CONFIDENTIAL

Contract No. DA-30-069-ORD-1448

NIKE-AJAX

EVENT RECORDS ANALYSIS

15 MAY 1958

PREPARED BY BELL TELEPHONE LABORATORIES, INC.
ON BEHALF OF WESTERN ELECTRIC CO., INC.

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This memorandum is written to clarify the role of the event recorder and plotting board records in the evaluation of Nike-Ajax System performance. An attempt will be made to explain how to analyze normal and peculiar traces on these records, not only when they are used normally, but also when used to record simultaneous tracking and computer dynamic tests.

Three records are made automatically during an engagement: the two plots from the horizontal and altitude plotting boards, and the multi-channel event recorder record. Information from the records can be used in checking the operation of the tracking radar systems, the computer, and the missile; and in analyzing events that occur during engagements. These records are also important because once an engagement is completed, they furnish the only source of information for analyzing that engagement. Even on engagements which appear satisfactory, the records may show malfunction in some of the early phases of flight for which the system was able to compensate, but which should be corrected. The event recorder and plotting board records are the only sources of such information. It is then beneficial to study the records, even on successful engagements, to discover possible troubles which are not apparent from other sources. All troubles will not show up on these records, but in many cases, an analysis of the plotting board and event recorder records will aid in localizing malfunctions.

1. ANALYSIS OF RECORDS

1.1 General

As an aid in correlating the traces and the records, fire marks and timing marks are made automatically on all three records. The fire marks occur simultaneously on all three records when the FIRE switch at the battery control console is operated. The timing marks occur simultaneously on all three records at approximately 10-second intervals.

Reference marks should be made on the two plotting board plots as a further aid in correlating the traces of the two plots after the plots have been removed from the plotting boards. The reference marks indicate the location of the target track antenna on both the horizontal and the altitude plots after the plots have been removed from the plotting board. This location of the target track antenna furnishes a common point from which all directions and distances can be measured. Before the plots are removed from the plotting boards, the location of the target track antenna is indicated by the location of the origins on the etched grids of the horizontal and altitude plotting boards. During an engagement, the recorder pens may be lifted momentarily from the paper to reference an occurrence of interest for later analysis. When the PEN LIFT switch is depressed, the recorder pens of both plotting boards lift causing a break in each of the traces which may be used later for locating the desired point.

Subsequent to Nike-Ajax System No. 246, a later model of the event recorder was placed into service. The later model provides for three additional channels and an increase in tape speed. These additional channels cause recording of target tracking radar AGC, missile speed, and time-to-intercept and plotting board timing marks. The change also shifts the zero positions of the other channels. Channel 24 has been assigned to record time-to-intercept; channel 17, missile speed; and channel 14, target AGC. Channel 13, missile AGC, is not an addition, but the scale factor has been changed to conform to that established for the target AGC channel. Event recorder records from both models are used for illustrations in this memorandum.

Nike-Ajax Systems assigned for Annual Service Practice at Red Canyon Range and for Package Training at McGregor Range include a temporary modification which provides for the display of missile velocity components X, Y, and H. The event recorder channels normally assigned to indicate launcher number, section number and spare are used for these assignments.

1.2 Horizontal Plotting Board Plot

The horizontal plot is the most natural in appearance of the three records since it is a plan view of the entire engagement. The horizontal plot consists of the following three traces: (1) present position of the target in the horizontal plane, (2) position of the predicted intercept point in the horizontal plane, and (3) missile position in the horizontal plane. Only two traces are made at a time. Before missile-away is detected by the computer, the traces indicate the predicted intercept point and the present position of the target. After missile-away the traces indicate the present position of the missile and the present position of the target.

Figure 1 shows a horizontal plot of a typical engagement. The plot is shown superimposed on the horizontal plotting board grid as it would appear before being removed from the plotting board. The reference mark shown on the plot indicates the location of the center of the plotting board grid after the plot is removed from the plotting board. The fire marks on the traces of the plot appear as short excursions to the left and downward, and the timing marks appear as short excursions upward and to the right. The numbers on the plot near the timing marks are not normally on the plot. The numbers indicate the time of occurrence of the timing mark using time of fire as a reference. That is, -29 indicates the timing mark made 29 seconds before fire; whereas 21 indicates the timing mark made 21 seconds after fire.

At the beginning of the engagement shown on figure 1, the target is flying approximately south-southeast at 38,000 yards range and 6,150 mils azimuth. This is indicated by the plot of target position in the vicinity of the -29 second timing mark. An approximate target velocity in knots can be found by multiplying the distance between two timing marks by 1,250 knots per inch. The distance between the -29 second and -19 second timing marks on the actual plot is between 0.1 and 0.2 inch, indicating a target velocity between 125 and 250 knots. The target continues at about the same velocity for the remainder of the engagement. Note, however, that the target is gradually turning from south-southeast to south throughout the engagement. Further examination of the plot of target position indicates that intercept occurred approximately 51 seconds after fire at 28,000 yards range and 6,100 mils azimuth.

The plot of the predicted intercept point on figure 1 also shows that the target was slowly turning toward the south during the early stages of the engagement. Since the predicted intercept point is based on target velocity as well as target position, a target maneuver before missile-away is always more easily detected by examing the plot of the predicted intercept point. One second after the fire mark is made on the plot of the predicted intercept point, the 1-second timing mark is made. Three seconds after the fire mark is made, missile-away is detected and the pen which was plotting the predicted intercept point now begins plotting the missile position.

The beginning of the plot of missile position shows the approximate location of the launcher with respect to the target track antenna. The plot also shows the path of the missile to the intercept point. The approximate speed of the missile in knots can be found by multiplying the distance between two timing marks by 1,250 knots per inch. Timing marks on horizontal plotting board plots will not appear if the timing mark signals arrive while the recorder pens are interchanging functions.

1.3 Altitude Plotting Board Plot

The altitude plotting board plot is made simultaneously with the horizontal plot. This plot also has three traces:

1. the altitude of the predicted intercept point versus the predicted time to intercept which is plotted by the right recorder pen before missile-away,

2. the altitude of the target versus the predicted time-to-intercept which is plotted by the right recorder pen after missile-away,

3. the altitude of the missile versus the predicted time-to-intercept which is plotted by the left recorder pen.

Figure 2 shows the altitude plot of the engagement discussed above. In the figure, the plot is shown superimposed on the altitude plotting board grid as it would appear before being removed from the plotting board. The reference marks shown on the plot indicate the location of the base lines of the plotting board grid after the plot is removed from the plotting board. The fire mark on the trace of the plot appears as a short excursion downward on the plot of predicted intercept

