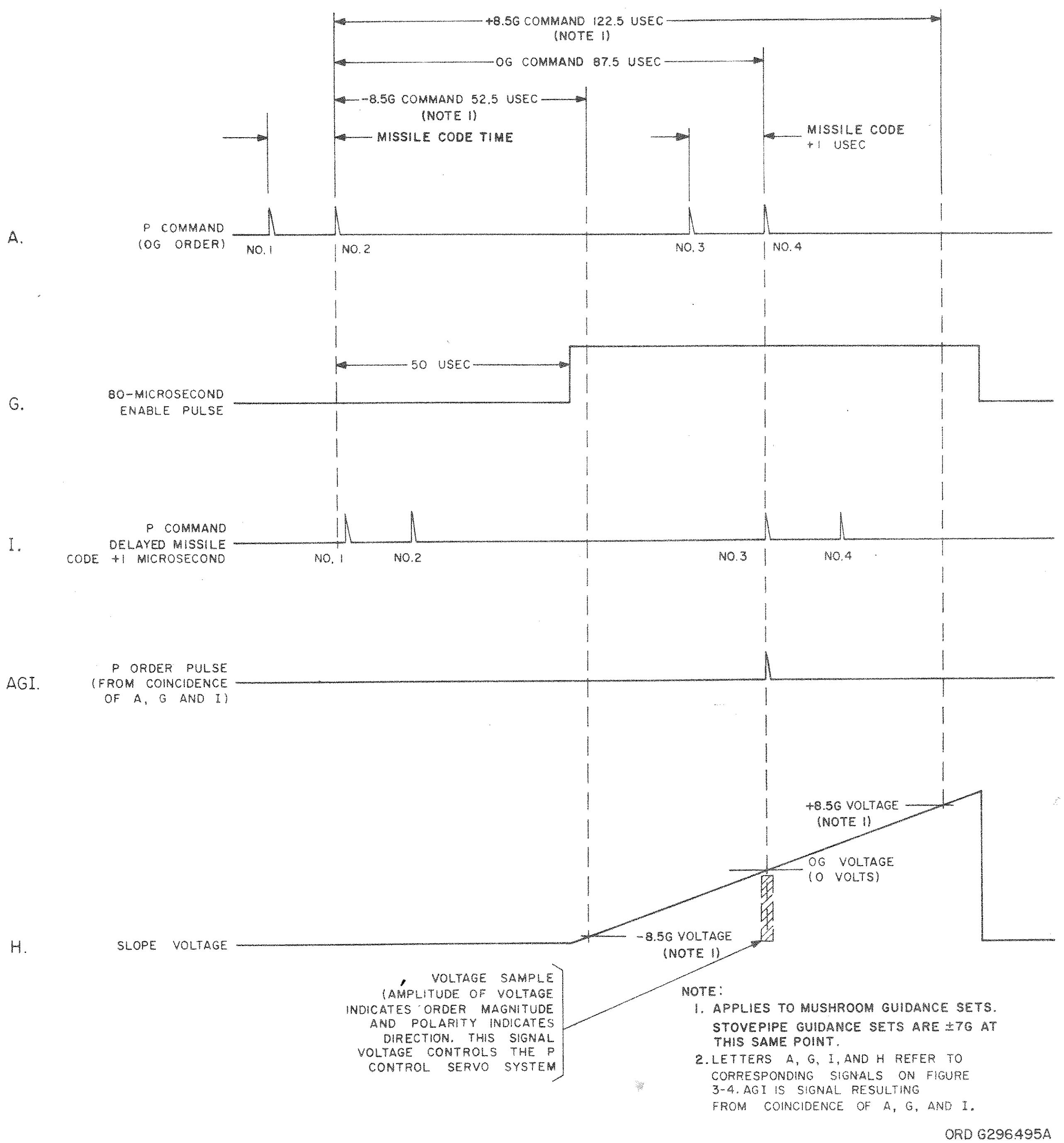

Figure 3–5 (C). P order signals (U).

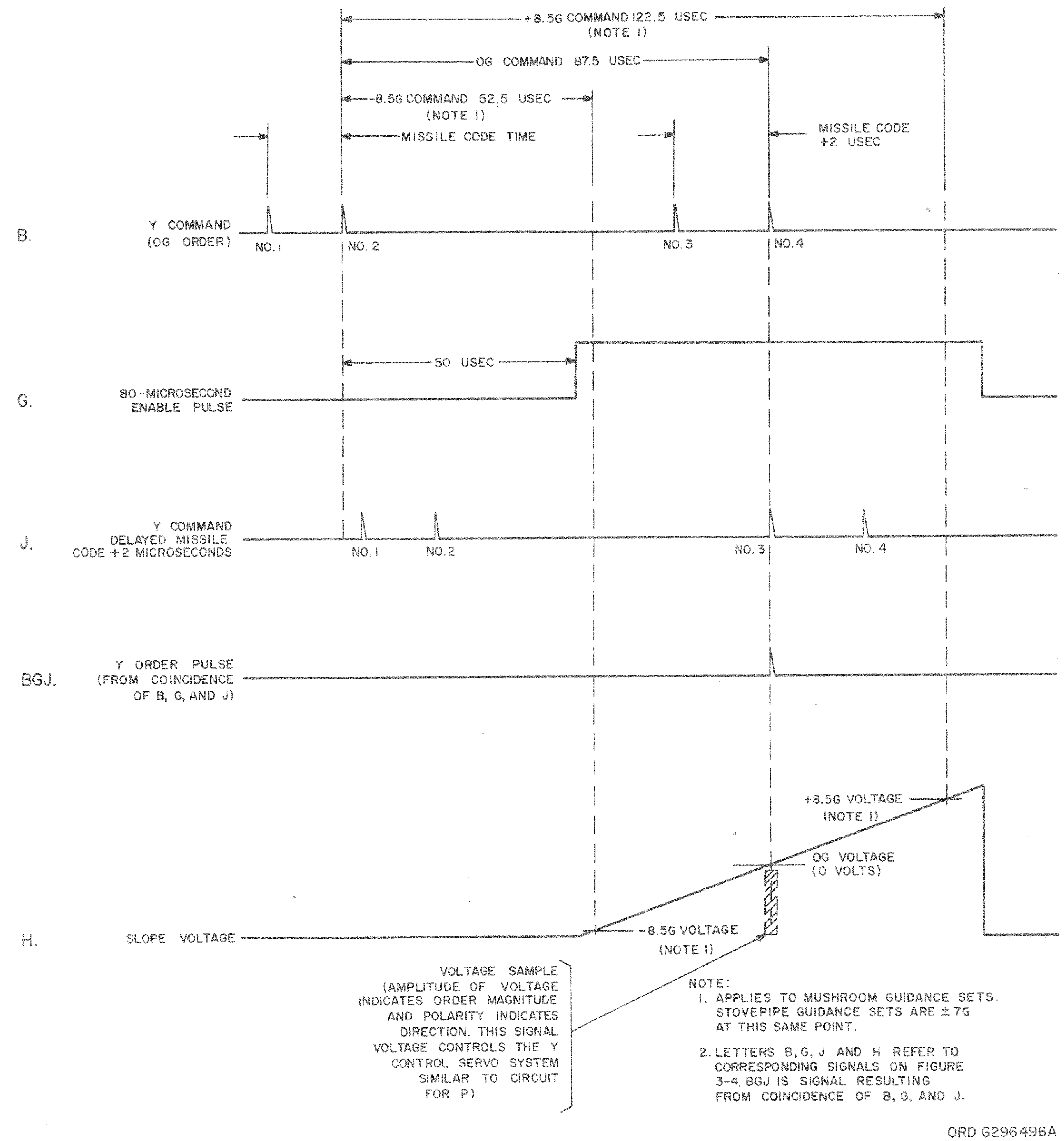

Figure 3–6 (C). Y order signals (U).

positive or more negative. This Y command voltage is applied to the Y control servo system which controls the missile elevons for Y maneuvers.

h. Burst Order Determination. The burst order is determined from coincidence of the burst command (C, fig. 3–4), the burst enable pulse (F), and the burst command delayed by the missile code time plus 1.58 microseconds delay in the stovepipe guidance set and 1.5 microseconds in the mushroom guidance set (K). Figure 3–7 shows these pulses in time sequence. Letters C, F, and K on figure 3–7 refer to corresponding signals on figure 3–4. Signal CFK on figure 3–7 is a signal resulting from coincidence of signals C, F, and K. The No. 5 or burst pulse of the received burst command (C) and the No. 1 pulse of the delayed burst command (K) are in time coincidence during the presence of the burst enable pulse (F). Coincidence of these three pulses produces a resultant burst order pulse (CFK). A sequence of 10 burst order pulses generates the missile detonation command. To prevent random pulses or jamming signals from detonating the missile during the steering phase of missile flight, the burst command circuit is disabled until near the end of flight. The burst command circuit is enabled about one-half second before intercept by a sequence of 0G P commands at 2,000-microsecond intervals (500-pulse groups per second) and no Y commands. Actual detonation of the missile is accomplished by mechanisms external to the missile guidance set. Operation of the missile guidance set is the same for high explosive and prime warheads. The ground equipment determines from missile and target positions and their relative movements the correct time for detonating the missile warhead. Calculation of the time to send the burst order to the missile includes delays in the ground equipment and in the missile.

3–4 (U). Basic Mechanisms

a. General. Five basic mechanisms located in the guidance set aid in flight control and serve as sensing devices for the missile during flight. The basic theory of operation for each mechanism is covered in this paragraph. The mechanism and its purpose are described in (1) through (5) below.

(1) *Roll amount gyro.* The missile may roll in flight, causing one pair of elevons to control right-left movement

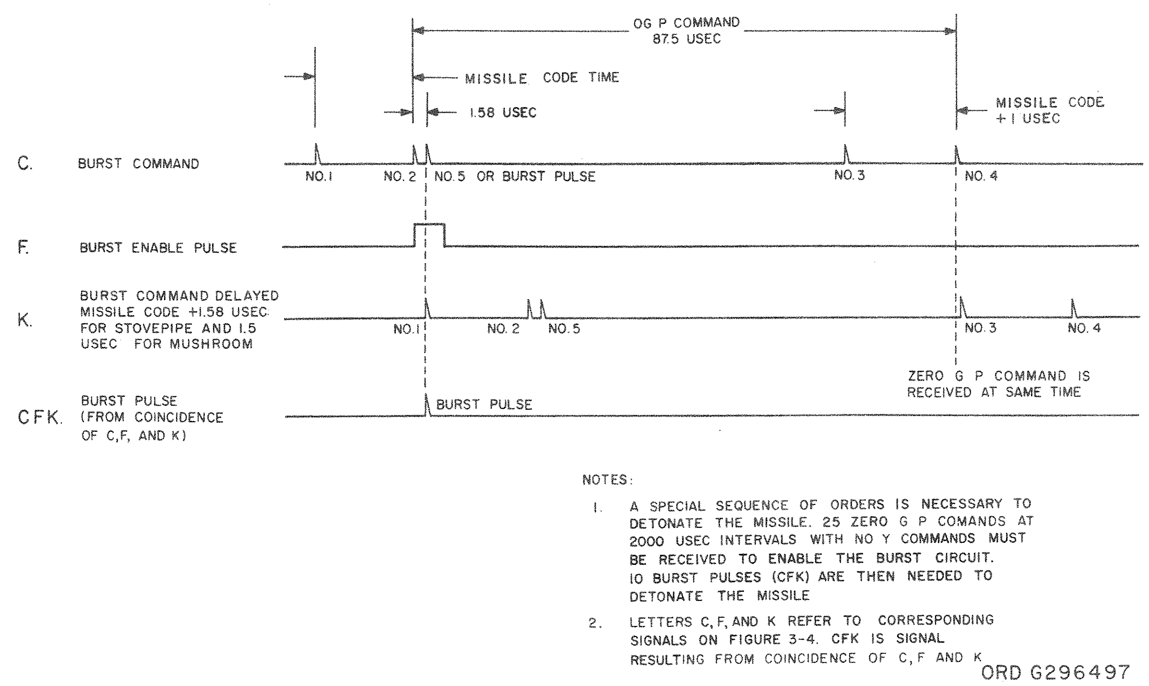

Figure 3–7 (C). Burst order signals (U).

one moment and to control up-down movement the next moment. This situation is prevented by a roll amount gyro which provides a belly-down reference. This reference enables the ground guidance equipment to determine which pair of elevons should be actuated to produce the desired missile movement.

(2) *Rate gyro.* Three rate gyros are used to damp the rate of turn which serves to stabilize the missile. The P and Y gyros are used to stabilize the missile during P and Y maneuvers, respectively. The roll rate gyro is used with the roll amount gyro in roll stabilizing the missile.

(3) *Accelerometers.* Two accelerometers detect lateral acceleration and provide a means of reducing the amount of skidding in P and Y maneuvers. The P and Y accelerometers together produce the largest controlling feedback involved in the missile turn.

(4) *Pressure transmitter.* A pressure transmitter is used as an absolute pressure sensing device to measure static and dynamic air pressures acting on the missile control surfaces. Outputs from the pressure transmitters are used to vary the gain of the roll control amplifier and elevon feedback variable resistors.

(5) *Inertia switch.* Inertia switches are used to perform switching functions related to missile lift-off.

b. Amount Gyro.

(1) *General.* An amount gyro (fig. 3–8) is an instrument that, once initially oriented, provides a fixed angular reference in space. The instrument measures the amount of angular change from the initial reference if the orientation of the instrument is subsequently changed. An amount gyro, also called a free gyro, depends on the rigidity or gyroscopic stability of a fast-spinning wheel having great angular momentum for its operation. Rigidity is the tendency of a spinning

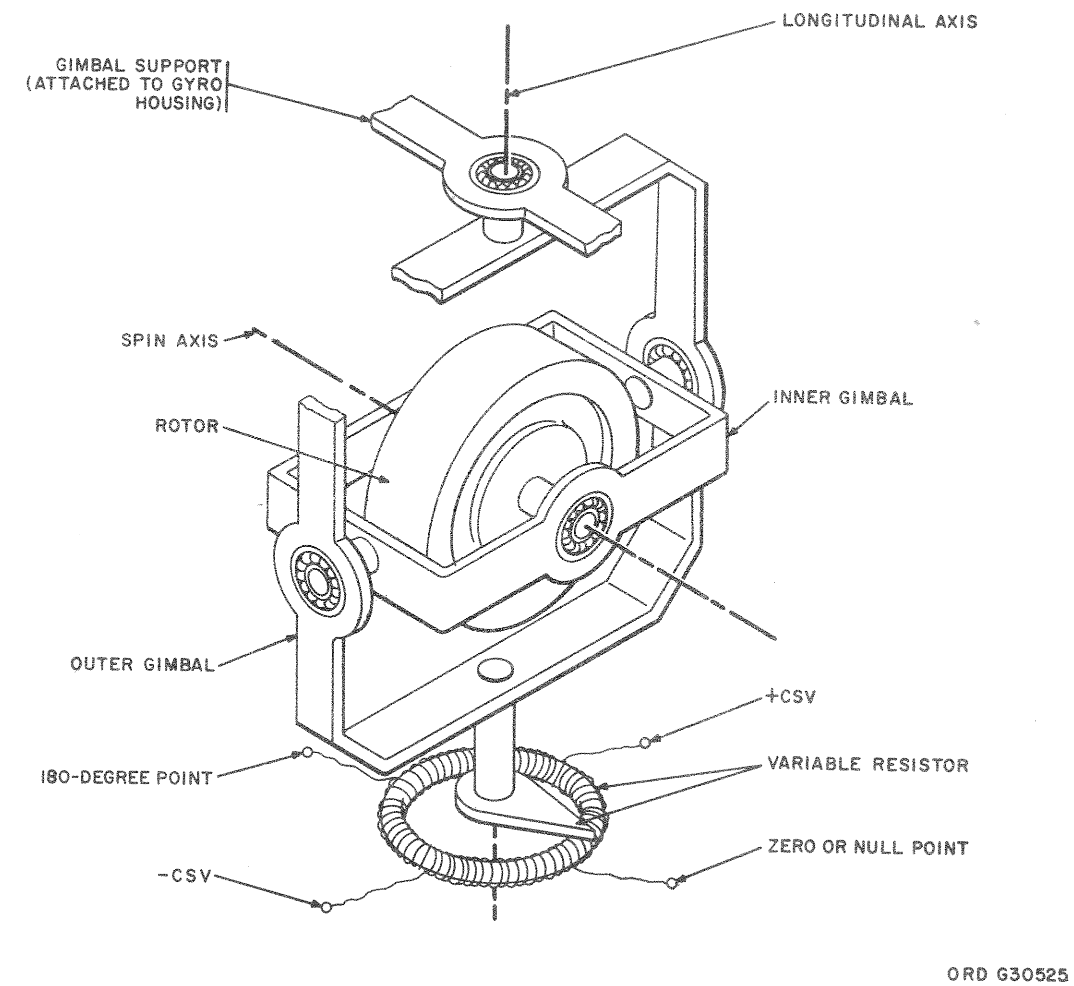

Figure 3–8 (U). Amount gyro (U).

wheel to maintain its axis of rotation in the same angle. The amount gyro indicates the angular displacement from a reference position and controls a variable resistor which produces an error voltage representing the direction and amount of error.

(2) *Operation.* A basic amount gyro consists of a balanced rotor, an inner gimbal, an outer gimbal, and a gimbal support or base for supporting the assembly. Because of the universal mounting arrangement of the two gimbals, the rotor may be turned or tilted in any direction. In practice, the movement of the inner gimbal is limited to prevent gimbal lock. Gimbal lock is a condition which nullifies the effectiveness of the amount gyro. If the base of the gyro were tilted so that the outer gimbal lay in the plane of the inner gimbal, gimbal lock would occur. If gimbal lock should occur, the spinning rotor would impart rotation to the gimbals through bearing friction. The ability of the gyro to sense its space orientation would then be lost. The control mechanism is a variable resistor. Although the spin axis retains its orientation in space in both azimuth and elevation, it is not practical to measure angular changes in both azimuth and elevation with one instrument. Thus, if the gimbal sup-

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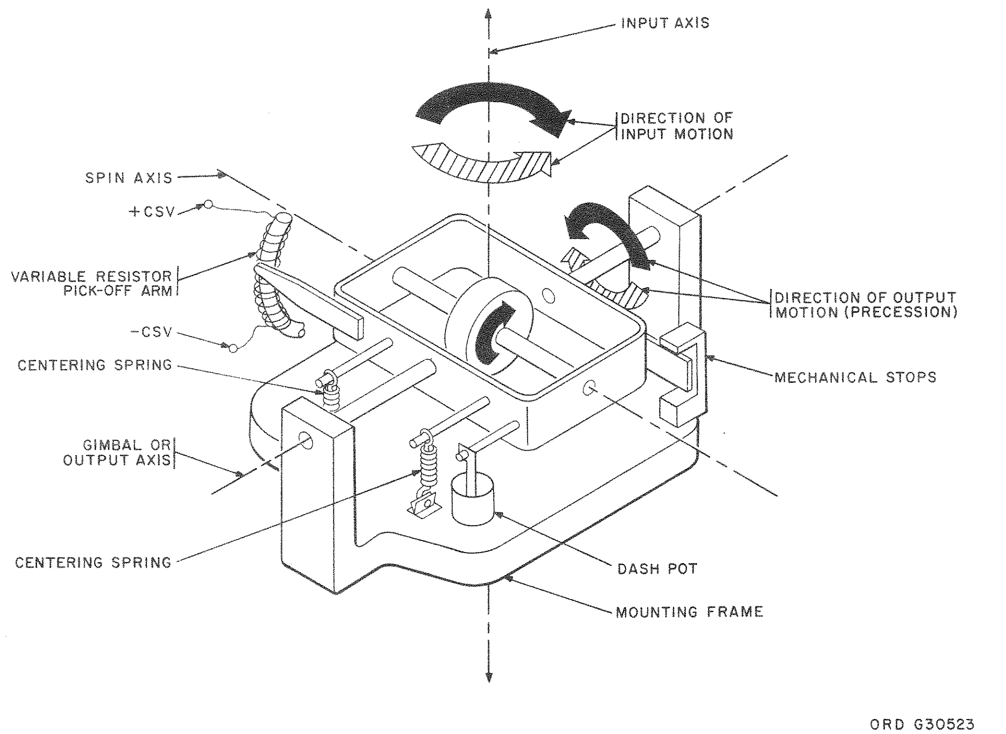

Figure 3-9 (U). Simple rate gyro (U).

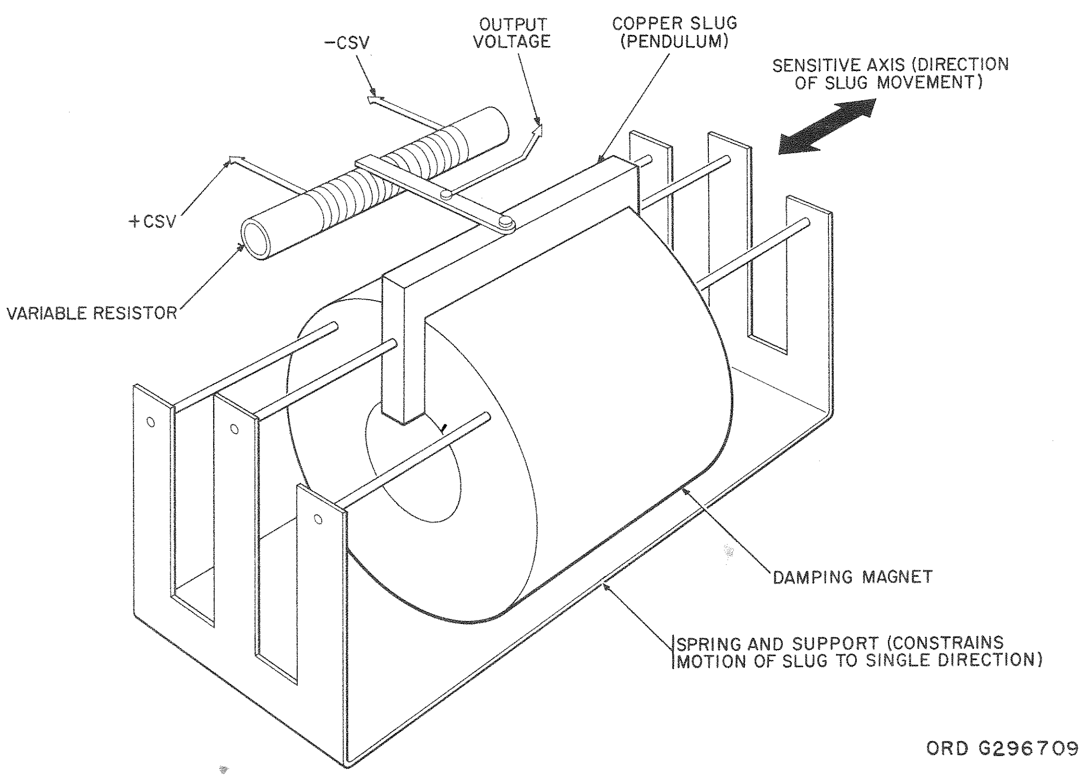

Figure 3-10 (U). Accelerometer (U).

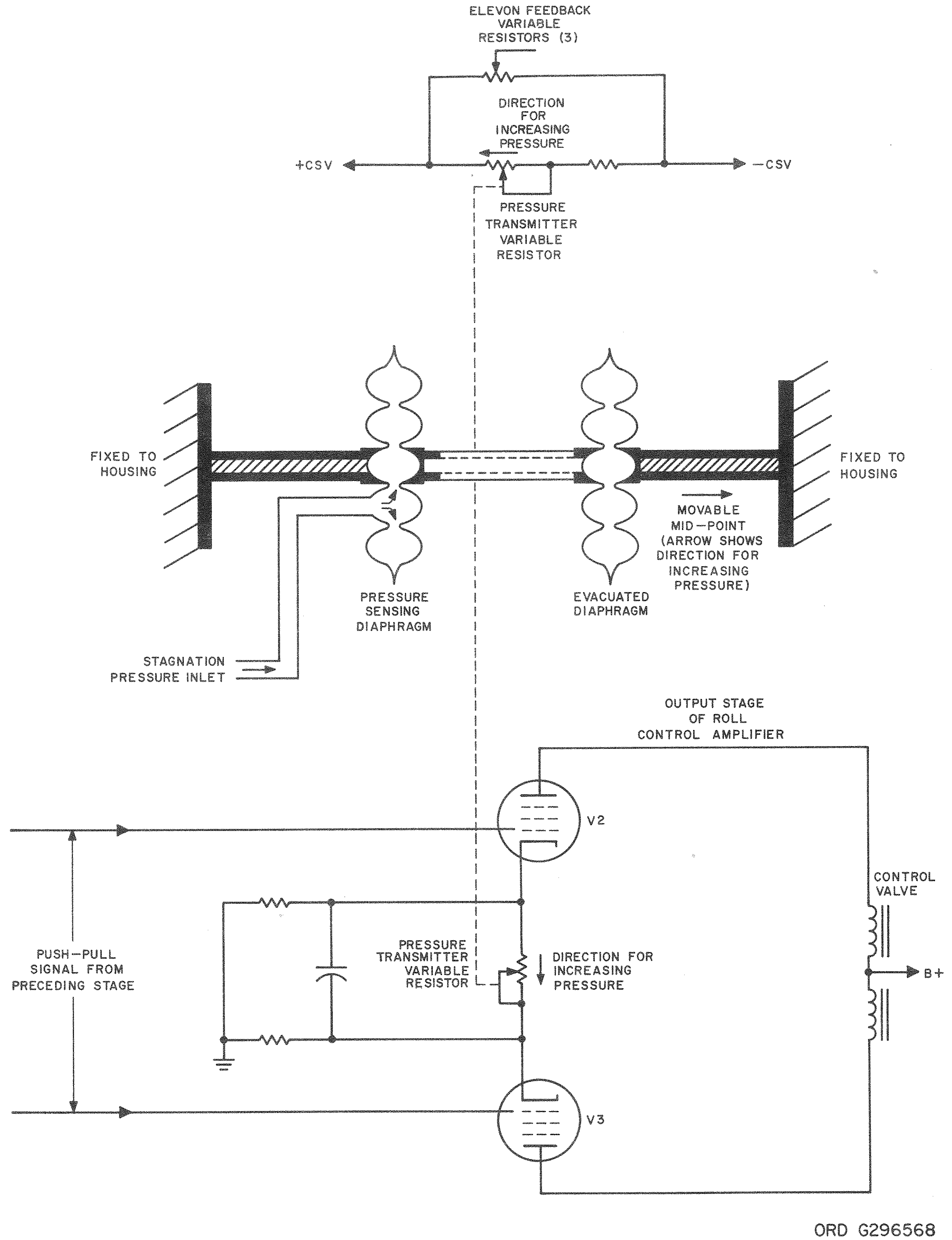

Figure 3-11 (U). Pressure transmitter (U).

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porter base of the amount gyro is rotated in azimuth to a new position, the amount and direction of the rotation with respect to the original azimuth is represented by a roll position correction voltage produced by the variable resistor and applied to the roll control amplifier.

c. Rate Gyro.

(1) *General.* A rate gyro (fig. 3–9) is an instrument that measures the rate of angular change when the instrument experiences a torque around its sensitive (input) axis. The instrument depends for its operation on the precession of a spinning wheel mounted inside the gimbal restrained by springs as it reacts to the applied torque. Precession is the tilting motion of a spinning wheel that results when a torque (turning force) attempts to change the angle of the spin axis. The wheel tilts in a direction which would result in the wheel spinning in the same direction as the applied torque. This causes the gimbal to move from its position perpendicular to the input axis which repositions the wiper arm of the variable resistor. This instrument indicates the rate of angular change and controls a variable resistor to produce an output voltage representing the direction and rate of change.

(2) *Operation.* A basic rate gyro (fig. 3–9) consists of a balanced rotor, a gimbal held by a centering spring, and a base or mounting frame for supporting the assembly. The instrument actuates a variable resistor which as a control mechanism produces a voltage proportional to the rate of angular change. The movement of the gimbal is limited to small angles by mechanical stops. This insures that the input axis is always approximately at right angles to the spin axis. In the absence of an input torque, the centering spring holds the gimbal parallel to the base. An input torque produces a proportional torque of precession which tends to move the gimbal against the restraint of the centering spring. The spring deflection is proportional to the rate of the original angular motion. The movement of the gimbal controls the movement of the wiper arm of the variable resistor. The movement of the wiper arm is proportional to the deflection of the centering spring. The wiper arm picks off a rate voltage which is transmitted to the associated steering amplifier. When the input torque is removed, the centering spring returns the gimbal to its original orientation parallel to the mounting frame. However, the spin axis points in a new direction as determined by the amount of rotation of the mounting frame. Thus, its reference for rate of angular change is the position it last assumed when the input torque was removed.

d. Accelerometer.

(1) *General.* An accelerometer (fig. 3–10) is an instrument that measures the acceleration that occurs when the instrument experiences a change in velocity along its sensitive (input) axis. The instrument depends on the inertia of a spring-loaded weight (copper slug) for its operation. The instrument controls a variable resistor to produce an output voltage representing the direction and magnitude of the accelerating force.