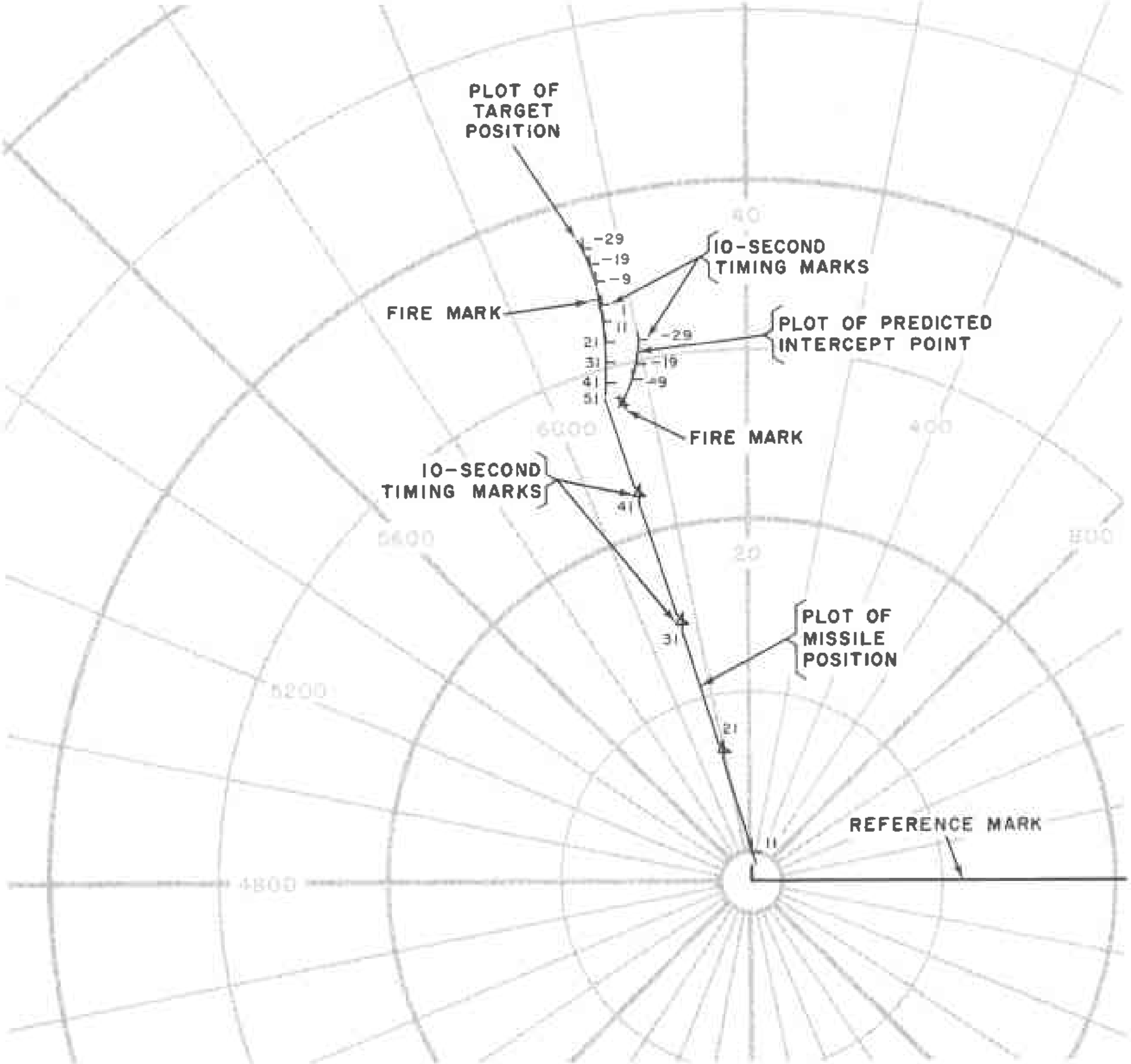

Figure 1. Horizontal Plotting Board, Engagement Plot

point altitude. The timing marks appear as short excursions upward. The numbers near the timing marks are not normally on the plot. They have been added to aid in analyzing the plot. The numbers indicate the time of occurrence of the timing mark using time of fire as a reference. These times correspond with the times indicated on the timing marks of the horizontal plotting board plot (figure 1).

At the beginning of the engagement shown on figure 2, the target is 17,000 feet above the target track antenna and the predicted time-to-intercept is 48 seconds. This is indicated by the plot of predicted intercept point in the vicinity of the -29 second timing mark. The plot of the predicted intercept point continues until the missile is fired. One second later the 1-second timing mark is made. Three seconds after the fire mark is made, missile-away is detected and the pen stops plotting predicted intercept point altitude and begins plotting the target altitude. Simultaneously, the left recorder pen begins plotting the missile altitude versus the predicted time-to-intercept.

Inspection of the plot of target altitude shows that the target flew on a level course at approximately 17,000 feet throughout the engagement until intercept occurred at the point where the 51-second timing mark appears. The plot of missile altitude follows a normal path to the intercept point where the 51-second timing mark appears. The trace indicates that the missile reached a maximum altitude of approximately 23,000 feet above the target track antenna during its flight to the intercept point. The plots also show that the missile and target were at approximately the same altitude at intercept.

1.4 Multi-channel Event Recorder Record

The primary function of the event recorder is to present on light sensitive photographic paper the indications of how well the computer solves the missile-to-target intercept problem. The event recorder record is made simultaneously with the horizontal and altitude plots. Figure 3 shows the event recorder record of the engagement discussed above. Indications of time in seconds with respect to burst have been placed across the top of the record to provide easy time reference when discussing the record. Note that this is real time and should not be confused with the predicted time-to-intercept. Channel designations with the zero positions, calibrate positions, and scales are shown at the left of the figure. Traces and important points are called out for easy location.

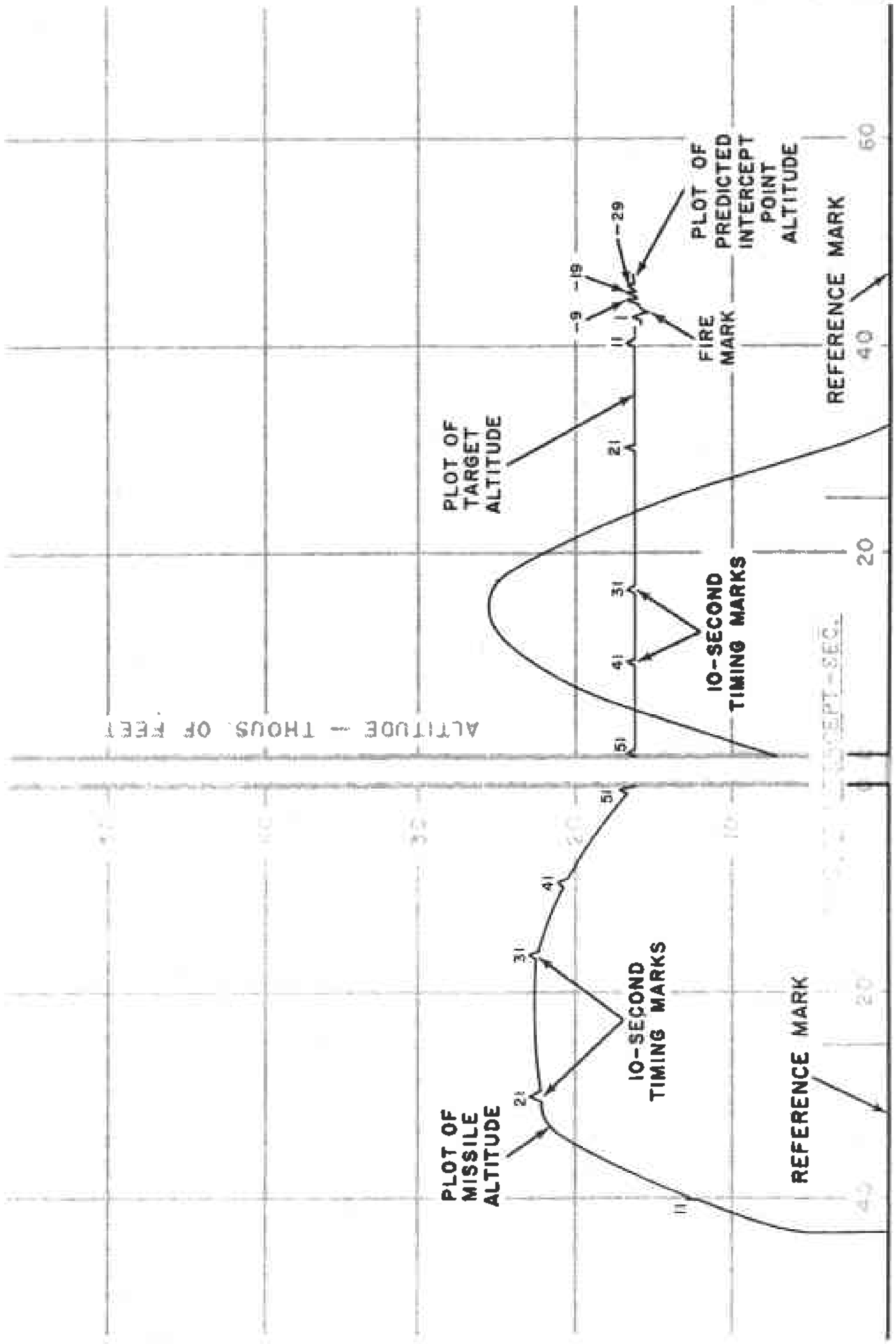

Figure 2. Altitude Plotting Board, Engagement Plot

Events are shown on the data recorder record from left to right with a time scale of 0.2-inches per second. At the beginning of the record, the zero position of each channel is indicated automatically. This is followed by an automatic indication of the calibrate position of each galvanometer. These positions are useful when analyzing the record to verify that each channel was adjusted properly. The zero positions followed by the calibrate positions may be obtained at any time during an engagement by depressing the GALVANOMETER ZERO switch. This may be done to reference a point for easy location after the record has been processed, or to check galvanometer drift. At 90-second intervals, each of the traces is broken in sequence, starting at the top with channel 24 and ending at the bottom with channel 8. This break in the trace is called the trace identifier. It is used to identify traces which may have crossed one another during an engagement. This sequence of trace identifiers occurs once in the engagement shown in figure 3. The sequence begins at 36 seconds before burst on trace 24 and ends at 29 seconds before burst.

a. Channels 8, 9, and 10. Channels 8, 9, and 10 traces show information from the launcher area. Channel 8 indicates the number of missiles prepared (1 through 16). The channel 9 trace shows which launcher in the section was designated (1, 2, 3, or 4). The channel 10 trace shows which section was selected (A, B, C, or D). These traces also give an indication of missile lift-off. The traces are stepped, that is a fixed displacement from zero will indicate a launcher, a section, or given number of missiles prepared. The displacements take the appearance of steps because of their short changes. The steps in these traces increases with launcher number, section letter, and missiles prepared. The launcher designated and section selected steps occur when a section has been selected. The steps occur at the same time since a launcher in a section must be designated before that section can be selected. The number of missiles prepared is shown at all times except when the galvanometer is at its zero position. The displacement indicates the number of missiles prepared.