(2) *Operation.* A basic accelerometer consists of a spring-loaded copper slug that is free to move in one axis only, a permanent damping magnet, and a variable resistor. Centripetal force, resulting from the imparted acceleration, displaces the slug against the confining influence of the retarding springs. The copper slug controls the wiper arm of the variable resistor which is displaced a proportional amount. As the wiper arm is displaced from the zero (center) position, it picks off an acceleration voltage representing the direction and magnitude of the accelerating force which is transmitted to the associated steering amplifier. When the copper slug moves through the field of a permanent (damping) magnet, a current is induced in the slug producing a second magnetic field. The magnetic field induced in the slug opposes the field of the damping magnet. The reaction of the two fields slows the motion of the slug, thereby reducing overshoot and suppressing oscillations.

e. Pressure Transmitter (Fig. 3–11). During flight, the missile is subjected to varying pressures which directly affect the amount of elevon deflection required to achieve a given guidance command. For the same command to the elevons, less deflection is required when the missile is flying at high speeds or in a dense atmosphere than when flying at low speeds or in a rare atmosphere. The pressure transmitter is a pressure sensitive device that senses stagnation pressure (total atmospheric and dynamic (ram) pressures acting on the missile). A typical pressure transmitter (fig. 3–11) utilizes two diaphragms placed end-to-end. One diaphragm is evacuated of air; the other receives stagnation pressure from four ram pressure probes in the four forward fin assemblies of the missile. The wiper arms of the two variable resistors are physically attached to the movable midpoint between the two diaphragms. An increase in stagnation pressure causes the left-hand diaphragm to expand and compress the evacuated diaphragm. This action causes the variable resistor pickoff arm to move towards increased resistance. One variable resistor is connected in the cathode circuit of the push-pull output stage of the roll control amplifier. This variable resistor varies the gain of the roll control amplifier by controlling the cathode bias of the push-pull output stage of the roll control amplifier. The gain of the roll control amplifier varies inversely with pressure. The second variable resistor varies the voltage impressed across the elevon feedback variable resistor in direct proportion to pressure changes—higher pressures resulting in increased feedback and smaller elevon displacements.

f. Inertia Switch. The inertia switch is a conventional two-position switch with a weight attached to its operating mechanism. When the inertia switch is accelerated in a direction away from the weight, the inertia of the weight exerts sufficient force to operate the inertia switch. The inertia switch performs switching functions related to missile lift-off.

Section II (C). THEORY OF THE MISSILE GUIDANCE SET (STOVEPIPE)

3–5 (C). Block Diagram Analysis

a. General. The stovepipe missile guidance set (fig. 3–12) consists of four functional circuits: the receiving and decoding circuit, the steering control circuit, the beacon transmitting circuit, and the detonation command circuit. The missile guidance set receives guidance signals from the missile tracking radar (MTR) system and transmits beacon response signals back to the MTR system so that the MTR can track the missile. The guidance set controls the positioning of the missile elevons to steer the missile according to received guidance commands and to keep it from rolling from its preset reference position. The guidance set also generates a burst impulse for detonating the missile warhead when burst commands are received. If no signal is received from the MTR or if the missile guidance set does not function properly, a fail-safe burst impulse is generated by the missile guidance set and the missile is destroyed. The four functional circuits of the missile guidance set are covered in *b* through *e* below.

b. Receiving and Decoding Circuit.

(1) The receiving and decoding circuit (fig. 3–12) consists of the RF detectors, amplifier-decoder, delay line driver-detector, missile-code delay line, P-Y-burst delay network, P and Y pulse demodulator, and the delay pulse generator. These units function to assure that only guidance signals received from the missile's own MTR will be effective. The receiving and decoding circuit receives pulses of RF energy (guidance signals) from the

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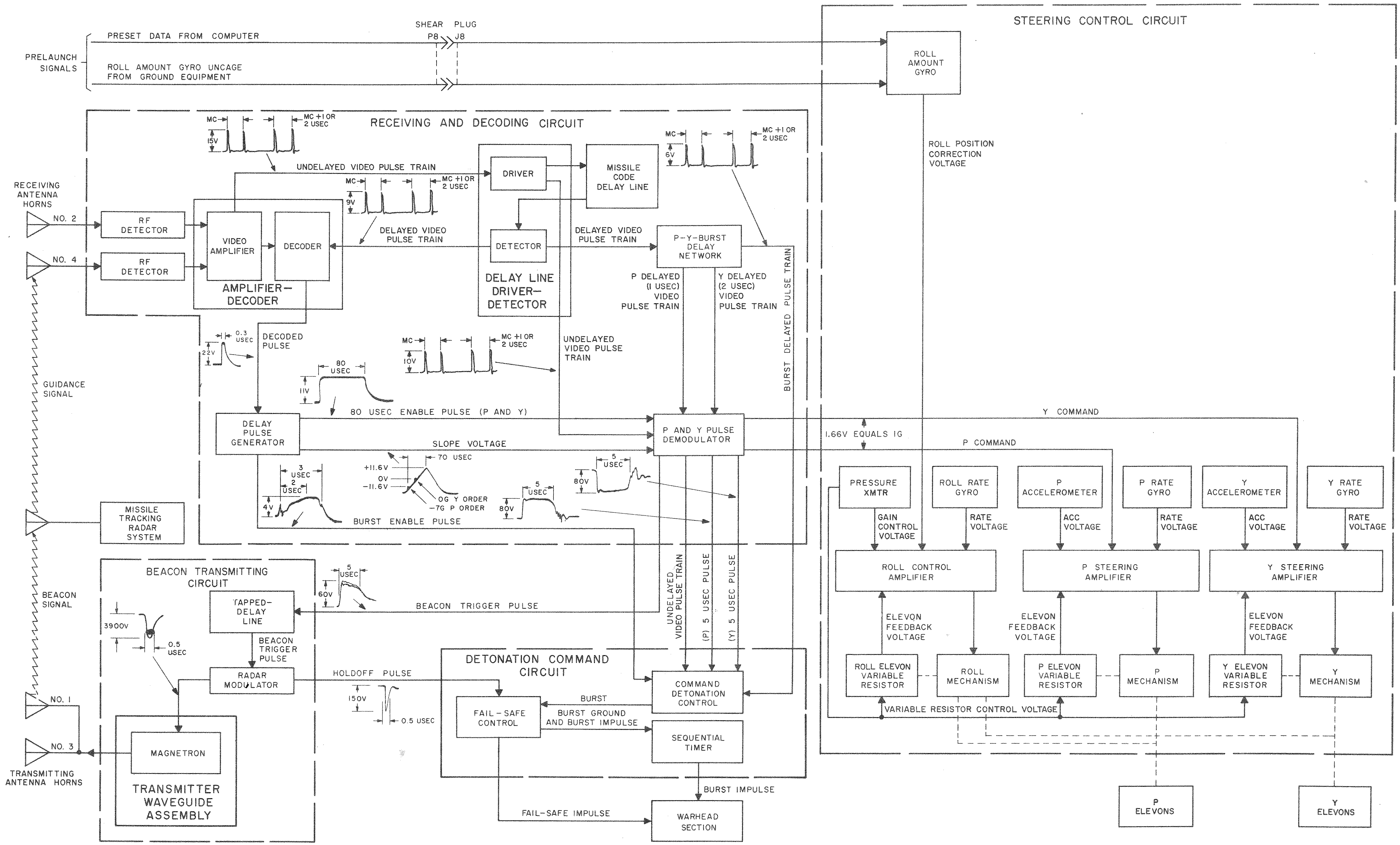

Figure 3-12 (C). Missile guidance set (stovepipe)—block diagram (U).

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MTR and converts these signals into a form which can be used by the other circuits of the missile guidance set.

(2) The pulses of RF energy are received in groups of four or five pulses (fig. 3-4) coded to contain the missile code and the missile command. The coding is contained in the time interval between various pulses in each group of pulses received (refer to para 3-3 for discussion of missile coding). The receiving and decoding circuit (fig. 3-12) detects, amplifies, and decodes the received energy and supplies P and Y commands (dc voltages) to the steering control circuit, beacon trigger pulses to the beacon transmitting circuit, and P and Y 5-microsecond pulses and burst commands to the detonation command circuit.

(3) Pulses of RF energy received by the receiving antennas (No. 2 and No. 4) are detected by crystal diodes in the RF detectors. These video pulses from the RF detectors consist of groups of four or five pulses (para 3-3) at a 500-pulse group-per-second rate which are applied to the video amplifier section of the amplifier-decoder.

(4) The video amplifier section sums the video pulse groups from the two RF detectors into one composite pulse train, amplifies the video pulse train, and applies it to the decoder section of the amplifier-decoder and the driver section of the delay line driver-detector.

(5) The driver section converts the undelayed video pulse train into amplified 15-megacycle output pulses that are applied to the missile code delay line. The undelayed video pulse train is also applied through the driver section to the P and Y pulse demodulator and through the P and Y pulse demodulator to the command detonation control in the detonation command circuit. The 15-megacycle pulses drive the missile-code delay line which delays each pulse by a time interval corresponding to the missile code. The delayed 15-megacycle pulses from the missile-code delay line are detected and amplified by the detector section of the delay line driver-detector. The delayed video pulse train output of the detector section is applied to a P-Y-burst delay network and to the decoder section of the amplifier-decoder.

(6) The decoder section compares this delayed video pulse train with the received undelayed video pulse train. If the No. 1 pulse of the delayed video pulse train and the No. 2 pulse of the undelayed video pulse train are properly coded, i.e., coincidental in time, the decoder produces a decoded pulse output which is applied to the delay pulse generator.

(7) This decoded pulse triggers the delay pulse generator which generates three outputs: an 80-microsecond enable pulse, a calibrated slope voltage, and a burst enable pulse. The 80-microsecond enable pulse and the calibrated slope voltage are generated 50 microseconds after the delay pulse generator is triggered and are applied to the P and Y pulse demodulator. The burst enable pulse which is coincident with the No. 2 pulse of the undelayed video pulse train is applied to the command detonation control in the detonation command circuit.

(8) The P-Y-burst delay network utilizes the delayed video pulse train input from the detector section of the delay line driver-detector to provide three outputs with additional delays of 1, 2, and 1.58 microseconds. These outputs are: the P delayed video pulse train, delayed by 1 microsecond; the Y delayed video pulse train, delayed by 2 microseconds; and the burst delayed video pulse train, delayed by 1.58 microseconds. The P and Y delayed video pulse trains are applied to the P and Y pulse demodulator. The burst delayed video pulse train is applied to the command detonation control in the detonation command circuit.

(9) The P and Y pulse demodulator has five inputs: the 80-microsecond enable pulse and the calibrated slope voltage from the delay pulse generator; the P and Y delayed video pulse trains from the P-Y-burst delay network; and the undelayed video pulse train from the driver section of the delay line driver-detector. The undelayed video pulse train is also applied through the P and Y pulse demodulator to the command detonation control in the detonation command circuit. Within the P and Y pulse demodulator, the 80-microsecond enable pulse, the calibrated slope voltage, and the undelayed video pulse train are applied to the P and Y demodulator channels. The P delayed (missile code plus 1 microsecond) video pulse train and the Y delayed (missile code plus 2 microseconds) video pulse train are also applied to the P and Y demodulator channels, respectively. The 80-microsecond enable pulse prepares both demodulator channels for operation. If the No. 3 pulse in the P delayed video pulse train is coincident with the No. 4 pulse in the undelayed video pulse train, and the 80-microsecond enable pulse, the P and Y pulse demodulator generates a P command signal which is applied to the P steering amplifier in the steering control circuits. The coincidence of these three pulses constitutes a P steering order. At the time this coincidence occurs, the P channel samples the calibrated slope voltage to determine the polarity and amplitude of the dc voltage transmitted as a P command. The operation of the Y channel in the P and Y pulse demodulator is identical to the P channel except for the time coding. The three pulses which must be in coincidence in the Y channel for the generation of a Y command are the 80-microsecond enable gate, the No. 3 pulse of the Y delayed video pulse train, and the No. 4 pulse of the undelayed video pulse train. The coincidence of these three pulses constitutes a Y steering order. Whenever a P or Y steering order is received, the P and Y pulse demodulator also generates a beacon trigger pulse and either a P 5-microsecond pulse or a Y 5-microsecond pulse. The beacon trigger pulse is applied through the tapped delay line in the beacon transmitting circuit to the radar modulator. The tapped delay line provides a means of adjusting the missile response time (delay between the receipt of a steering order and the transmission of a beacon response pulse) to maintain a constant response time for all missile guidance sets. The P or Y 5-microsecond pulse is applied to the command detonation control in the detonation command circuit.

c. Steering Control Circuit.

(1) The steering control circuit consists of the following units: a roll amount gyro; pressure transmitter; roll control amplifier; P, Y, and roll rate gyros; P, Y, and roll elevon variable resistors; P, Y, and roll mechanisms; P and Y accelerometers; and P and Y steering amplifiers. These units function to maintain roll stabilization and to control the movement of the missile in accordance with the received steering commands and atmospheric conditions.

(2) During the prelaunch phase, the steering control circuit receives preset data from the computer in the battery control area. This preset data is used to orient the roll amount gyro in the missile so that the initial dive of the missile will be toward the predicted intercept point. Just before launch (at launch order), a roll amount gyro uncage signal is received from the launching area equipment. The uncage signal causes the gyro to be released so that it can maintain its preset position during flight.

(3) The roll amount gyro, roll rate gyro, pressure transmitter, roll elevon variable resistor, and the roll control amplifier constitute a separate and completely automatic roll stabilization loop which provides roll stabilization of the missile. Roll stabilization maintains the belly-to-ground orientation of the missile, thereby establishing a reference in space from which the elevons may operate. Without adequate stabilization, a rolling movement could presumably reverse the physical positions of the P and Y elevons so that a pitch command would actually alter the missile's flight path about the yaw axis, or a yaw command about the pitch axis. The roll amount gyro senses any rolling motion of the missile and applies a roll position correction voltage to the roll control amplifier where the voltage is amplified to a level sufficient to actuate the missile control valve solenoids in the roll mechanism in the control section. A mechanical linkage allows the output of the control section to act independently upon each of the four elevons, thereby cancelling the rolling motion and moving the missile back to its preset position.

(4) Due to the high altitudes and extreme velocities attained, the missile encounters varying conditions throughout its flight. The steering control system incorporates a positive means of compensating for such variables as changing pressures and velocities, both of which directly affect the amount of elevon deflection required to achieve a given flight movement. The guidance set accomplishes the required compensation and damping action through the use of direct feedback elevon variable resistors and the rate sending capabilities of several flight-control instruments. The flight-control instruments in the guidance set consist of P, Y, and roll rate gyros, two accelerometers that measure accelerations in both the P and Y planes, and a pressure transmitter that senses changes in atmospheric pressures surrounding the missile. The roll amount gyro is also classified as a flight-control instrument; however, it provides a primary command voltage instead of a secondary feedback voltage. The voltages produced by the flight-control instruments are applied to the associated amplifiers. The secondary feedback voltages act in opposition to the primary command voltages, thereby restricting the net output of each amplifier to the exact value required to accomplish a flight movement under existing flight conditions.

(5) The roll rate gyro senses any roll of the missile and applies a roll rate feedback voltage to the roll control amplifier. The roll elevon feedback variable resistor supplies a feedback voltage to the roll control amplifier which represents the position of the elevons for correction of the roll displacement. The roll rate feedback voltage combines with the roll elevon feedback voltage in the roll control amplifier where the sum of these voltages is amplified and utilized to prevent excessive elevon deflection due to a roll position correction voltage from the roll amount gyro. The pressure transmitter senses the atmospheric pressure (static and dynamic) acting upon the missile and causes the elevon deflection to be controlled in accordance with this pressure. The pressure transmitter provides two outputs; one controls the gain of the roll control amplifier and the other controls the input voltages to the roll elevon variable resistor. Thus, the feedback voltage of the roll elevon variable resistor is partially controlled by the pressure transmitter.

(6) The P steering circuit consists of the P steering amplifier, P accelerometer, P rate gyro, P mechanism, and P elevon variable resistor. The P steering amplifier receives a P command voltage from the P and Y pulse demodulator in the receiving and decoding circuit. If this voltage is other than zero volt, the P steering amplifier produces an output which actuates the control valve solenoids in the P mechanism in the control section which deflects the elevons. The elevons are mechanically connected to the P elevon variable resistor, and a feedback voltage indicating the rate of elevon deflection is fed back to the P steering amplifier. The pressure transmitter controls the input voltage to the P elevon variable resistor in accordance with the atmospheric pressure (static and dynamic) acting upon the missile. Thus, the pressure transmitter partially controls the P elevon feedback voltage which is applied to the P steering amplifier. This feedback cancels all or a portion of the P command signal and elevon positioning stops. When the missile begins to turn, the P rate gyro will produce an output proportional to the rate at which the missile heading is changing and the P accelerometer will produce an output which is proportional to the centrifugal force acting on the missile because of its maneuver. The P rate gyro and the accelerometer outputs are applied to the P steering amplifier. These signals cause the steering amplifier output to the P mechanism in the control section to position the elevons correctly for the missile to perform the received order. When the missile is performing the received order, the P command signal is exactly cancelled by the signals from the P accelerometer, rate gyro, and elevon variable resistors. If the P command is suddenly removed, the P accelerometer, rate gyro, and elevon variable resistor signals cause the P steering amplifier to temporarily position the elevons in the opposite direction and quickly stop the missile maneuver.

(7) The Y command circuit consisting of the Y steering amplifier, Y accelerometer, Y rate gyro, Y mechanism, and Y elevon variable resistor functions to position the Y elevons in a manner similar to the P command circuit.

(8) The elevon deflection required to produce a given maneuver or roll correction depends upon the pressure acting on the missile because of its altitude and speed. The pressure transmitter senses this pressure and controls the feedback from the elevon variable resistors by controlling the voltage applied to the variable resistors. The pressure transmitter also controls the gain of the roll control amplifier to further compensate for changes in the pressure acting upon the missile. This additional compensation is needed for roll because of differences between a steering maneuver and a roll correction. For P or Y maneuvers the elevon deflection required for changing pressure is modified because the center of pressure, about which the missile turns, shifts with atmospheric pressure and speed and changes the effective moment arm of the elevons. There is no corresponding degenerative effect for missile roll and, hence, additional compensation is required and is produced by controlling the gain of the roll control amplifiers.

d. Beacon Transmitting Circuit.

(1) The beacon transmitting circuit consists of a tapped delay line, radar modulator, and magnetron. These units transmit beacon response pulses from the missile to the MTR so that the MTR can track the missile. A beacon response pulse is transmitted after the receipt of each steering order. The beacon transmitting circuit receives beacon trigger pulses at a rate of 500 pulses per second as long as the missile is receiving steering orders. It uses these pulses to control the generation of beacon response pulses of RF energy which are transmitted through transmitting antenna horns (No. 1 and No. 3) to the MTR.

Simultaneously, holdoff pulses are generated and applied to the detonation command circuit.

(2) The tapped delay line receives the beacon trigger pulse from the P and Y pulse demodulator of the receiving and decoding circuit. The tapped delay line is adjusted to delay the beacon trigger pulse so that the delay in all missiles between receipt of the No. 4 pulse and the transmission of a beacon response pulse will be the same. This delay must be the same for all missiles because the MTR considers this delay in determining radar-to-missile range. The beacon trigger pulse from the tapped delay line triggers the radar modulator.

(3) The modulator generates a high-voltage pulse which is applied to the magnetron and a holdoff pulse which is applied to the fail-safe control of the detonation command circuit to prevent fail-safe detonation of the missile.

(4) The high-voltage pulse drives the magnetron into oscillation. The RF pulse generated by the magnetron is the beacon response pulse which is radiated by transmitting antenna horns (No. 1 and No. 3) to the MTR.

e. Detonation Command Circuit.

(1) The detonation command circuit consists of the command detonation control, fail-safe control, and the sequential timer. The detonation command circuit receives burst enable pulses, the undelayed video pulse train, positive P 5-microsecond pulses, negative Y 5-microsecond pulses, and the burst delayed video pulse train from the receiving and decoding circuit. In addition, holdoff pulses are received from the beacon transmitting circuit. The detonation command circuit detonates the missile warhead in the warhead section when burst commands are received or if holdoff pulses are not received.

(2) The positive P 5-microsecond pulse and the negative Y 5-microsecond pulse from the P and Y pulse demodulator are applied alternately to the command detonation control. While both 5-microsecond pulses are applied, no burst command will be accepted. This prevents jamming signals from detonating the missile. When the missile is to be conditioned for burst, only the positive P 5-microsecond pulse will be received. After a series of at least 25 positive P 5-microsecond pulses, the command detonation control will accept a burst command.

(3) The undelayed video pulse train, burst delayed video pulse train (video pulse train delayed by the missile code plus 1.58 microseconds), and the burst enable pulses are applied to a coincidence gate in the command detonation control. If a burst command (see fig. 3-7 for relationship of burst command pulses) is received, the coincidence gate will pass the burst command. After a series of 10 consecutive burst commands, the command detonation control produces a burst output which is applied to the fail-safe control.

(4) This burst output causes the fail-safe control to apply a burst ground to the sequential timer. After a delay of 0.33 second, the sequential timer connects the burst impulse from the fail-safe control to the warhead section, causing the missile to detonate.

(5) Holdoff pulses from the radar modulator in the beacon transmitting circuit are applied to the fail-safe control at a rate of 500 pulses per second. As long as these pulses are present, the fail-safe control will not destroy the missile. If the holdoff pulses are absent or the guidance set does not function properly for a period of 1 to 3 seconds, the fail-safe control will send a burst impulse to the warhead section and the missile will be destroyed.

3-6 (C). Functional Description

a. Receiving and Decoding Circuit (Fig. 4-1). The circuit consists of the two receiving antenna horns, the RF detectors, the amplifier-decoder, the delay line driver-detector, the missile-code delay line, the P-Y-burst delay network, the delay pulse generator, and the P and Y pulse demodulator. These circuits accept, amplify, and decode the guidance commands from the MTR system. The received guidance commands consist of groups of RF pulses transmitted at a rate of 500-pulse groups per second. Each pulse group consists of four or five RF pulses which are detected and converted into a video pulse train. The video pulse trains produced by correctly coded incoming signals are decoded and applied to the steering control circuits. Video pulse trains produced by incorrectly coded guidance commands are not accepted by the receiving and decoding circuits. For each correctly coded guidance command received, the receiving and decoding circuit produces a beacon trigger pulse which is applied to the beacon transmitting circuit.

(1) *Antenna horns.*

(*a*) Two antenna horns (No. 2 and No. 4) located 180 degrees apart are used for receiving the vertically polarized RF energy beamed from the MTR.

(*b*) The receiving antenna horns contain RF filters which make them selective to a narrow band of frequencies. Antenna horns are selected for a system in accordance with the frequency assigned to the system. Different systems are assigned different frequencies to prevent interference between systems and to make enemy jamming more difficult. For more information on the nominal center frequencies of antenna horns equipped with filters, refer to table 3-1.

Table 3-1 (C). Antenna Horn Filters—Nominal Center Frequencies (U)

Code	Nominal center frequency (mcs)
L1	9550
L2	9300
L3	9050
L4	8800
L5	8550
L6	None

(*c*) The RF energy received by the receiving antenna horns is passed through waveguides to the RF detectors.

(2) *RF detectors.* The RF detectors operate in the 8,500- to 9,600-megacycle frequency range. Each contains a crystal detector for rectifying the RF signal energy from the receiving antenna horn. The crystal detector converts the received RF signal energy into video pulse trains. The resulting video pulse trains from the two RF detectors are applied to the amplifier-decoder as dual video pulse train inputs.

(3) *Amplifier-decoder, delay line driver-detector, and missile-code delay line.*

(*a*) The amplifier-decoder, delay line driver-detector, and the missile-code delay line are interdependent components that amplify the incoming video signals and reject false (incorrectly coded) signals. The amplifier-decoder accepts the dual video pulse train inputs from the RF detectors and applies these detected positive pulses across an RC network. This network averages the applied signals and forms a composite video pulse train. The output of the RC network is amplified by five video amplifiers, (A3) V1 through V5. Diode CR7 between V3 and V4 blocks any positive overshoots. The amplified negative pulse train at the output of V5 is inverted by transformer T1 and applied to coincidence gate V6 and to the delay line driver-detector as an undelayed video pulse train. A shorted delay line, consisting of inductors L13 and L14 and capacitor C35, reflects the positive input pulse as a negative pulse after 0.2 microsecond. This reflected pulse cancels the input and limits the pulse duration to 0.2 microsecond. Any remaining reflected pulse will be shorted out by diode CR4.

(*b*) The delay line driver-detector and missile-code delay line incorporate a fixed time delay which delays the applied video pulse train by an amount equal to the assigned missile code. The undelayed video pulse train from the amplifier-decoder is applied through cathode follower V1A to video amplifier V2A, to the P and Y pulse demodulator, and through the P and Y pulse demodulator to the command detonation control (C2, fig. 4–4).

(*c*) The amplified negative pulses at the output of V2A (A8, fig. 4–1) are applied to ringer V2B, driving V2B to cutoff. When cutoff occurs, inductance coil L1 attempts to maintain current flow through V2B. The inductive action of L1 produces oscillations at a 15-megacycle rate. These 15-megacycle ac oscillations are amplified by IF amplifier V3 and applied through transformer T1 to the missile-code delay line. An input transducer in the delay line converts the amplified ac oscillations into 15-megacycle mechanical vibrations. The mechanical vibrations are transmited through quartz crystal in the delay line. This crystal provides a time delay equal to the missile code. An output transducer in the delay line reconverts the mechanical vibrations into 15-megacycle ac oscillations. The heater and thermostat switch S1 heat and stabilize the temperature of the missile-code delay line. The ac oscillations are applied through transformer T2 of the delay line driver-detector to a diode bridge detector consisting of diodes CR1 through CR4. The diode bridge detects the 15-megacycle pulses, thereby restoring the delayed signals to the original video pulse train form. The negative pulse train at the output of the diode bridge is inverted by video amplifier V4 to provide a positive pulse train that is applied to cathode follower V1B. The missile-code delayed video pulse train is applied to the P-Y-burst delay network, and to coincidence gate V6 (B5) in the amplifier-decoder.

(*d*) The two inputs to coincidence gate V6 are the undelayed and the delayed video pulse trains. When the No. 2 pulse of the undelayed video pulse train and the No. 1 pulse of the delayed video pulse train arrive at V6 in time coincidence, V6 conducts and develops a decoded pulse output across transformer T2. The decoded pulse is applied to the delay pulse generator to control the generation of enabling pulses which allow the operation of steering and burst order circuits. The decoded pulse is also applied to AGC amplifier V7 of the amplifier-decoder. The output pulse from V7 is applied through transformer T3 and rectified by diode CR2. Cathode follower V8 supplies the AGC voltage to video amplifier V1 without loading the rectifier circuit. The level of the AGC voltage is controlled by gain adjust variable resistor R49 and the AGC voltage can be monitored at AGC test point J2–U.

(*e*) The time relationship between the No. 2 pulse of the undelayed video pulse train, the No. 1 pulse of the delayed video pulse train, and the decoded pulse is shown on figure 3–4. The decoded pulse can be generated only by received guidance commands which carry the correct missile code. An incorrect missile code causes the No. 2 pulse of the undelayed video pulse train to arrive at coincidence gate V6 either before or after the No. 1 pulse of the delayed video pulse train. When this occurs, the coincidence gate cannot conduct and the resulting lack of the decoded pulse causes the erroneous guidance commands to be rejected.

(4) *Delay pulse generator.*

(*a*) Input signals to the delay pulse generator are decoded pulses from the amplifier-decoder. Each time a properly coded guidance command is received by the missile receiving antenna horns, a decoded pulse from the amplifier-decoder is fed to the delay pulse generator. Output signals from the delay pulse generator consist of an 80-microsecond enable pulse (P and Y), and a slope voltage sent to the P and Y pulse demodulator, and a burst enable pulse sent to the command detonation control (B2, fig. 4–4).

(*b*) Positive decoded pulses from the amplifier-decoder are applied to trigger generator V1B (C5, fig. 4–1). The positive pulse is inverted by V1B and applied to the primary of transformer T1. Transformer action inverts the pulse and a positive pulse taken from the secondary of T1 is applied to blocking oscillator V1A. There are two positive outputs from V1A. One is applied through R33 to the command detonation control (B2, fig. 4–4) as the burst enable pulse. The other output is applied through diode CR2 (C8, fig. 4–1) to phantastron V2. Diode CR2 prevents V1A from being triggered by V2. Phantastron V2 supplies a positive 5-volt output pulse, after approximately a 50-microsecond delay, which triggers enabling gate generator V3A and V3B. The phantastron delay time can be adjusted ±1 microsecond by delay time adjust variable resistor R11. Thermistor RT1 compensates for temperature variations in the phantastron circuit. Triggering of V3 supplies an 80-microsecond enable pulse to cathode follower V4A. Cathode follower V4A supplies two positive outputs. One positive output is the 80-microsecond enable pulse applied through R27 to the P and Y pulse demodulator. The other 80-microsecond positive output is applied through capacitor C12 to diode CR6. Prior to the application of this positive pulse, diodes CR6 and CR5 are conducting and current flows from the −18 control signal voltage supply to the +18 control signal voltage supply. During the conduction of CR5 and CR6, capacitor C13 becomes negatively charged. The positive output from V4A cuts off the conduction of CR5 and CR6, and C13 begins to charge positively. The positive-going pulse on C13 is applied to cathode follower V4B. The output of V4B is the slope voltage which is applied to the P and Y pulse demodulator. The slope voltage is sampled, and the P and Y pulse demodulator and the magnitude and polarity of the slope voltage at the time of sampling represents the received order. In addition, the positive output of V4B is coupled as a feedback voltage through capacitor C15 to CR5, reverse biasing CR5 and cutting off its conduction. This increasing voltage at CR5 provides an almost constant voltage across variable resistor R30 and resistor R34, resulting in a constant charging current for C13 and a linear slope voltage from V4B. Slope voltage adjustable variable resistor R30 varies the rate at which C13 charges, thereby varying the slope of the output pulse from V4B.