During an engagement a new section and launcher usually will be designated soon after missile-away. In figure 3, the launcher and section selected signals are indicated immediately after the zero reference, the selection of the launcher and section having been made before the record began. The launcher trace (channel 9) has a 0.1-inch upward displacement from its zero position, which with a scale

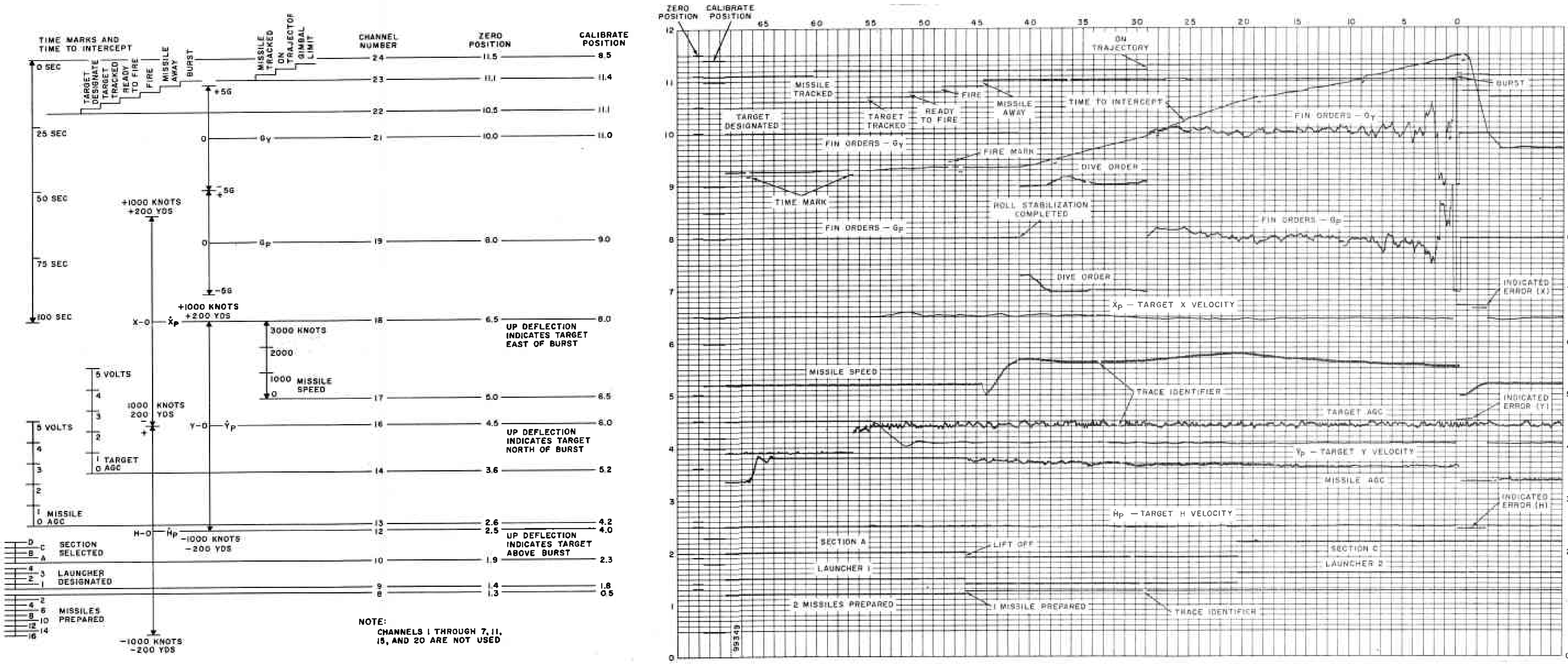

Figure 3. Sample Record of Event Recorder

factor of 0.1 inch per launcher indicates launcher number 1. The section selected trace (channel 10) has 0.1-inch upward displacement from its zero position, which at 0.1 inch per section indicates section A. The missile prepared trace has a downward displacement of 0.1 inch, which with a scale factor of 0.1 per two missiles prepared indicates two missiles are ready. The traces for all three channels remain constant until missile lift-off at 46 seconds before burst, but had the status of any of the functions changed, the traces would have shown the change. At missile lift-off (46 seconds) the section selected and launcher designated traces return to their zero position while the missiles-prepared trace steps up to 0.05 inch indicating that now there is only one missile prepared. At 20.5 seconds before burst a new section is selected. The indicated section and launcher are shown by the trace deflections of 0.2 inch for launcher 2 and 0.3 inch for section C; that is, section C and launcher 2 have been selected.

b. Channels 13 and 14. The channel 13 trace which shows the missile AGC voltage is an indication of the strength of the signal received from the missile. For any single system at a given location, there are characteristic values of missile AGC voltage (1) for an acceptable missile in its launcher, and (2) for no missile at all. These values will vary from system to system and location to location; therefore, voltage values mentioned hereafter in this paragraph and the one below, are only typical values. For automatic acceptance of the missile by the missile tracking radar system, the missile AGC voltage must be greater than three volts for a 3-second period. The missile AGC scale factor is 0.25 volts per 0.1 inch.

Immediately after the calibrate trace is made, the channel 13 trace drops to 0.75 inch above the zero position. This trace position represents 1.87 volts AGC (7.5 x 0.25 volt). This value represents the noise level of the missile AGC and is normally set to 1.5 volts. The missile AGC trace remains at this level until 66 seconds before burst. At this time, it increases to approximately 1.2 inches above the zero position. This represents a missile AGC voltage equal to the 3-volt minimum for automatic acceptance. The missile is accepted (either manually or automatically) after five seconds as indicated by the missile tracked signal on channel 23 at 55.4 seconds before burst. As the missile gets farther from the missile track antenna during flight, the missile AGC voltage decreases gradually as shown in the figure. After burst, the missile AGC voltage drops to 1.87 volts as shown in the figure; and after 0.4 second, the missile antenna will begin to slew to a new missile. While the radar is locking on the new missile, the AGC voltage may fluctuate as shown on the record, until the antenna stabilizes. After the antenna has slewed to a new missile, there is a 3-second time during which the AGC voltage must remain above three volts for automatic acceptance. This can be checked by referring to channel 23 for the missile tracked indication which occurs after three seconds during which time the AGC voltage remains above three volts.

The channel 14 trace shows the target AGC voltage and is an indication of the strength of the signal received from the target. At 56 seconds before burst, the target AGC voltage changes from 0.75 volt to two volts indicating that a target is being tracked. Approximately one second later, the target-tracked signal is received in channel 22. After burst occurs, target AGC remains at 2 volts indicating that a strong signal is still being received from the target.

c. <u>Channels 12, 16, and 18.</u> Channel 12, 16, and 18 traces record the target velocity in H, Y, and X coordinates, respectively, until 0.25 second before burst when these three channels are conditioned to record the indicated error at burst. Since all three channels are similar, only channel 18 (X coordinate) will be discussed in detail. Both positive (up) and negative (down) displacements occur from the zero reference indicating north or south, east or west and up or down respectively.

In the figure, the coordinate velocities are at the zero position until the prelaunch differentiators in the computer are enabled at target tracked. About four seconds time is necessary for the differentiators to settle. The settling of the differentiators begins at target track (55 seconds) and lasts until ready-to-fire (51 seconds). Target tracked and ready-to-fire can be determined from the channel 22 trace. At the ready-to-fire (48 seconds) the target has velocity components in X and Y, but none in H. The traces have a scale of 50 knots per 0.1 inch. The X component is +0.1 inch which represents a 50-knot easterly component. The Y component is -0.4 inch which represents a 200-knots southerly component.

Although the target Y and H velocities remain fairly constant throughout the engagement, the target X velocity, which is 50 knots east at ready-to-fire, begins to decrease. The target X velocity continues to decrease, passes through zero at approximately 32 seconds before burst, and finally settles at 25 knots west (0.05 inch below zero reference) at approximately 24 seconds before burst.

At 0.25 second before burst, the velocity inputs to the event recorder are removed and the indicated error at burst voltages are then applied to these channels. These indicated miss distances do not represent the actual miss distances between target and missile at burst since it cannot be assumed when they are zero that the target has been intercepted. Near zero, miss distances indicate only that the computer has satisfactorily carried out its solution. Large miss distances on the record indicate computer or system malfunction or that the target outmaneuvered the missile. The indicated error traces drift slightly from their original values; therefore, readings should be taken at the leading edge of each trace. The indicated error recorded at burst with a scale factor of 10 yards per 0.1 inch are: X=20 yards east of burst; Y=0 yards; and H=5 yards below burst. An upward deflection of these traces means the target is east, north, or above the indicated burst while a downward deflection means the target is west, south, or below the indicated burst. The total distance can be found by adding the three vectorially for an apparent miss distance of 20.6 yards. The length of the indicated error trace shows the time required for the time-to-intercept servo in the computer to settle for the next engagement. Usually the time required is three to six seconds. When the servo settles, the indicated error is disconnected and target velocities are again plotted. If the target is lost because it was shot down, the target velocity traces indicate the same velocity because coast circuits in the track radar system keep the rates as they were when tracking the target. In figure 3, the indicated error traces last for three seconds while the time-to-intercept servo slews toward a new solution. The indicated error is then disconnected and the target velocities are again recorded.

d. Channel 17. Channel 17 indicates the missile speed in knots during an engagement. Before missile-away, this trace indicates a velocity of approximately 390 knots. This is normal and is due to a bias which the computer applies to the H_M differentiator to cause the climb angle and turn angle servos to remain at zero mils until missile-away. After missile away, this trace drops to zero knots and begins indicating the actual missile speed. At on-trajectory, the missile speed is an approximately 1,300 knots. The missile speed increases to approximately 1,575 knots at 21 seconds before burst and then decreases slowly to a final velocity of approximately 1,100 knots at burst. After burst, the trace goes to zero knots. The trace then goes to and remains at approximately 390 knots until the next engagement.

e. Channels 19 and 21. Channels 19 and 21 are traces of the G_P and G_Y orders respectively which go to the missile tracking radar system from the computer. A positive G_Y order turns the missile upward to the right and a positive G_P order turns the missile upward to the left. Combinations of G_Y and G_P orders can produce turns in any direction. G_Y or G_P orders are not sent to the missile-tracking radar system until roll stabilization is completed; therefore, no orders are shown on the event recorder record before roll stabilization is completed. At missile-away plus 4.2 seconds, roll stabilization is completed and the first steering orders are issued. In figure 3, the time between missile-away in trace 22 and the application of steering orders as indicated by the change from zero in traces 19 and 21 is 4.0 seconds.

After roll stabilization is completed, maximum dive orders are sent to the missile. Traces 19 and 21 beginning at 41 seconds before burst, indicate a -5G G_Y order which is normal, and a -3G G_P order which indicates that the missile is not flying parallel to the gyro plane and is being ordered to turn to the left so that it will be parallel to the gyro plane. For the next 2.5 seconds, the G_P orders increase to -5_G and G_Y remains at -5G. Because of the high rate of the turn and dive, there is some overshoot in the left turn direction. The computer corrects for this overshoot by reducing the orders to the G_Y fins between 38.5 seconds and 34 seconds. This causes the missile to turn right until it is again flying parallel to the gyro plane. When the missile is flying parallel to the gyro plane, both fin orders should remain at -5G until on-trajectory unless order limiting is required because of missile altitude. Checking the corresponding altitude plotting board plot will indicate if order limiting can be expected. The -5G orders continue until on-trajectory for this engagement.

On-trajectory can usually be recognized by the removal of the maximum dive order. In figure 3, on-trajectory occurs at 29 seconds. Steering orders are then sent to the missile on the basis of the time-to-intercept and the distance concerned. After burst the G_Y and G_P orders are disconnected and zero orders are indicated. The zero orders occur on the record at the same time missile tracked and on-trajectory in channel 23 drop out. G_Y and G_P traces will show zero orders until the next missile has been fired and roll stabilized.

f. Channel 22. Channel 22 indicates the time occurrence of functions connected with the engagement. The trace has steps with each step indicating that a function has been completed. The functions listed below with their deflection from zero position are always in the same sequence.

Function	Deflection
Target Designated	0.1 inch
Target Tracked	0.2 inch
Ready-to-Fire	0.3 inch
Fire	0.4 inch
Missile-Away	0.5 inch
Burst	0.6 inch

Target designated, shown at 66 seconds on figure 3, indicates that the target to be tracked has been indicated at the battery control console. When the TARGET TRACKED switch at the target track console is depressed, it indicates that the target track antenna is tracking the target. The target tracked step on the event recorder record occurs at 55.3 seconds. After the computer has settled, provided the missile is being tracked and the target has been designated as a foe, the ready-to-fire step will appear. Ready-to-fire occurs at 51.3 seconds before burst indicating that the computer is ready to receive the fire signal. The fire signal is received at 48.3 seconds before burst. About two seconds after the fire signal, missile lift-off occurs. This time can be determined from the record by the interval between the fire signal in channel 22 and the lfit-off signal which appears in channels 8, 9, or 10. In figure 3, this time is 2.3 seconds.

The missile-away step in channel 22 indicates that the computer has detected the upward motion of the missile track antenna as it follows the missile. The missile-away circuit requires about one second to detect missile lift-off. In figure 3, the time to detect missile-away can be determined by the interval between the lift-off signal in channels 8, 9, or 10 and missile-away in channel 22. The time indicated for this engagement is one second. The burst indication occurs at zero seconds indicating that the burst signal has been sent to the missile from the computer. After burst, computer reset takes place in preparation for another engagement. During computer reset, the target and missile progress signals on channels 22 and 23 drop out in a certain sequence indicating that the associated signals in the computer have been removed.

Approximately 0.4 second after burst, the missile-tracked signal drops out as indicated on channel 23. When the missile-tracked signal drops out, the channel 22 trace drops down three steps indicating that ready-to-fire, fire, and missile-away signals have been removed in preparation for the next engagement. The burst signal remains until the time-to-intercept servo stops slewing. At this time, the burst signal is removed and the channel 22 trace drops down to target tracked. If the DESIGNATE-ABANDON switch is depressed at this time, the channel 22 trace drops down two steps to its zero position and remains there until the next target is designated.

g. Channel 23. Channel 23 indicates the occurrence of missile tracked, on-trajectory, and gimbal limit. Steps are used for the indications with displacements as follows:

Missile tracked	0.1 inch
On-trajectory	0.2 inch
Gimbal limit	0.3 inch

In figure 3, missile-tracked occurs at 60.3 seconds which indicates that the missile AGC was sufficient for automatic acceptance or that the MISSILE TRACKED switch at the missile track console has been depressed. The on-trajectory signal is indicated at 29 seconds. At this time, the missile is on-trajectory to the predicted intercept point. No indication of gimbal limit occurs on figure 3. Had gimbal limit occurred, there would be an additional step above the on-trajectory indication.

h. Channel 24. Channel 24 shows the predicted time-to-intercept during the engagement. As an aid in correlating the event recorder records with horizontal and altitude plots, timing marks and fire marks are superimposed on this trace. These marks occur simultaneously on all three firing records.

The time marks appear as a short displacement downward on the channel 24 trace and the fire mark appears as a short displacement upward. Examination of the time intervals between the time marks on the channel 24 trace reveals that the time marks during this engagement occurred at approximately 9.6-second intervals with one exception. The exception is the 1-second timing mark at 46.5 seconds before burst which occurred about 0.8 second later than it normally would have occurred. This time mark was delayed because the fire mark would normally have occurred.

Before the target tracked signal is received, the time-to-interceptt trace indicates the standby value of approximately 44.5 seconds. After target tracked, the trace indicates the computed prelaunch time to intercept which is approximately 44 seconds. At 46.5 seconds before burst, the fire mark appears on the trace. The predicted time-to-intercept at fire is approximately 43 seconds. During the period between fire and roll stabilization completion, the dead time servo is running down to zero seconds and the predicted time-to-intercept remains fairly constant. Upon completion of roll stabilization, the predicted time-to-intercept servo begins to run down at a second per second rate and continues to run down at this rate until on-trajectory. During this 12-second period, the time-to-intercept runs down from 43 seconds to 31 seconds.