(5) *P-Y-burst delay network.*

(*a*) The delayed video pulse train input to the P–Y–burst delay network (A15, fig. 4–1) is supplied from the delay line driver–detector. The delayed video pulse train applied to the delay network has been delayed by a period of time corresponding to the missile code. Because all the pulses in the pulse train were previously delayed by the same amount of time, the pulses arriving at the pulse delay network remain in the same relative positions they occupied when received at the missile antenna horns.

(*b*) For each delayed video pulse train entering the P–Y–burst delay network three trains of pulses leave, each with a different delay time. One output from the delay network is a train of pulses delayed 1 microsecond and fed to the P "and" gate of the P and Y pulse demodulator. Another output is delayed an additional 0.58 microsecond, or a total of 1.58 microseconds, and is applied to the command detonation control as the burst delayed pulse train. A third output, a train of pulses delayed still another 0.42 microseconds, or a total of 2 microseconds, is fed to the Y "and" gate of the P and Y pulse demodulator.

(6) *P and Y pulse demodulator.*

(*a*) The P and Y pulse demodulator receives the following five inputs: the undelayed video pulse train from the delay line driver-detector; the P-delayed video pulse train delayed by the missile code plus 1 microsecond and the Y-delayed video pulse train delayed by the missile code plus 2 microseconds from the P–Y–burst delay network; and the 80-microsecond enable pulse and the 70-microsecond slope voltage from the delay pulse generator. It supplies the undelayed video pulse train, positive P 5-microsecond pulses, and negative Y 5-microsecond pulses to the command detonation control; beacon trigger pulses through the tapped delay line to the radar modulator; and dc P and Y command voltages to the P and Y steering amplifiers. The P and Y pulse demodulator has two "and" gates, two blocking oscillators, and two sampling circuits. (The "and" gate is a circuit that supplies an output pulse only when three input pulses are applied simultaneously.) The P and Y pulse demodulator has two channels (P and Y). The operation of the P and Y channels is almost identical. The slight differences in the operation of the two channels result from differences in signal inputs to the "and" gates. In both the P and Y channels, the pulse utilized is the No. 3 pulse of the delayed video pulse train. However, in the P channel, the No. 3 pulse has been delayed by the missile code plus 1 microsecond, and in the Y channel, the No. 3 pulse has been delayed by the missile code plus 2 microseconds. The P 5-microsecond output pulse from the P and Y pulse demodulator is positive while the Y 5-microsecond output pulse is negative. Only the operation of the P channel will be discussed.

(*b*) Before the arrival of a signal at the input of the P "and" gate, the three diodes, CR1, CR2, and CR3 comprising the "and" gate are conducting. This conduction is from the —28 volt source through the diodes and their associated components to ground. Whenever a positive pulse appears, the diode in the circuit which receives the signal is cut off during the period of time the pulse is present. When one of the diodes is cut off, the voltage at the junction of the three diodes rises slightly. This change in voltage appears across capacitor C3 at blocking oscillator V1. The amplitude of this voltage is not sufficient to trigger blocking oscillator V1. It is only when three positive pulses arrive at the same time that the output from the "and" gate triggers blocking oscillator V1.

(*c*) The three signals which operate the "and" gate are the No. 3 pulse in the P delayed video pulse train from the P–Y–burst delay network, the 80-microsecond enable pulse from the delay pulse generator, and the No. 4 pulse in the undelayed video pulse train from the delay line driver-detector. When these three pulses arrive in coincidence, a positive pulse is applied to V1A. The V1A section of the blocking oscillator is connected as a trigger amplifier and prevents blocking oscillator V1B from loading the input signals from the "and" gate circuit. Diode CR4 is used in the plate circuit of this stage to eliminate any positive overshoot at the trailing edge of the output pulse.

(*d*) The negative pulse from V1A is fed as a positive pulse from secondary winding 1–2 of transformer T5 to V1B. The amplitude and width of the blocking oscillator output pulse are determined by the characteristics of transformer T5, capacitor C5, and pulse-width adjust-control variable resistor R7. Pulse width adjust control R7 is adjusted to give a pulse width of 5 microseconds. Before the blocking oscillator is triggered, diodes CR5 and CR6 in the sampler circuit are conducting and current is flowing through inductor L1. Conduction of these diodes establishes a positive voltage at the junction of diodes CR7 and CR9 and a negative voltage at the junction of diodes CR8 and CR10. These voltages cut off the bridge circuit diodes CR7, CR8, CR9, and CR10, and the bridge circuit presents a high-impedance path for the charge or discharge of capacitor C7. When the blocking oscillator is triggered, transformer T5 couples a negative 5-microsecond pulse to CR5 which reverse biases CR5 and a positive 5-microsecond pulse to CR6 which reverse biases CR6. These pulses cut off CR5 and CR6 and there is no bias current to cut off the diode bridge. The bridge presents a low impedance and capacitor C7 charges or discharges to a voltage corresponding to the slope voltage developed in the delay pulse generator at the instant the blocking oscillator conducts. If the charge on C7 is more negative than the slope voltage at the instant of sampling, current will flow from C7 through CR10, L1, and CR7 until C7 has the same potential as the sampled slope voltage. If the charge on C7 is more positive than the sampled slope voltage, current will flow from the slope voltage input through CR8, L1, and CR9 to charge C7 to the sampled slope voltage potential. If the P command has not changed since the last received P command, only enough current will flow to maintain the charge on C7. The resultant voltage across C7 is applied to the input network of the P steering amplifier as a dc command voltage. To prevent false operation of the Y channel during the time a P order is being received, a negative disabling pulse (inhibit pulse) of 6-volt amplitude from transformer T5–9 is applied through coupling capacitor C9, resistor R19, and diode CR32 to V2A.

(*e*) Scale factor adjust variable resistor R8 is set for a scale factor of 1.66 volts per G at the output of the P and Y pulse demodulator. Each time P channel blocking oscillator V1 is triggered, the negative pulse at T5–3 appears as a positive pulse at T5–8. This positive pulse is approximately 80 volts in amplitude and 5 microseconds in duration and is applied to the command detonation control. During the normal steering phase of missile flight, the positive pulse from the P channel blocking oscillator and a negative pulse from the Y channel blocking oscillator are combined in the command detonation control. The positive P 5-microsecond pulse can be monitored at test point terminal RR and the negative Y 5-microsecond pulse can be monitored at test point terminal N. When the burst enable command is sent by the ground guidance system, the P and Y channels do not operate alternately. Instead, the P channel operates continuously, and the command detonation control circuit is conditioned for burst command.

(*f*) Triggering of either the P or Y channel blocking oscillator, V1 or V2 causes a positive 5-microsecond beacon trigger pulse to be fed through the tapped delay line to the radar modulator. This pulse causes the missile magnetron to be triggered. The magnetron produces a pulse of energy which is transmitted to the ground guidance system.

b. Steering Control Circuit.

(1) *General.*

(*a*) The steering control circuit (fig. 4-2) receives roll amount gyro positioning signals from the launching area during the prelaunch phase. These signals cause the roll amount gyro to be positioned so that the initial dive of the missile will be toward the predicted intercept point. The steering control circuit receives P command and Y command signals from the receiving and decoding circuit (fig. 4-1) during flight. These signals' indicate necessary missile maneuvers and cause the steering control circuit to position the missile elevon in accordance with the received order. The steering control circuit also controls the elevon position to keep the missile oriented according to the preset position of the roll amount gyro.

(*b*) The steering control circuit consists of three electronic units plus their associated flight control instruments and the relays and switches which perform the switching functions. (The basic theory of operation of the flight control instruments is described in para 3-4.) Also included in the steering control circuit, but external to the missile guidance set, are three hydraulic mechanisms and three feedback variable resistors in the actuator assemblies. These steering control circuit components are divided into four functional systems. These systems are the gyro preset system, the P control servo system, the Y control servo system, and the roll control servo system. These systems are discussed in (2) through (5) below.

(2) *Gyro preset system.*

(*a*) *General.* The gyro preset system consists of the A_G data converter (B1, fig. 4-2) and the gyro preset servo amplifier (C1) located externally to the missile, and the roll amount gyro (C5), preset relay K3 (B4), and associated circuitry located in the missile. During prelaunch, the gyro preset system uses externally derived reference voltages to preset the roll amount gyro to the A_G (gyro azimuth) angle indicating the direction of the predicted intercept point. At lift-off, internally derived reference voltages are applied to the roll amount gyro variable resistor and are used after rocket motor cluster separation to roll-stabilize the missile.

(*b*) *Roll amount gyro.* The roll amount gyro is sensitive to missile roll and provides a fixed space reference for the roll position servo system. The inner gimbal of the roll amount gyro is mechanically limited in its motion to prevent gimbal lock (para 3-4*b*(2)). To avoid approaching the gimbal lock condition during missile maneuvers, the roll amount gyro is caged, preset toward the predicted intercept point, and uncaged before launch. In the caged condition, the inner and outer gimbals of the roll amount gyro are locked together and move as a unit. When caged, the roll amount gyro is in a condition to be preset. Presetting orients the roll amount gyro toward the predicted intercept point. Uncaging releases the inner and outer gimbals allowing the gyro to maintain a fixed space reference. The missile then has the widest latitude for target maneuvers without approaching gimbal lock.

(*c*) *Caging.* During prelaunch, the —28 volt cage relay power is applied from the launching area through P8-28 (D2) and through the missile distribution box to energize cage coil L2 (C5) in the roll amount gyro and from L2 through the contacts of cage-uncage switch S1 (C5) to ground. Energizing coil L2 operates the caging mechanism which cages the roll amount gyro (the condition shown on figure 4-2). As the caging mechanism operates caging the roll amount gyro, the following operations occur: switch S1 transfers the ground from cage coil L2 to uncage L1, uncage indicator switch S3 opens, and preset motor switch S2 closes, energizing preset motor B1. Connecting a ground to L1 permits it to be energized during the uncaging operation. When S3 opens, the ground return circuit for an indicator light used with external test eequipment is removed.

(*d*) *Presetting.* Data concerning the predicted intercept plane (gyro azimuth) is received from the launching area. This data consists of preset voltages 1, 2, 3, and 4 (C2). These preset voltages are supplied by the A_G data converter located in the Hercules section-simulator group (B1) through contacts 7-8, 4-5, 10-11, and 1-2 of deenergized preset relay K3 (B4) in the gyro servo control to the terminals of roll amount variable resistor R1 in the roll amount gyro. An error existing between the actual position of the roll amount gyro spin axis and the predicted intercept plane is picked off as a roll position error voltage (C5) by the arm of roll amount variable resistor R1 and applied to gyro preset servo amplifier (C1) located in the Hercules section-simulator group. The roll position error voltage may be monitored at test connector J2-F (B5). This error voltage represents a displacement to the right or left of a null point. The error voltage is amplified by the gyro preset servo amplifier and applied to preset motor B1 (D5) in the roll amount gyro. The presence of an error voltage causes preset motor B1 to drive the outer gimbal and the wiper arm of roll amount variable resistor R1 in the proper direction to reduce the error. When the wiper arm of R1 reaches the null or zero error point, the spin axis of the gyro rotor is perpendicular to the predicted intercept plane.

(*e*) *Uncaging.* At fire order, the gyro preset circuit is fixed so that there are no more changes in gyro azimuth. At launch order, the roll amount gyro is uncaged. In the uncaged condition, the gimbals are free to operate independently, permitting the gyro to maintain its rotor spin axis perpendicular to fixed gyro azimuth plane. The —28 volt uncage relay power is applied from the launching area through P8-6 (D2) and through the missile distribution box to uncage coil L1 (C6). (A second circuit, inertia switch S1 (D7), operates at missile lift-off to assure —28 volt power to uncage the roll amount gyro if the external circuit is defective.) Uncage coil L1 is energized and releases the caging mechanism. When the caging mechanism operates uncaging the roll amount gyro, the following operations occur: cage-uncage switch S1 (C6) transfers the ground from uncage coil L1 to cage coil L2; preset motor switch S2 opens the preset servo circuit preventing the operation of preset motor B1; and uncage indicator switch S3 closes completing the ground return circuit to an indicator light used with external test equipment. The operation of uncage indicator switch S3 may be monitored at test connector J2–b.

(3) *P control servo system.*

(*a*) *General.* The P control servo system consists of contacts 13, 14, and 15 of flipover relay K1 (A6), contacts 6 and 8 of transfer relay K4 (B12), capacitor C7, P steering amplifier (A11), P rate gyro (A7), and P accelerometer (A9) in the missile guidance set, and the P hydraulic mechanism (B15) and P elevon feedback variable resistor (B16) of the P actuator assembly in the missile. Variable resistor R2 of the pressure transmitter (D8) in the missile guidance set controls the input to the P elevon feedback variable resistor.

(*b*) *Inputs.* The P command voltage received from the signal data converter (A3) is a dc voltage representing the magnitude and direction of the received P command. This voltage has a scale factor of 1.66 volts per G of order and causes the P control servo system to position the P elevons to produce a P maneuver. Flight control instruments (the P rate gyro and P accelerometer) and the elevon feedback variable resistor determine when the missile is performing the received command and cause the missile to execute the command as received.

(*c*) *Steering amplifier operation.* The P command (A3) from the signal data converter is applied through closed contacts 13–14 of energized flipover relay K1 in the gyro servo control. Flipover relay K1 is energized before launch by external —28 volt transistor power applied through closed contacts 5–6 of deenergized transfer relay K2 (A5) and closed contacts of deenergized burst relay K1 in the command detonation control to the coil of flipover relay K1. This power is maintained at a launch order because transfer relay K2 becomes energized and contacts 4–5 (B5) of K2 close to apply —28 volt battery power to the coil of flipover relay K1. Flipover relay K1 will remain energized until burst order when burst relay K1 on the command detonation control is energized; its contacts open deenergizing flipover relay K1. Deenergizing K1 opens its contacts 13–14, removing the P command, and closes its contacts 14–15 to ground the P command input to the P steering amplifier and effectively applies a 0G P command. The P command voltage applied through contacts 13–14 of energized flipover relay K1 is applied through terminal P2–E of the P steering amplifier and through a resistor network which proportions the inputs to amplifier V1B. For testing, a P command calibrate input is applied to terminal J2–K (A9). Amplifier V1B is directly coupled to amplifier V1A by common cathode resistor R26. Amplifiers V1B and V1A produce a push-pull output which drives push-pull power amplifiers V2 and V3. A P command input voltage (if not zero volt) causes an unbalance in the output currents of V2 and V3. This unbalance in output currents, flowing through control solenoid windings of the P hydraulic mechanism (B15), causes motion of the solenoid core.