After on-trajectory, the predicted time-to-intercept is continuously corrected on the basis of the latest position and velocity of the target and missile. The channel 24 trace shows these corrections as a change in the rate at which the trace goes to zero second predicted time-to-intercept.

The channel 24 trace reaches zero at burst and approximately 0.5 second later, the time-to-intercept servo begins to slew at the rate of 15 seconds per second to the predicted time-to-intercept for the next engagement. Approximately 2.8 seconds after burst, the servo stops slewing at 15 seconds per second but continues to run down at approximately 4 seconds per second to the correct predicted time-to-intercept for the next engagement. The point at which the time-to-intercept servo stops slewing is also indicated on the indicated error at burst traces (channels 12, 16, and 18) and on the channel 22 trace. At this time, the channel 12, 16, and 18 traces begin plotting the H, Y, and X velocities and the channel 22 trace drops down to target tracked.

2. ANALYSIS OF DYNAMIC TEST RECORDS

2.1 General

The dynamic tracking test consists of two separate checks known as courses 1 and 2. These are checks on various switching operations of the computer. In this test, the computer is supplied with target position data for a fixed target, and missile position and velocity data, to simulate a missile firing. The target data potentiometers are positioned to fixed values to simulate a stationary target at 40,000-yards slant range, 800-mils azimuth, and 300-mils elevation. The missile potentiometers are positioned to fixed initial values, and at the appropriate time, the missile flight is simulated by insertion of a range rate into the missile range unit positioning systems. The fire order is then given by operating the FIRE switch on the battery control console. At that time, to simulate the flight of the missile, the missile-tracking radar operator changes from manual tracking to aided tracking and sets in a uniform tracking rate.

<u>Course 1</u>: From an initial setting of 0 range, 800-mils azimuth, and 1600-mils elevation, the simulated missile flies straight up to an altitude in excess of 50,000 feet. This course checks the following circuits: signaling circuits; 4-second computer settled timer; missile-away circuit; 4.5-second timer; proper dead time rundown; time servo sec/sec circuit; and order limiting circuit.

<u>Course 2</u>: From the initial setting of 0 range, 800-mils azimuth, and 300-mils elevation, the missile flies directly toward the stationary target. This course permits checking the on-trajectory and burst order circuits.

The first course simulates the first stages of missile flight. However, the 7g dive is not simulated, and on-trajectory and all subsequent events do not occur. These events do occur in the second course. During course 2, the simulated missile is always directed at the target, and the missile will be on-trajectory as roll stabilization occurs.

2.2 Preliminary Procedure

The event recorder is energized during the preliminary procedure and remains energized throughout courses 1 and 2. Processed event recorder records should be compared with the sample event recorder record included as figures 4, 5, and 6. These same records may be used to verify that all events occurred in the correct sequence during the computer dynamic tests.

Figure 4 is a sample dynamic test record made during the preliminary procedure. During that portion of the dynamic test the BURST switch was operated and held for approximately two minutes and the resulting X, Y, and H indicated error bias voltages (channels 18, 16, and 12, respectively) were monitored by the

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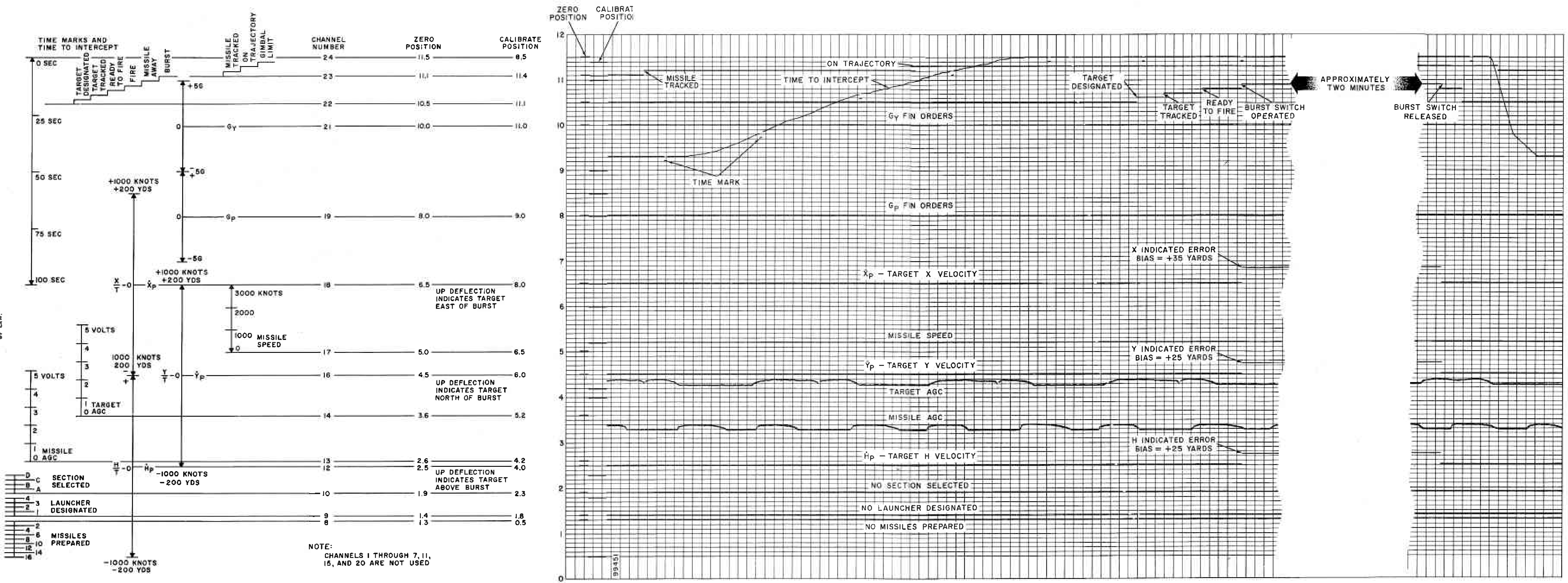

Figure 4. Event Recorder - Sample Dynamic Test Record, Preliminary Procedure

event recorder. The X indicated error bias equals +35 yards, the Y indicated error bias equals +25 yards, and the H indicated error bias equals +25 yards. Since both missile and target range position potentiometers are set to zero yards during that portion of the dynamic test, the actual X, Y, and H errors should be zero. Therefore, the bias values X = +35, Y = +25, H = +25 represent the fixed errors for this particular system. This error is present in the indicated error at burst circuitry and will vary within any one system from day to day. The use of the X, Y, and H indicated error bias values is indicated in the discussion below.

2.3 Test Records

a. <u>Course 1</u>. Figure 5 shows a sample dynamic test record made during first run portion of course 1. This sample dynamic test record is also typical of records obtained during the second or third run of course 1. Channels 19 and 21, fin orders G_Y and G_P, are of particular interest. At roll stabilization completed, the G_Y fin orders becom +4.0G and the G_P fin orders become -5.5G. These orders continue until the altitude of the simulated missile reaches 30,000 feet at which time the order limiting circuits begin to function to reduce the magnitude of the fin orders. When the missile reaches 50,000 feet, the G_Y fin orders should have been reduced to approximately +2.5G and the G_P fin orders to approximately -2.5G.

At an altitude of 50,000 feet or more, the rate of fin order reduction due to order limiting is decreased. This reduction is indicated in figure 5 by the change in slope of the G_Y and G_P fin order traces at the point marked "order limiting (alt. 50,000 feet)." The G_Y and G_P fin orders will continue to be reduced at this new rate until the IFF - FRIEND switch on the battery control console is depressed at the end of the test.

It should be noted that the G_Y and G_P fin orders on figure 5 are of opposite polarity, indicating that the simulated missile is being ordered to turn. In this case, the direction of turn is toward the right. Since the computer does not receive a response from its turn orders, the turn order is maintained throughout the simulated missile flight. The normal indication for channels 19 and 21 would be fin orders with a magnitude of approximately 5G. The fin orders may be of opposite polarity, indicating that a left or right turn is being ordered, or both orders may be negative, indicating that the missile is being ordered to dive. There are no requirements as to the degree of slope or length of the trace between changes.

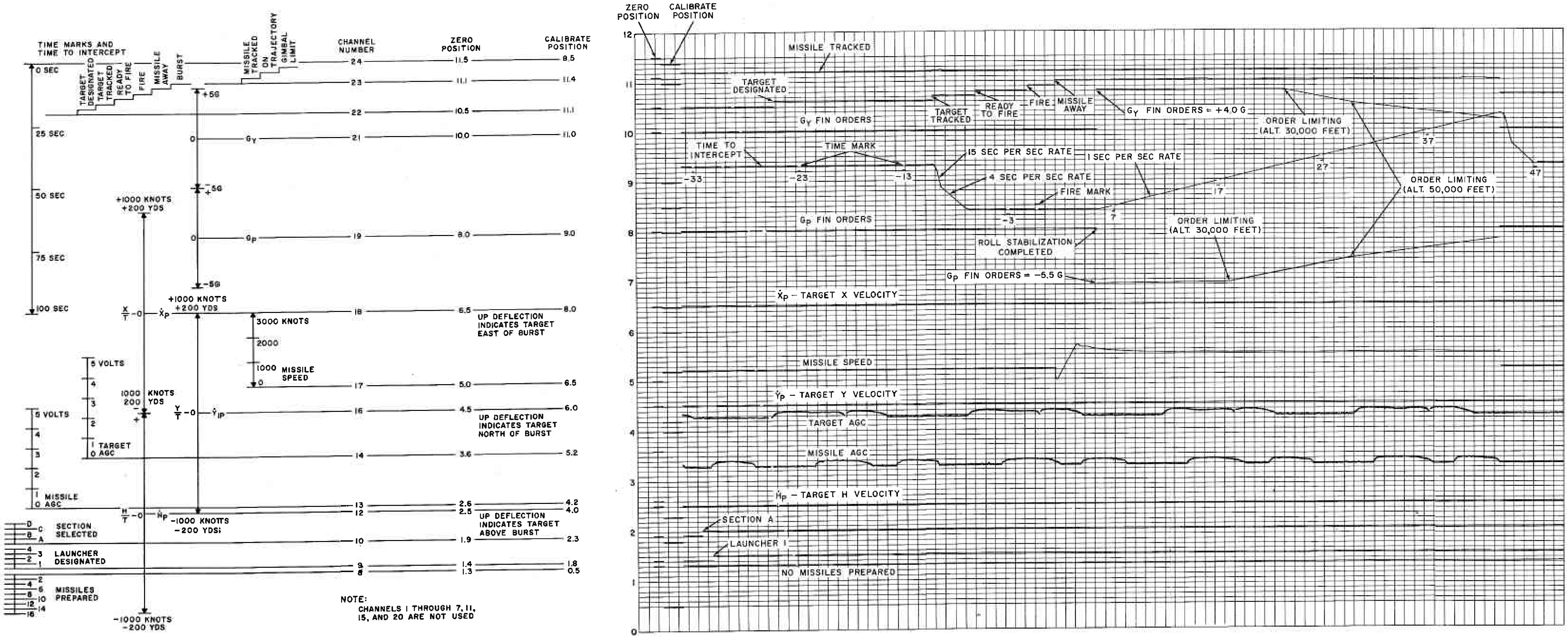

Figure 5. Event Recorder - Sample Dynamic Test Record, Course 1

The requirements are that the event recorder ZERO switch be manually operated at 30,000 and 50,000 feet of range and the slope of the G_Y - G_P orders should change within ±1 second of the time the specified range is reached. The operation of the ZERO switch has no effect on the order limiting, but is an indication of when the limiting should begin. The change in slope of the two orders will not be at exactly the same time, but should be within one second of each other. The requirements are the same for both check points, 30,000 and 50,000 feet. In addition, at 50,000 feet the orders should be 2.5G in both channels. There is no requirement on the orders decreasing to zero; therefore, the test may be terminated as soon after 50,000 feet or as soon as the slope of the orders can be determined.

b. Course 2. Figure 6 shows a data recorder record made during course 2. The G_Y and G_P fin orders traces (channels 19 and 21) should be analyzed along with the X, Y, and H indicated error traces (channels 12, 16, and 18). After "roll stabilization completed", the G_Y and G_P fin orders each go to approximately -5G and remain there for about one-half second. In this case, the G_Y fin order registered -4.7G, and the G_P fin order registered -4.8G. At this time on-trajectory occurs and the G_Y and G_P fin orders each go to +1G and remain there until the time-to-intercept equals 10 seconds. When time-to-intercept equals 10 seconds, the 1/2-G climb bias is removed and a slight discontinuity occurs in the fin orders' traces. The G_Y and G_P fin orders continue to increase in magnitude as the time-to-intercept approaches zero until at burst the magnitude of the G_Y and G_P fin orders each equals 5G.

The X, Y, and H indicated error traces occur after burst (fig. 6). The initial X indicated error reading (channel 18) is +9 yards. The trace then drifts towards +35 yards which is the fixed error bias (fig. 4) for this system. To solve for the actual error in each coordinate, algebraically subtract the fixed error bias from the initial indicated error as indicated below:

1. For the X coordinate (fig. 6) the values obtained during this test are as during this test are as follows:

   Initial indicated error = +9 yds

   Fixed error bias = +35 yds

   Actual error = (+9) - (+35) = -26 yds

   Actual error for the Y coordinate = (+2) - (+25) = -23 yds

   Actual error for the H coordinate = (+10) - (+25) = -15 yds

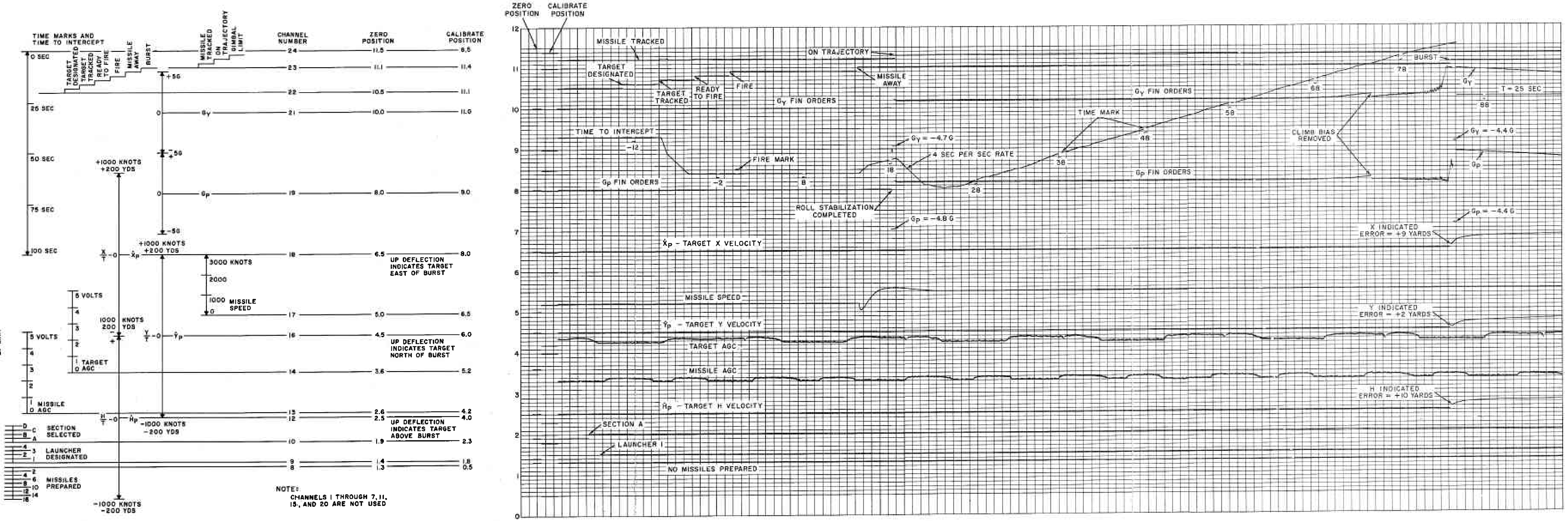

Figure 6. Event Recorder - Sample Dynamic Test Record, Course 2

2. Compare the data recorder record obtained during computer sequence dynamic tests with the sample records shown on figures 4, 5, and 6 and note any abnormal indications.

3. DUAL TRACKING TEST RECORDS

The dual or dynamic tracking test provides a good check of the over-all operation of the systems. It is particularly useful for checking the sensitivity of the two tracking radar receivers, the boresight of the radars, the collimation of the radars and the radar tracking smoothness while simultaneously tracking the same target.

The amount of position difference to be expected during a simultaneous tracking test is contingent on the different environmental factors existing at each site and on the reflectivity characteristics of the targets being tracked. In addition, the altitude of the target with respect to the surrounding terrain, its course, altitude, and maneuvers influence the position difference readings. Consequently, it is virtually impossible to predict and specify limits that will be applicable to all equipments considering all the variables of target parameters and location environment.