(*d*) *Elevon feedback circuit.* These solenoids control a hydraulic system which positions the P elevons and also the wiper arm of P elevon feedback variable resistor R1 (B16). The elevon feedback variable resistor receives minus elevon feedback voltage and plus elevon feedback voltage from variable resistor R2 of the pressure transmitter (D8). The P elevon feedback voltage for a given displacement of the arm of P elevon feedback variable resistor R1 varies directly with the pressure sensed by the pressure transmitter. If the missile flies faster or in a denser atmosphere, the output voltage is greater and the voltage taken from P elevon feedback variable resistor R1 (B16) will be greater for a given elevon deflection. During testing, transfer relay K4 is deenergized and the P elevon feedback voltage representing elevon deflection for a given pressure is applied through contacts 6 and 8 of K4, P2–B, and an RC network which proportions and smooths the signal to the input of amplifier V1A. Transfer relay K4 (B2, fig. 4–5) is energized at the time of missile launch order. Contacts 6 and 8 of energized K4 (B12, fig. 4–2) open, removing the short across capacitor C7 so that the P elevon feedback voltage passes through C7. Capacitor C7 filters the dc component from the elevon feedback voltage. This filtering prevents a bias voltage which will affect missile flight if there is an error in initial orientation of the elevons. The elevon feedback voltage functions to cancel all or a portion of the P command input and to stop elevon deflection. The deflected P elevons cause the missile to turn.

(*e*) *Rate gyro operation.* The turning motion of the missile is sensed by the P rate gyro (A7) which positions the wiper arm of its variable resistor R2 in accordance with the direction and rate of turn. The —18 volt and +18 volt control signal voltages are applied across R2. The P rate feedback voltage can be monitored at terminal J2–H and is 0.18 volt per degree of turn per second. Because the sensitivity of the rate gyro depends upon the speed of spin motor B1, the motor speed is regulated. Speed regulation is controlled by centrifugal switch S1. Switch S1 is closed when power is first applied to motor B1. The motor speed increases until contacts of S1 are opened by the centrifugal force of rotation and dropping resistor R3 is inserted in the power lead to motor B1. Resistor R3 reduces the voltage applied to motor B1 and causes the motor to slow down until S1 closes and B1 again speeds up. Thus, the speed of B1 is reduced to a narrow range and the sensitivity of the P rate gyro is relatively constant. The —28 volt heater and gyro power for the gyro power is applied through closed contacts 8–9 of deenergized transfer relay K2 (A6) before launch order; —28 volt battery power is applied through closed contacts 7–8 of energized transfer relay K2 (A6) after launch order. Transfer relay K2 is energized at the time of missile launch order. The P rate feedback voltage from R2 is applied through resistor R1 in the P rate gyro (A7) and through pin P2–A of the P steering amplifier and through an RC network to amplifier V1B. This rate gyro signal is in opposition to the P command voltage and causes a change in the current output from power amplifiers V2 and V3 which reduce elevon deflection.

(*f*) *Accelerometer operation.* As the missile changes course, a centrifugal force is created. This force is an indication of the missile P maneuver and is sensed by the P accelerometer (A9). The force is indicated by a displacement of the wiper arm of variable resistor R1 in the P accelerometer. Variable resistor R1 is connected between the —18 volt and +18 volt control signal voltages. The voltage at the resistor arm represents the centripetal acceleration and can be monitored at J2–J. This accelerometer voltage has a scale factor of 1.8 volts per G of maneuver and is applied through pin P2–D of the P steering amplifier and through the resistor network which proportions the signal to amplifier V1B. The signal is coupled to amplifier V1B and a push-pull driving signal is applied to power amplifiers V2 and V3. The output currents of V2 and V3 change to cause further reduction in elevon deflection. When the missile is performing, the received order, the feedback signals from the P rate gyro, the P accelerometer, and the P elevon feedback variable resistor exactly cancel the P command signal. The output currents from power amplifiers V2 and V3 are balanced and the elevon position is stationary. This condition will be maintained until the P command is removed or changed. If the command is quickly removed, the feedback signals, which are degenerative, will still exist and will quickly stabilize the missile on the new heading with little overshoot.

(*g*) *P steering amplifier adjustments.* P balance variable resistor R20 (B10) of the P steering amplifier is adjusted to balance the output currents of amplifiers V2 and V3 under static conditions. To overcome static inertia, the elevons are made to vibrate by application of a buzz voltage to the P steering amplifier. A 45 volt, 250-cps voltage (D8) is applied through resistor R1 and across 250-cps resonant tank C1 and L1. This 250-cps voltage called buzz voltage is applied to all three control servo systems. The buzz voltage is applied through P1–J (A10) of the P steering amplifier and is developed across series resistors R13 and R14. A portion of this voltage taken from the arm of P buzz variable resistor R14 is applied through an RC network to amplifier V1A. This ac signal produces fluctuations in the output current which cause the elevons to vibrate. P buzz variable resistor R14 is adjusted for a 65 to 75 volt output across the control solenoids. This buzz voltage and other P steering amplifier outputs can be measured between J2–S and J2–T (A12).

(4) *Y control servo system.*

(*a*) *General.* The Y control servo system functions exactly as the P control servo system. Therefore, this subparagraph gives only the overall operation of the Y control servo system. Refer to (3) above for more detailed information. The Y control servo system controls the Y elevons in accordance with the Y commands received, the feedback from its flight control instruments, and the elevon feedback variable resistor. The flight control instruments are physically oriented to monitor Y maneuvers. The Y control servo system consists of contacts 10, 11, and 12 of flipover relay K1 (A6), contacts 2–4 of transfer relay K4 (C12), capacitor C8, Y steering amplifier (C11), Y rate gyro (C7), and Y accelerometer (C9) in the missile guidance set, and Y hydraulic mechanism (C15) and Y elevon feedback variable resistor (C16) of the Y actuator assembly of the missile. Variable resistor R2 of the pressure transmitter (D8) in the missile guidance set controls the input to the Y elevon feedback variable resistor.

(*b*) *Inputs.* The Y command (A3) from the signal data converter is applied through closed contacts 10–11 of energized flipover relay K1 (A6) in the gyro servo control and to P2–E of the Y steering amplifier. This signal will unbalance the minus Y valve and plus Y valve output currents of the amplifier, and cause the Y hydraulic mechanism to change the position of the Y elevons. The elevon positioning will produce a Y elevon feedback from the Y elevon feedback variable resistor. This signal with the Y rate feedback voltage from the Y rate gyro (B8) and the Y accelerometer feedback voltage from the Y accelerometer (B9) cause the missile to maneuver in accordance with the received Y command.

(*c*) *Test points.* The Y command signal (1.66 volts per G) can be monitored at J2–W (A4). The Y steering amplifier outputs can be monitored at J2–M and J2–N (C12). The Y elevon feedback signal can be monitored at J2–V. The Y rate feedback voltage (0.18 volt per degree of turn per second) can be monitored at J2–C (C9) and the Y accelerometer feedback (1.8 volts per G) can be monitored at J2–D (C9). For testing, the Y command calibrate signal is applied to J2–L (C9).

(5) *Roll control servo system.*

(*a*) *General.* The roll control servo system generates its own control signal and causes the P and Y elevons to be positioned to keep the missile oriented at its reference position. The roll control servo system consists of the roll amount gyro (C5), preset relay K3 (B4), flipover relay K1 (A6), roll control amplifier (D11), and roll rate gyro (B7) in the missile guidance set, and the roll hydraulic mechanism (C15) and the roll elevon feedback variable resistor (D16) of the roll actuator assembly of the missile. Variable resistor R2 of the pressure transmitter (D8) in the missile guidance set controls the input to the roll elevon feedback variable resistor; variable resistor R1 of the pressure transmitter controls the gain of the roll control amplifier. The gain varies inversely with pressure.

(*b*) *Roll amount variable resistor.* At launch, safety and arming inertia switch S30 (B3) closes to complete the energizing path for preset relay K3 (B4). The preset relay can also be energized during tests through J2–d (B5). Normally, closed contacts 1–2, 7–8, 4–5, and 10–11 of energized K3 open to break the gyro preset circuit; normally, open contacts 2–3, 8–9, 5–6, and 11–12 close to connect reference voltages and grounds to roll amount variable resistor R1 (C5) in the roll amount gyro. Terminal 1 of R1 is grounded through contacts 8–9 of energized K3 and terminal 3 of R1 is grounded through contacts 11–12 of energized K3. Normally, —18 volt control signal voltage is applied to terminal 2 of R1 and +18 volt control signal voltage is applied to terminal 4 of R1. The —18 volt input to terminal 2 of R1 is applied through contacts 7–8 of energized flipover relay K1 (A6) and through contacts 5–6 of energized K3. The +18 volt input to terminal 4 of R1 is applied through contacts 16–17 of energized flipover relay K1 and through contacts 3–2 of energized preset relay K3. Flipover relay K1 is energized during prelaunch phase by external power and is kept energized during flight by internal battery power. During the time K1 is energized, —18 volts is applied to terminal 2 of R1 (C5) and +18 volts is applied to terminal 4 of R1. When a burst order is received, the closed contacts of energized burst relay K1 (A3) open to break the energizing path of flipover relay K1 (A6). Contact 17 of flipover relay K1 switches from contact 16 to 18 and changes the voltage on terminal 2 of R1 in the roll amount gyro from —18 volts to +18 volts; contact 8 switches from contact 7 to 9 and changes the voltage on terminal 4 of R1 from +18 volts to —18 volts. Switching these voltages causes the stable null to be at terminal 3 of R1 rather than at terminal 1. This change will cause the missile to roll 3,200 angular mils to the new null position, terminal 3.

(c) *Roll control operation.* The roll position output voltage from the arm of roll amount variable resistor R1 is zero volt if the missile is correctly oriented. If the missile is rolled from its reference position, a roll position error voltage will be transmitted by variable resistor R1. During the missile flight phase (preset relay K3 and flipover relay K1 energized) if the missile rolls clockwise as viewed from the rear from its reference position, the roll position error voltage will be negative. If the missile rolls counterclockwise, the roll position error voltage will be positive. The value of this voltage is 0.2 volt per degree of roll error. The roll position voltage can be monitored at J2–F (B5). This roll position error voltage is applied through P2–B of the roll control amplifier (D10) and through an RC network which proportions the signal to amplifier V1B. Amplifier V1B is directly coupled to amplifier V1A. Amplifiers V1A and V1B produce a push-pull output which drives push-pull power amplifiers V2 and V3. A roll position error voltage causes an unbalance in the output current of V2 and V3. The gain of V2 and V3 and, hence, the magnitude of the unbalance in currents for a given error is controlled in accordance with the resistance of variable resistor R1 of the pressure transmitter (D8). The gain of V2 and V3 varies inversely with pressure. The unbalance in output current because of the error voltage causes motion of the cores of the control solenoids in the roll hydraulic mechanism (C15). These solenoids control a hydraulic system which positions the P and Y elevons to cause the missile to roll back toward its reference position and also positions the arm of the roll elevon feedback variable resistor (D16). The roll elevon feedback variable resistor receives minus elevon feedback voltage and plus elevon feedback voltage from variable resistor R2 of the pressure transmitter (D8). The roll elevon voltage for a given displacement of the arm of roll elevon feedback variable resistor R1 varies directly with pressure sensed by the pressure transmitter. The roll elevon voltage can be monitored at J2–U (D12). The roll elevon voltage is applied through pin P2–C and an RC network which proportions and smooths the input to amplifier V1A. The roll elevon feedback functions to cancel the roll error input and stop elevon deflection. Deflection of the elevons by the roll hydraulic mechanism causes the missile to roll toward its reference position. Any roll of the missile produces a roll rate feedback voltage from the roll rate gyro. The roll rate gyro is similar to the P and Y rate gyros but is less sensitive. Its speed regulation circuit, composed of centrifugal switch S1 and dropping resistor R3, regulates motor B1 at a lower speed to produce a sensitivity of 0.072 volt per degree of roll per second. The output roll rate feedback voltage from variable resistor R2 of the roll rate gyro (B7) passes through resistor R1 and is applied through pin P2–A of the roll control amplifier (D10) and through an RC network which proportions and smooths the rate voltage to amplifier V1A. The roll rate feedback voltage can be monitored at J2–E (C9). The roll rate feedback input to the roll control amplifier always produces a change in output current which will cause the elevons to be positioned to slow down the roll. The roll rate gyro first aids the roll amount gyro in stopping the roll displacement and then opposes the roll amount gyro in correcting the roll displacement. The roll rate feedback is especially effective during the roll stabilization phase of flight when the roll rate might be too large for roll position correction voltage from the roll amount gyro to control. The roll rate feedback can never completely stop missile roll, but it does greatly reduce the rate of roll.

(d) *Burst operation.* When the burst order is received, burst relay K1 in the command detonation control (C7, fig. 4–4) is energized, and its contacts open to deenergize flipover relay K1 (A6, fig. 4–2). When flipover relay K1 deenergizes, its contacts 4–5 open to remove the —100 volt charging voltage from capacitor C4; contacts 5–6 close to apply the stored voltage at C4 as an input to the roll control amplifier. This input is applied at the same time that the polarities of the reference voltages applied to the roll amount variable resistor R1 (C5) in the roll amount gyro are changed. The negative voltage charge across C4, when applied to the roll control servo system, causes the missile to roll in a counterclockwise direction. This motion moves the missile away from its now unstable null (terminal 1 of R1 in the roll amount gyro) toward the flipover reference position (terminal 3 of R1). Missile flipover occurs on each missile firing but is ineffective on surface-to-air missions because there is only 0.33 second between the operation of flipover relay K1 and missile detonation. On surface-to-surface missions, the burst order does not detonate the missile warhead; it only conditions the missile for an unguided portion of flight. Flipover of the missile (3,200-mil rotation) reduces missile drift for increased accuracy.

(e) *Roll control adjustments.* Roll centering variable resistor R10 (D10) is adjusted to produce balanced output currents from the roll control amplifier. Roll buzz variable resistor R28 is adjusted for a 65 to 75 volt buzz output voltage across the control solenoids of the roll hydraulic mechanism (C15). This voltage can be measured between pins J2–P and J2–R (D12).

c. Beacon Transmitting Circuit.

(1) *General.* The relatively small size of the missile makes it difficult to obtain a satisfactory reflection of the signal transmitted by the missile tracking radar system. To insure more positive tracking of the missile, a beacon signal is sent back to the missile tracking radar system. Each time the No. 4 pulse (fig. 3–4) of a properly coded pulse group is received by the missile receiving and decoding circuit, the beacon transmitter is triggered (para 3–6*a*) and sends back a beacon signal. The units comprising the beacon transmitting circuit (fig. 4–3) are located in the radio set. These units consist of the P and Y pulse demodulator, tapped delay line, radar modulator, magnetron VI, and transmitter waveguide assembly.

(2) *Tapped delay line.* The ground guidance equipment is able to determine the range of the missile by determining the time interval between the transmission of the No. 4 pulse by the missile tracking radar (MTR) and the receipt of the beacon signal at the MTR due to this transmission. The time required by the missile to detect, decode, and send back a beacon signal is called missile response time.