The following broad criteria are recommended for the conduct of a tracking test:

1. The elevation angle should be greater than 70 mils.
2. If at all possible, the target being tracked should be controlled, either directly or by means of a specified flight plan.
3. The target should be tracked in all four azimuth quadrants.
4. The target should have a radar cross-section of a minimum of 10 square meters. If the tracking tests are conducted at Red Canyon or McGregor Ranges, the target will likely be a Radio Controlled Aerial Target (RCAT) with a reflecting surface that is something less than ideal.
5. The target should fly two complete nearly identical patterns. This will permit a cross reference between patterns if difficulty is experienced at any particular point in a single pattern.

6. Correlation should be maintained throughout the test between the event recorder record and the horizontal plotting board plot.

Upon completion of the test, the event recorder record should be analyzed for generally smooth tracking throughout the test. There should be no indication of erratic tracking or wide excursions. In the event apparent inconsistencies exist, a careful analysis of the record should be made to determine the cause. The following guides should be helpful:

1. Potentiometer discontinuities, "bats", will show up as an erratic deflection to one side of the trace. They are usually preceded and followed by smooth position difference traces.

2. Azimuth boresight error, due either to poor individual antenna boresight or poor collimation, will appear as a cyclic error with the X and Y coordinate position difference traces varying from a minimum to a maximum at adjacent quadrant crossover points. When X is a minimum, Y should be a maximum and vice versa.

3. Elevation boresight error, due either to poor individual antenna boresight or poor elevation collimation, will be shown as a roughly constant deflection, to one side of the zero trace position, in the H coordinate.

4. If the position difference is excessive at any particular combination of range and azimuth, examine the record and the plots to determine if the same effect was present during both patterns. If it was, it is an indication of some obstruction, either natural or artificial. Power lines, buildings, hills, or mountains may cause the excessive position difference. Also, excessive position difference is often experienced when one of the antennas is tracking over tops of the battery and/or radar control trailers.

5. Noisy or erratic tracking at the longer ranges will indicate either interference from adjacent radars or poor receiver sensitivity in one of the radars. A correlation with observed noise or interference indications on the tracking indicators during the test should determine which was the cause.

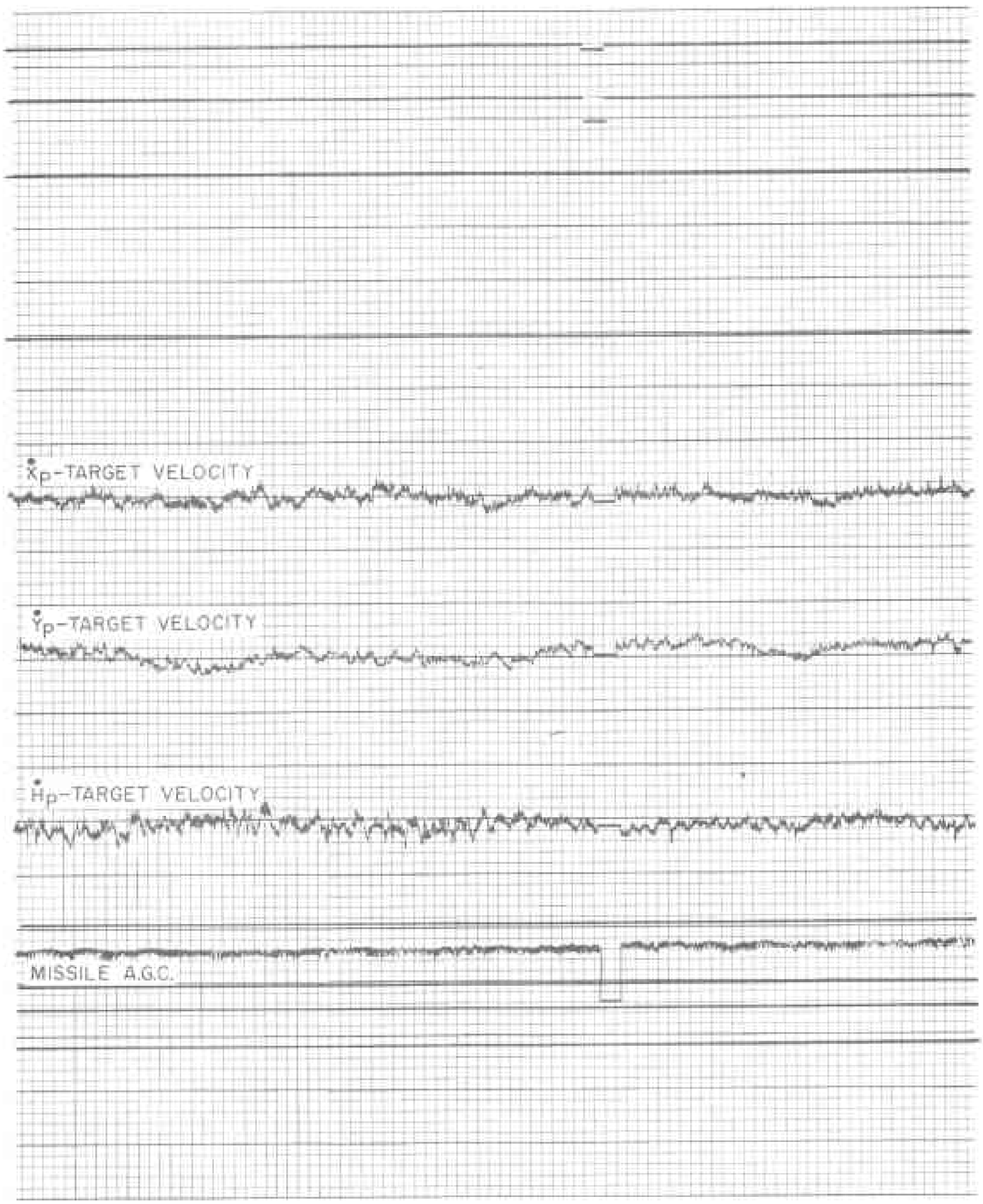

Figure 7. Sample Record, Good Dual Tracking Test

It should be emphasized that the conditions given and the results expected are general in nature and will not necessarily apply in all cases. Considerable judgment must be exercised in the determination of a successful or unsuccessful flight test. It should also be pointed out that experience gained through periodic flight tests, conducted with similar targets flying similar courses,will provide the best criteria by which to judge a system's performance over a period of time.

Figure 7 presents an example of a good dual tracking test. Actually, the only traces we are interested in are the X_T, Y_T, and H_T, and missile AGC. These traces indicate the position difference between the two tracking radars when they are tracking the same target. The target and missile progress traces are at the tracked position and the missile AGC is at maximum level, indicating a good signal from the missile beacon; the other traces, excepting target X, Y, and H are at the zero position. It is to be noted that X, Y, and H variations are of relatively low amplitude. This low amplitude is a good indication of smooth radar tracking.

Figure 8 presents the results of a poor tracking test. Note the high amplitude of the X, Y, and H traces. These wide variations indicate that one or both of the radar receivers have low sensitivity. However, since the missile AGC trace appears at about normal level, it is probably the target radar receiver which has the low sensitivity. In addition, the average of the variations are quite a bit off the zero line, especially the X_T trace. This indicates that the boresight of one antenna or the collimation between the two is not properly adjusted.

A secondary purpose of the simultaneous tracking test is to check for discontinuities (bats) in the data potentiometers. This check will be discussed in section 4 below.