(*a*) *Response time.* If the missile response time were neglected in the computation of missile range, the ground guidance equipment would interpret incorrectly the range between the missile and the MTR. Therefore, the missile response time must be included in determining the range of the missile. A tapped delay line permits adjustments of the response time to a value within approximately 0.01 microsecond of a selected nominal value. The NIKE-HERCULES response time is set as close to 0.85 microsecond as possible. Computation of range becomes more accurate when the missile response time is known.

(*b*) *Response time adjustment.* The tapped delay line is a passive network composed of 10 inductors connected in series. Response time switch S1 is used to provide selection of the desired delay time by selecting the number of inductors to be used. The 60 volt, 5-microsecond beacon trigger pulse from the P and Y demodulator is applied through the number of inductors selected by switch S1 to the radar modulator.

(3) *Radar modulator.* Positive 60 volt 5-microsecond beacon trigger pulses from the P and Y pulse demodulator are fed through the tapped delay line to the radar modulator. The radar modulator produces a sharp pulse to cause the magnetron to generate an RF pulse called the beacon signal. This signal is sent back to the MTR to acknowledge the receipt of orders sent to the missile by the MTR. The radar modulator also provides a dc holdoff pulse which is sent to the fail-safe control. This dc pulse acts as a bias voltage which holds the fail-safe circuit inoperative unless the command signals fail. If command signals fail, the fail-safe control is activated within 3 seconds, detonating the missile.

(*a*) *Triggering modulator V3.* Signals delayed through the tapped delay line are applied to amplifier V1B (C2). The positive pulse received causes V1B to conduct. A resulting negative pulse from V1B is applied to the primary of transformer T1. A positive pulse from the secondary of T1 is fed to blocking oscillator V1A. The 90 volt, 0.5-microsecond output pulse of monostable blocking oscillator V1A is coupled to thyratron modulator V3, causing V3 to fire.

(*b*) *Charging network Z1.* When modulator V3 is triggered into conduction, network Z1 discharges. Discharge of Z1 produces a voltage pulse of 275 volt amplitude across the primary of transformer T2 and also supplies a 150 volt, 0.5-microsecond negative holdoff pulse which is applied to the fail-safe control. Charging network Z1 is recharged by the flow of electrons from ground through the primary of transformer T2 to the network, then from the network through charging diode V2, choke L1, and deenergized contacts of overload relay K1 to the +300 volt dc power supply. Charging diode V2 clamps the voltage across the charging network at the peak value resulting from the LC resonance charging of the network and choke L1. The peak value of this voltage is approximately 550 volts.

(*c*) *Overload relay K1.* The normal charging current developed across Z1 is not sufficient to energize overload relay K1. However, if V3 fails to deionize after Z1 discharges, the current flow through V2 and K1 to the +300 volts will be sufficient to energize K1, and energized contacts of K1 will open the power circuit and force deionization of V3.

(*d*) *Magnetron V1.* The 6229 magnetron is a cavity-resonant type magnetron using a grounded anode and a negatively pulsed cathode. The magnetron is tunable to any frequency between 8,900 and 9,400 megacycles; tuning is accomplished by mechanically varying the dimensions of the cavity by the magnetron adjust control. A negative 3,900 volt, 0.5-microsecond pulse is applied to the cathode of the magnetron from pulse transformer T2. This pulse is shaped so that the magnetron oscillating time is approximately 0.25 microsecond in duration. The RF output of the magnetron is coupled directly to the waveguide by means of an output transformer which is part of the magnetron. The output transformer is used to match the output impedance of the coupler to that of the waveguide.

(*e*) *Pattern modulator B1.* A pattern modulator is used to vary the relative phase radiation of one antenna horn with respect to the other at an 80- to 90-cps rate. Varying the relative phase radiation of one antenna horn with respect to the other rapidly shifts the radiation pattern so that any dead spots in the radiation pattern will be shifted at a rate sufficient to allow the MTR to track the missile.

d. Detonation Command Circuit.

(1) *General.* Missile detonation is controlled by the detonation command circuit (fig. 4-4) consisting mainly of the command detonation control in the radio set of the transponder-control group and the fail-safe control and sequential timer located in the warhead section. The fail-safe control is located in the warhead section to allow fail-safe detonation even with missile breakup, thus increasing the reliability of the fail-safe circuit. Detonation commands are received from the MTR (command detonation) or are generated by the fail-safe control circuit (fail-safe detonation) in the missile. Command detonation is initiated by a burst order (para 3-3) from the MTR about 0.35 second prior to intercept. Upon receipt of the burst order, the command detonation control, the fail-safe control, and the sequential timer (which introduces a 0.33-second delay) activate the detonation devices in the warhead section, and the missile warhead detonates. The fail-safe control will initiate warhead detonation whenever ground guidance ceases or a malfunction occurs within the missile guidance set. The theory of command detonation is discussed in (2) below. The theory of fail-safe detonation is discussed in (3) below. This subparagraph covers detonation of a high explosive warhead. The operation of the detonation command circuit is the same for a prime warhead but the wiring from the detonation command circuit is different. With a prime warhead, the fail-safe and command outputs are separated. Then the fail-safe output controls a small explosive charge which will destroy the missile without detonating the prime warhead. The command detonation output controls the prime warhead detonating mechanism.

(2) *Command detonation.* Command detonation of the missile is controlled by signals from units of the receiving and decoding circuit (fig. 4-1). These signals are applied to the command detonation control and consist of the following inputs: the positive P 5-microsecond pulse (D2, fig. 4-4), the negative Y 5-microsecond pulse, and the undelayed video pulse train from the P and Y pulse demodulator; the burst delayed pulse (delayed by missile code plus 1.58 microseconds) from the P-Y-burst delay network; and the burst enable pulse from the delay pulse generator. The command detonation control produces a current pulse that is applied through burst relay K1 (D12) in the burst pulse forming network and burst relay K1 (D7) in the command detonation control. These burst relays control opera-

tion of the sequential timer and flip-over relay K1 (A3, fig. 4-2) which function to disable the receiving circuit and to cause the missile to roll 3,200 angular mils. The sequential timer, after a 0.33-second delay, energizes the detonators of the missile warhead. Figure 4-4 shows arming mechanisms connected for high explosive warhead.

(*a*) *Command detonation control.* The command detonation control consists of an integrating circuit, an "and" gate, two multivibrators, a relay control stage, and a relay. The integrator circuit (D3, fig. 4-4) consists of resistors R1, R2, and R3, capacitors C1A and C1B, and diodes CR1, CR2, and CR11. The integrating circuit and multivibrator V1 form an enabling circuit and are controlled by the P and Y 5-microsecond pulses. The enabling circuit prevents acceptance of a burst order during the steering phase of flight when alternate positive P and negative Y pulses are received. The enabling circuit allows the burst circuit to accept burst orders when only positive P 5-microsecond pulses are received (time-to-intercept less than 0.5 second or just before guidance cutoff on surface-to-surface firings). The "and" gate consists of transformers T1, T2, and T3, diodes CR3, CR4, and CR5, and biasing network resistors R12 and R19. The "and" gate; multivibrator V2; clamping diode CR12; diode CR8; filter resistor R11 and capacitor C5; relay control V3 and burst timing adjustment circuit resistors R15, R16, and R17 with bypass capacitor C8; storage capacitor C6; and burst relay K1 form the burst channel of the command detonation control. Burst relay K1 (D12), and storage capacitor C2 and its associated charging circuit in burst pulse forming network Z4 and the sequential timer function with the burst channel and control the arming mechanism.

(*b*) *Enabling circuit.* Positive 80 volt P 5-microsecond pulses are applied through R1 (D3) and CR1 to capacitors C1A and C1B. Negative 80 volt Y 5-microsecond pulses are applied through R2, CR2 to C1A, and C1B. As long as the P and Y pulses arrive alternately, as they do during the steering phase of missile flight, the voltage across C1A and C1B will be very near zero volt. The relative resistances of R1 and R2 assure that the negative pulse will always cancel the positive pulse. With zero volt applied, multivibrator V1 will be conditioned so that the output applied to V2 will be —14 volts. Diode CR11 prevents any negative voltage across C1A and C1B. Resistor R3 is a high resistance discharge path for C1A and C1B. The —14 volt output of V1 disables multivibrator V2. When the missile is to be conditioned for burst, only the positive 80 volt P 5-microsecond pulses will be received and a positive voltage will build up across C1A and C1B. After 25 consecutive P pulses, the voltage across C1A and C1B (about 8 volts) causes multivibrator V1 to change state and the output voltage changes from —14 volts to +7.5 volts. The positive output of V1 removes the disabling bias on multivibrator V2. Diode CR10 cuts off for any positive cathode voltage and prevents multivibrator V1 from applying a positive voltage to multivibrator V2.

(*c*) *Burst channel operation.* The undelayed pulses are applied to "and" gate transformer T1 and the burst delayed pulses (delayed by the missile code plus 1.58 microseconds) are applied to T2. The 3-microsecond burst enable pulse is applied to T3. Refer to paragraph 3-3 for a discussion of missile orders. The transformers provide impedance matching and isolate bias current flowing in the "and" gate from the input circuit. When no positive pulses are applied through the transformers, filtered bias current is flowing from a —28 volts through R19, the three transformers secondary windings 3-4, and "and" gate diodes CR3, CR4, and CR5, and R12 to ground. If a positive pulse is applied to the cathode of one of the "and" gate diodes, there will be no significant change in the bias current because the three diodes are in parallel paths. Even if two positive pulses are applied simultaneously to two of the diodes, there will be no significant change in bias current. If three positive pulses (fig. 3-7) are applied simultaneously to all three of the diodes, then the bias current will be cut off and the voltage across R12 (C4, fig. 4-4) will change in a positive direction until the anode to cathode potential will cause one of the diodes to conduct. This conduction will stop the positive voltage change and maintain this voltage until one of the coincident signals is removed. The positive change in voltage (burst pulse) is coupled through C3 and triggers multivibrator V2. Multivibrator V2 is monostable and produces a positive 90-microsecond pulse each time it is triggered. The negative portion of the 90-microsecond pulse is clamped to ground by diode CR12. Diode CR8 allows the positive signal to pass to filter R11 and C5, without allowing C5 to discharge. Resistor R11 is a high resistance discharge path for C5. Ten 90-microsecond pulses from multivibrator V2 build up a positive voltage across C5 sufficient to fire thyratron relay control V3. Bias control variable resistor R15 is adjusted so that 10 burst pulses at 2-millisecond intervals (500-pulse groups per second) cause V3 to fire. Capacitor C8 bypasses the burst bias circuit. When relay control V3 fires, it acts as a switch to discharge storage capacitor C6. Capacitor C6 discharges through series connected coils of burst relay K1 (D12) in the burst pulse forming network of the fail-safe control and burst relay K1 (D7) in the command detonation control and through bypass capacitor C8, relay control V3, and back to C6.

(*d*) *Burst relays.* Contacts of burst relays K1 on the command detonation control open to deenergize flipover relay K1 (A3, fig. 4-2) of the gyro servo control and close to provide a holding circuit for the burst relays. Parallel contacts of energized burst relay K1 (D12, fig. 4-4) in the burst pulse forming network close to complete the path for energizing the arming mechanisms. The arming mechanisms are normally in their safe condition, preventing premature detonation of the missile during the prelaunch period. With the arming mechanisms in their safe condition, the detonators within the arming mechanisms are not alined to receive the ignition charge. After the period of sustained acceleration at launch, the detonators within the arming mechanisms are rotated into position by inertia switches. As an added precaution, shorting plug P8 prevents possible detonation of the missile before launch should the mechanism be armed. When contacts of K1 close, the ground paths for the sequential timer are completed. The parallel ground paths are from J1-P and G of the sequential timer through J1-2 and 14 of the fail-safe control, and the parallel contacts of energized burst relay K1 of the burst pulse forming network to J1-1 and 15 of the fail-safe control, and to J1-D and E on the sequential timer.

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(e) *Sequential timer.* This ground completes the energizing path for input transfer relay K2 of the sequential timer. Contacts of energized relay K2 perform switching to enable output control relay K1 and change the input to the time delay network from the reset to the operate condition. The time delay network uses the time required for saturation of an inductor to introduce a 0.33-second delay. The exact delay is set by adjustment of time adjust variable resistor R5. At 0.33 second after ground is applied, saturation of the time delay network is such that Q1 and Q2 are forward biased and conduct sufficiently to energize output control relay K1 and complete the path for energizing the arming mechanisms. When parallel contacts 6 and 1, 2 and 5 of energized relay K1 in the sequential timer close, an electrical charge on capacitor C2 (C13) of the burst pulse forming network sends current through resistors R3 and R4 (C12) on the burst pulse forming network, through the two parallel connected arming mechanisms, and through parallel contacts of energized output control relay K1 in the sequential timer back to C2. This current pulse activates the two arming mechanisms causing the missile warhead to burst.

(f) *Burst pulse forming network.* Capacitor C2 of the burst pulse forming network is charged to almost 240 volts whenever plate voltage is generated. The charging path for C2 is from detonator ground through parallel resistors R3 and R4, C2, diode CR1, and resistor R1, all in the burst pulse forming network, through resistor R5 in the gyro servo control to +240 volts. Diode CR1 assures an electrical charge on C2 even if the +240 volt circuit fails in flight. This assurance is necessary because this electrical charge is also used for fail-safe operation. Contacts of connector J2 allow monitoring of command burst circuit operation.

(3) *Fail-safe detonation.*

(a) *General.* Fail-safe detonation of the missile is controlled by negative 150 volt holdoff pulses from the radar modulator (B8). As long as these negative pulses are present, the missile will not be destroyed. A negative holdoff pulse is normally generated for each correctly coded pulse group received. If no signals are received for a period of 1 to 3 seconds, the fail-safe circuit will operate to destroy the missile. Also, should some portion of the guidance set not function so that holdoff pulses are not generated, the fail-safe circuit will operate to destroy the missile. The fail-safe portion of the detonation command circuit consists of three electronic switches Z1, Z2, and Z3, and a portion of burst pulse forming network Z4, all in the fail-safe control located in the warhead section.

(b) *Electronic switches Z1, Z2, and Z3.* The negative 150 volt holdoff pulse from the radar modulator is applied to step-down transformer T1 in the gyro servo control. The —30 volt output pulse of T1 is at a +240 volt level and is applied to terminal 12 of the burst pulse forming network (D12). The —30 volt holdoff pulse passes through capacitor C1 which blocks the +240 volts and is applied to terminal 7 of all three electronic switches. A —28 volt bias is also applied to terminal 7 through resistor R2 in the burst pulse forming network. The holdoff pulse applied to blocking oscillator Q1 produces a negative pulse at terminal 4 of winding 4–3 of transformer T1 which induces a negative pulse at T1–6. This negative pulse is passed by diodes CR3 and CR7 to storage capacitors C2 and C3. As long as holdoff pulses are received, these capacitors will be charged sufficiently negative to prevent any output from amplifier Q2; electronic switch Q3 will conduct sufficiently to energize fail-safe relay K1. The contacts of all fail-safe relays in the three electronic switches will then be open. The six sets of relay contacts form parts of a circuit consisting of storage capacitor C2 and its associated components in the burst pulse forming network, the fail-safe relay contacts, and the two parallel arming mechanisms. The six sets of relay contacts are interconnected in a series parallel arrangement so that contacts in two of the three electronic switches must be closed to complete the circuit between C2 and the arming mechanisms. Capacitor C2 is kept charged to +240 volts by +240 volts in the gyro servo control. Diode CR1 prevents discharge of C2, should the +240 volts fail. If for any reason the holdoff pulse is not present for a period of one to three seconds, storage capacitors C2 and C3 (B13) of electronic switches Z1, Z2, and Z3 will discharge sufficiently so that the output of amplifier Q2 will cause conduction through electronic switch Q3 to decrease and fail-safe relay K1 to deenergize. Contacts of the fail-safe relays close and C2 (C13) of the burst pulse forming network discharge through the two parallel arming mechanisms ((2) (*d*) above) causing the missile to be destroyed. The discharge path for C2 is through resistors R3 and R4 of the burst pulse forming network, the detonator ground circuit, the two parallel arming mechanisms, through series parallel connected contacts of the fail-safe relays of the three electronic switches (six possible paths exist, each involving two sets of contacts), and back to C2 in the burst pulse forming network. The use of three electronic switches improves reliability. The series arrangement of relay contacts prevents a faulty electronic switch which allows its relay contacts to close from destroying the missile. The parallel arrangement of relay contacts assures that a faulty electronic switch, with contacts that do not close, will not prevent the fail-safe circuit from destroying the missile. Contacts of test connector J2 allow monitoring of fail-safe circuit operation. No operating connections are made to connector J2.

e. Power Supply Distribution Circuits.

(1) *General.* All operating voltages, except —28 volts required by the missile in flight, are produced by the power supply. All dc voltages, a 45 volt, 250-cps pattern modulator motor, and buzz voltage are produced from a transistor converter and rectifier circuits within the power supply. During the prelaunch period, various external voltages are applied to the missile for test purposes and as warmup power. The sequence in which these voltages are applied is given in (2) below.

(2) *Power application sequence.* Delay line heater power of 120 volts ac is applied through contacts 18 and 17 of deenergized transfer relay K2 (D2, fig. 4–5) in the gyro servo control to the delay line heater in the missile-code delay line (B10, fig. 4–1). The thermostatically controlled heater maintains the missile-code delay line at a constant temperature through the operation of thermostatic switch S1. External —28 volt heater and gyro power is applied through contacts 9 and 8 of deenergized transfer relay K2 (D2, fig. 4–5) to the gyro motors and through contacts 3 and 2 to all electron tube filaments.

(a) *External input power.* External —28 volt transistor power is applied through contacts 6 and 5 of deenergized transfer relay K2 to the dc and 45 volt ac producing circuits of the power supply and through contacts of deenergized burst relay K1 (A3, fig. 4-2) in the command detonation control to the coil of flipover relay K1 (A6) in the gyro servo control. The power supply then applies dc voltages to all units within the guidance set. Burst relay K1 remains deenergized until a burst order is received. When a burst order is received, burst relay K1 becomes energized removing the —28 volts from flipover relay K1 (para 3-6*b* (3)). Deenergizing flipover relay K1 removes +240 volts normally fed through contacts 1 and 2 (B8, fig. 4-4) of flipover relay K1 to the amplifier-decoder.

(*b*) *Internal power.* At launch order, the guidance set is transferred from external power to internal power supplied from a —28 volt battery. External to internal power transfer is accomplished by applying (as initial energizing power) external transfer relay power (—28 volts) to transfer relays K2 (D2, fig. 4-5) and K4 (B2). Relays K2 and K4 remain energized by the application of internal battery power through resistor R3 and contacts 10 and 11 of energized relay K2. Deenergizing K2 and K4, after internal battery power is applied, is accomplished by shorting through external circuitry the —28 volt dc external transfer relay power lead to ground. Resistor R3 in the circuit prevents a direct short of the —28 volt battery to ground when relay K2 is deenergized.

(*c*) *—28 volt dc internal battery power.* Relay K2, when energized, applies —28 volt dc internal battery power through contacts 4 and 5, replacing external —28 volt transistor power: through contacts 16 and 17 replacing external 120 volt, 400-cps delay line heater power; and through contacts 7 and 8, replacing external heater and gyro power. Contacts of relay K4 perform switching to convert the elevon feedback circuits from dc to ac operation (para 3-6*b*(3) an (4)).

(*d*) *Lift-off power distribution.* At lift-off, inertia switch S1 (C3) closes. Contacts 3 and 4 of S1 close supplying —28 volt battery power to relays K2 and K4, insuring that they are energized. Contacts 1 and 2 of S1 also close at lift-off, applying —28 volt uncage power to the uncage solenoid of the roll amount gyro in the steering control circuit (C6, fig. 4-2).

(3) *Power supply.* The power supply (B3, fig. 4-5) consists of a dc voltage and 45 volt, 250-cps producing circuit. The pattern modulator motor and buzz voltage are supplied from the 45 volt output. Application of —28 volt transistor power energizes the dc voltage and 45 volt ac producing transistor converter. Transistor converter Q1 and Q2 produce an ac voltage across the primary of transformer T1. AC voltages from the secondaries of T1 are applied to the 5 bridge rectifier circuits, a half wave rectifier circuit, and a 45 volt ac output is applied as buzz voltage after filtering to the P and Y steering amplifiers and the roll control amplifier, and as 45 volt ac motor power to the pattern modulator in the transmitter waveguide assembly. The bridge rectifier circuits supply filtered dc outputs (A4 to D4) to all electronic subassemblies of the missile guidance set. The +300 and +150 volt outputs are regulated by electron tube regulators in the power supply. The —75 volt output is regulated by voltage regulator V1 (B14) in the signal data converter. The +300 volt output potential is achieved by adding the output of bridge rectifier CR2 and CR5 to the +240 volt output. The +220 volt unfiltered output is obtained by half-wave series-connected rectifiers CR14 and CR15 which are connected to winding 9-10 of T1. Control signal adjust variable resistor R9 permits the +18 volt and —18 volt outputs to be adjusted for a 36 volt difference. Output voltages from the power supply can be monitored at connector J2 (A10 to C10).

f. —28 Volt and Ground Distribution Circuit.

(1) *General.* During the prelaunch period, various external voltages are applied to the missile for test purposes and as warmup power for the missile-code delay line, power supply circuits, electron tube filaments, and gyro motors. In flight, power is supplied from the guidance set battery, one of three —28 volt nickel-cadmium batteries housed in the battery box (A1, fig. 4-6). The guidance set battery furnishes sufficient power for both guidance set operation and warhead detonation when the missile is equipped with a nonnuclear warhead. The two additional batteries (warheads 1 and 2) are required for nuclear warhead detonation. External voltages are applied from the launching area (C1 to D1) to the missile through connector P8 (C2 to D2). The missile guidance set receives external inputs from connector P8 through the missile distribution box and internal wiring to guidance set connector P1 (C5 to D5). A description of external voltages applied during the prelaunch period is given in (*a*) through (*d*) below. The power supply circuits of the two guidance sets described in *e* above (stovepipe) and paragraph 3-8 (mushroom) should be referred to for distribution of voltages after they enter the guidance set.

(*a*) *120 volt ac delay line heater power.* Delay line heater power of 120 volts ac is applied from connector P8-45 (D2) to the missile-code delay line heater through connector P1-29 (D5) on the guidance set.

(*b*) *External —28 volt heater and gyro power.* Gyro motor and electron tube filament warmup power is provided by the application of external —28 volt heater and gyro power from connector P8-30 (D2) to connector P1-17 (D5) on the missile guidance set.

(*c*) *External —28 volt transistor power.* DC voltage producing power supply circuits are energized by the application of —28 volt transistor power from connector P8-29 (D2) to connector P1-4 (D5) on the missile guidance set.

Note. External —28 volt transistor power is referred to as B+ activate power after it enters the mushroom guidance set.

(*d*) *Control internal-external power.* At launch order, all external voltages applied to the guidance set are removed and replaced by —28 volt internal power from the guidance set battery. This is accomplished through the energized function of transfer relay K2 (D2, fig. 4-5) stovepipe, or relays K3 and K4 (A2, fig. 4-11) mushroom, within the guidance set. Energizing the transfer relay(s) is accomplished by applying —28 volt control internal-external power (transfer relay power) from connector P8-5 (C2, fig. 4-6) to the transfer relay through P1-5 (C5, fig. 4-6) on the guidance set.

(*e*) *Missile heat, phase A power.* Missile heat, phase A, 120 volt, 400-cps power is applied to the battery heater within the battery box (A1) from connector P8-58 (D2) through battery box connector J510-R (B2). Thermostatic switch S24 controls power to the battery heater to prevent battery temperature from going below 75°F.

(2) *Battery box.* One —28 volt guidance set and two —28 volt warhead batteries are housed within the battery box (A1). The two warhead batteries are used only with a nuclear warhead and are replaced with dummy batteries to provide proper weight dis-

tribution when a high explosive (HE) type warhead is used. The three batteries are of nickel-cadmium construction, insuring long operating life. The battery box is heated during the prelaunch period by external power (phase A) which is applied to the battery heater in the battery box. The heater maintains the temperature at a level for maximum battery efficiency. During flight, the heat generated by normal battery discharge keeps the batteries warm.

(*a*) During the prelaunch period, missile heat phase A power is applied from connector P8–58 (D2) through battery box connector J510–R (B2) to one side of the battery box heater circuit consisting of the battery heater element and thermostatic switch S24. The energizing path of the heater circuit is completed through J510–P (B2) and P8–32 (C2) to ground (ac power). Thermostatic switch S24 closes when the battery box temperature falls slightly below +75°F, and opens when the temperature becomes slightly greater than +75°F, assuring that the battery temperature does not fall below +75°F. Thermostatic switch S25 provides a means of monitoring the heater circuit by closing when the temperature falls below +50°F. This action is monitored at heater monitor connector P8–75 (D2) through external circuitry located in the launching area.

(*b*) Battery voltage of the guidance set battery and the two warhead batteries (1 and 2) may be monitored at guidance set battery meter P8–7, warhead battery No. 1 meter P8–8 (D2), and warhead battery No. 2 meter P8–9. The three batteries may be charged by applying charging current through guidance set battery P8–31 (C2), warhead battery No. 1 charge P8–23 (D2), and warhead battery No. 2 charge P8–12 (D2). Warhead batteries No. 1 and No. 2 cannot be monitored or charged until their respective circuit paths are completed through connectors J500 and J501 located in the warhead section (A6 to B6). This is accomplished by connecting a shorting plug between connectors J500 and J501, thereby completing the circuit path from P8 to the battery box connector J510.

(3) *Safety and arming inertia switch S30.* Safety and arming inertia switch S30 (C6) closes at lift-off, supplying a preset relay ground to connector P1–6 (C5) on the missile guidance set. Inertia switch S30 functions as part of the steering control circuit described in paragraph 3–6*b* (stovepipe) or paragraph 3–7*b* (mushroom). The function of S30 is identical for both stovepipe and mushroom guidance sets.

Section III (C). THEORY OF THE MISSILE GUIDANCE SET (MUSHROOM)

3–7 (C). Block Diagram Analysis

a. General. The mushroom missile guidance set (fig. 3–13) consists of four functional circuits: the receiving and decoding circuit, the steering control circuit, the beacon transmitting circuit, and the detonation command circuit. The missile guidance set receives guidance signals from the missile tracking radar (MTR) system and transmits beacon response signals back to the MTR system so that the MTR can track the missile. The guidance set controls the positioning of the missile elevons to steer the missile according to received guidance commands and to keep it from rolling from its present reference position. The guidance set also generates a burst impulse for detonating the missile warhead when burst commands are received. If no signal is received from the MTR or if the missile guidance set does not function properly, a fail-safe burst impulse is generated by the missile guidance set and the missile is destroyed. The four functional circuits of the missile guidance set are covered in *b* through *e* below.

b. Receiving and Decoding Circuits.

(1) The receiving and decoding circuit (fig. 3–13) consists of the radio receiver, amplifier-decoder, delay line driver, missile-code delay line, RF detector, P–Y–burst delay network, command signal decoder, P command signal converter, Y command signal converter, sweep generator, and pulse delay oscillator. These units function to assure that only guidance signals from the missile's own MTR will be effective. The receiving and decoding circuit receives pulses of RF energy (guidance signals) from the MTR and converts these signals into a form which can be used by the other circuits of the missile guidance set.

(2) The pulses of RF energy are received in groups of four or five pulses (fig. 3–4) coded to contain the missile code and the missile command. The coding is contained in the time interval between various pulses in each group of pulses received (refer to para 3–3 for discussion of missile coding). The receiving and decoding circuit detects, amplifies, and decodes the received energy and supplies P and Y commands (dc voltages) to the steering control circuit, beacon trigger pulses to the beacon transmitting circuit, and P and Y 5-microsecond pulses and burst commands to the detonation command circuit.

(3) Pulses of RF energy received by the receiving antennas (No. 2 and No. 4) are detected by crystal diodes in the radio receiver. These video pulses from the radio receiver consist of groups of four or five pulses (para 3–3) at a 500-pulse group per second rate which are applied to the video amplifier section of the amplifier-decoder.

(4) The video amplifier section sums the video pulse groups from the two RF detectors in the radio receiver into one composite pulse train, amplifies the video pulse train and applies it to the decoder section of the amplifier-decoder and the delay line driver.

(5) The delay line driver converts the undelayed video pulse train into amplified 15-megacycle output pulses that are applied to the missile code delay line. The undelayed video pulse train is also applied through the delay line driver to the command signal decoder and the command detonation electronic switch in the detonation command circuit. The 15-megacycle pulses drive the missile-code delay line which delays each pulse by a time interval corresponding to the missile code. The delayed 15-megacycle pulses from the missile-code delay line are detected and amplified by the RF detector. The delayed video pulse train output of the RF detector is applied to the decoder section of the amplifier-decoder and to the P–Y–burst delay network.

(6) The decoder section compares this delayed video pulse train with the received undelayed video pulse train. If the No. 1 pulse of the delayed video pulse train and the No. 2 pulse of the undelayed video pulse train are properly coded, i.e., coincidental in time, the decoder produces a decoded pulse output which is applied to the pulse delay oscillator. Negative pulses in the decoded pulse output will not affect the pulse delay oscillator.

(7) The decoded pulse triggers the pulse delay oscillator which generates a burst enable pulse and an 80-microsecond gate pulse. The 80-microsecond gate pulse is generated 50 microseconds after the pulse delay oscillator is triggered and applied to the sweep generator. The burst enable pulse, which is in time coincidence with the No. 2 pulse of the undelayed video pulse train, is applied to the command detonation electronic switch in the detonation command circuit.

(8) The P–Y–burst delay network utilizes the delayed video pulse train from the RF detector to provide three outputs