4. ANALYSES OF ERRATIC OR PECULIAR TRACES

Since the number of missiles to be fired for battery training is limited, the event recorder's permanent record of events during an engagement may indicate a human weakness or an equipment malfunction, which would otherwise be difficult to detect. The record can also be used to evaluate the combat effectiveness and to improve the tactical use of the Ajax system. In this section, event records from

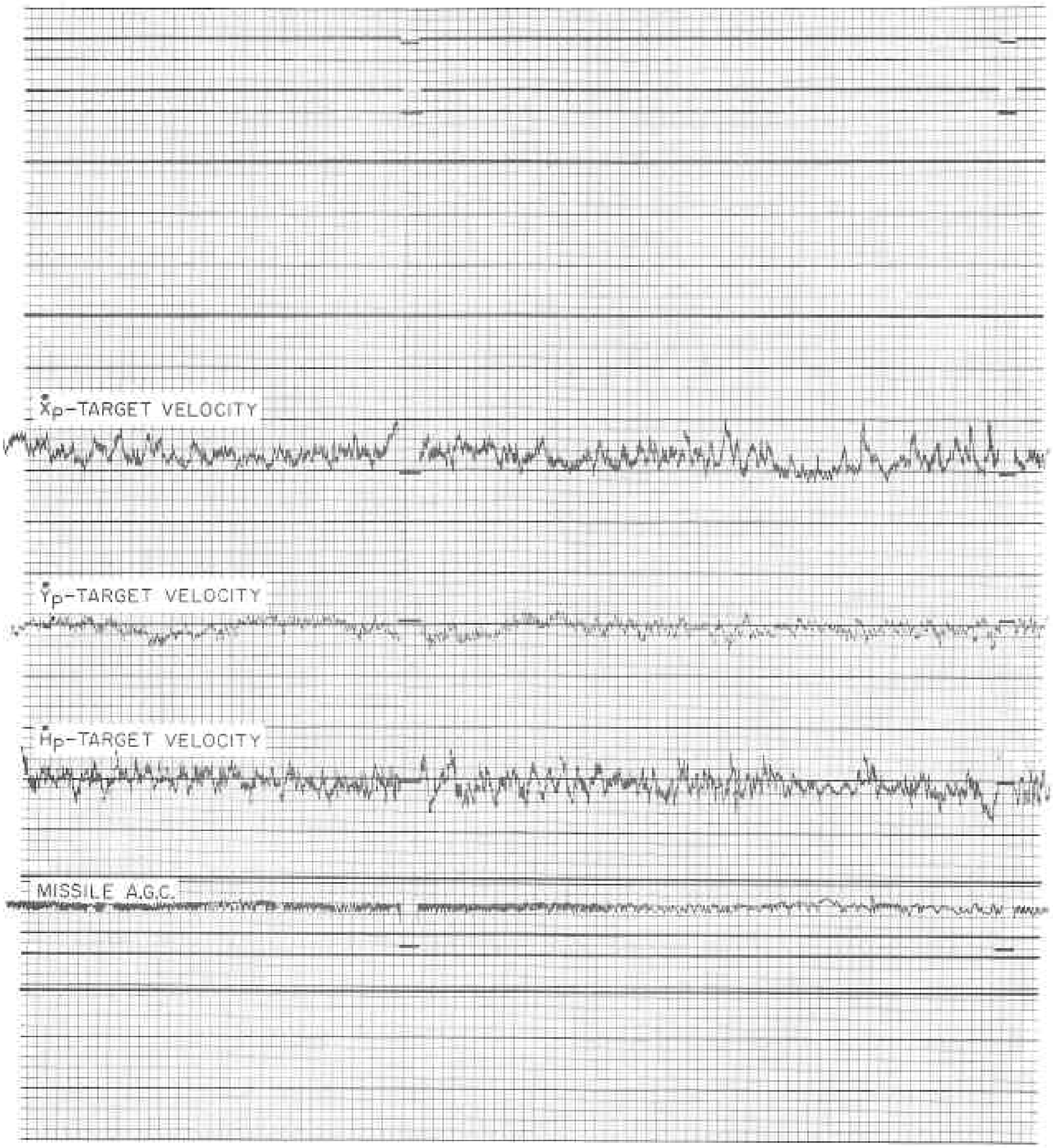

Figure 8. Sample Record, Poor Dual Tracking Test

engagements at Red Canyon Range which denote erratic or peculiar traces and/or aborted missile flights will be analyzed.

4.1 Missile Motor Malfunctions

Motor difficulties are usually listed under two general classifications, no start and delayed start. Figure 9 presents a record of a no start. Notice that all traces are normal up to approximately 100 seconds except for the missile velocities. X, Y, and H all show a decrease once the effect of boost ends. The peak of all three is at about 15 seconds, and the total velocity is very low. With a normal motor burn, the velocity should peak between 25 and 28 seconds; at this time, the motor ceases to operate and this point is known as "motor burn out". The missile is flying slow and takes much longer to reach intercept, if it is possible to do so. In the example, intercept was not achieved. By launch plus 100 seconds, the missile was below the target and the G_Y - G_P orders were calling for a climb which the missile could not accomplish. At about 101 seconds, the velocities were so low that the missile became unstable; and 13 seconds later the MANUAL BURST switch was operated, destroying the missile.

It is possible with a no start to achieve a successful intercept by diving the target to the missile; however, it is doubtful that unfriendly aircraft would cooperate in this.

Figure 10 is a record from a delayed motor start. This entire flight was normal except for the missile velocity traces. By plotting the resultant of X, Y, and H on a graph, such as figure 11, it can be seen that the motor did not start until launch plus 15 seconds and burned only until launch plus 37.5 seconds.

The graph of figure 11, which shows speed in knots versus time from launch, was developed from the results obtained from a considerable number of flights. The two lower dotted lines represent the area into which a no-motor-start plot would fall, and the upper dotted lines represent the area into which a normal motor burn would fall. Any plot, such as the one from figure 10, that is between these two areas would represent a short burn or delayed start.

Motor burn out (the peak of the delayed start plot) indicates that this motor had a longer period of operation than is usual. The normal peak of velocity is a little over 1500 knots for an operating time of approximately 21 seconds whereas this missile reached 1700 knots, indicating a slightly longer operating time.

Figure 9. Record of Missile No Start

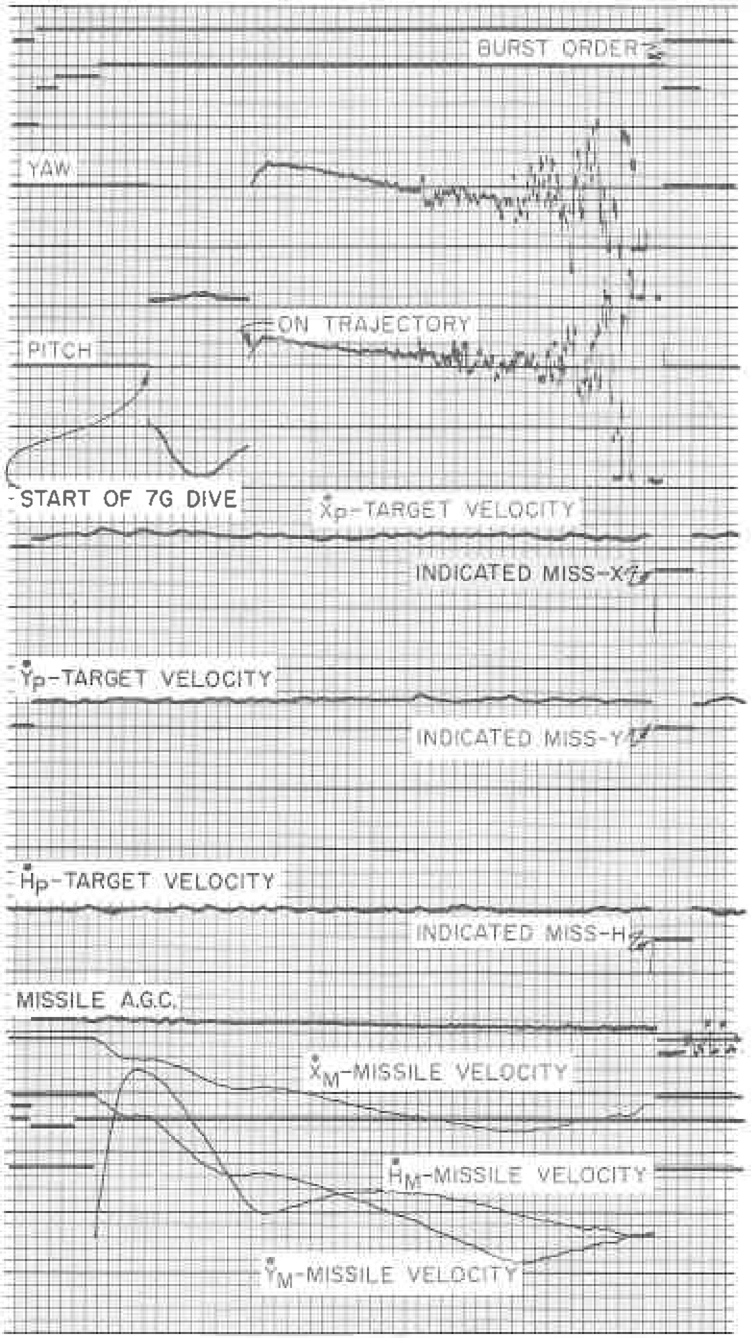

Figure 10. Record of Missile Delayed Motor Start

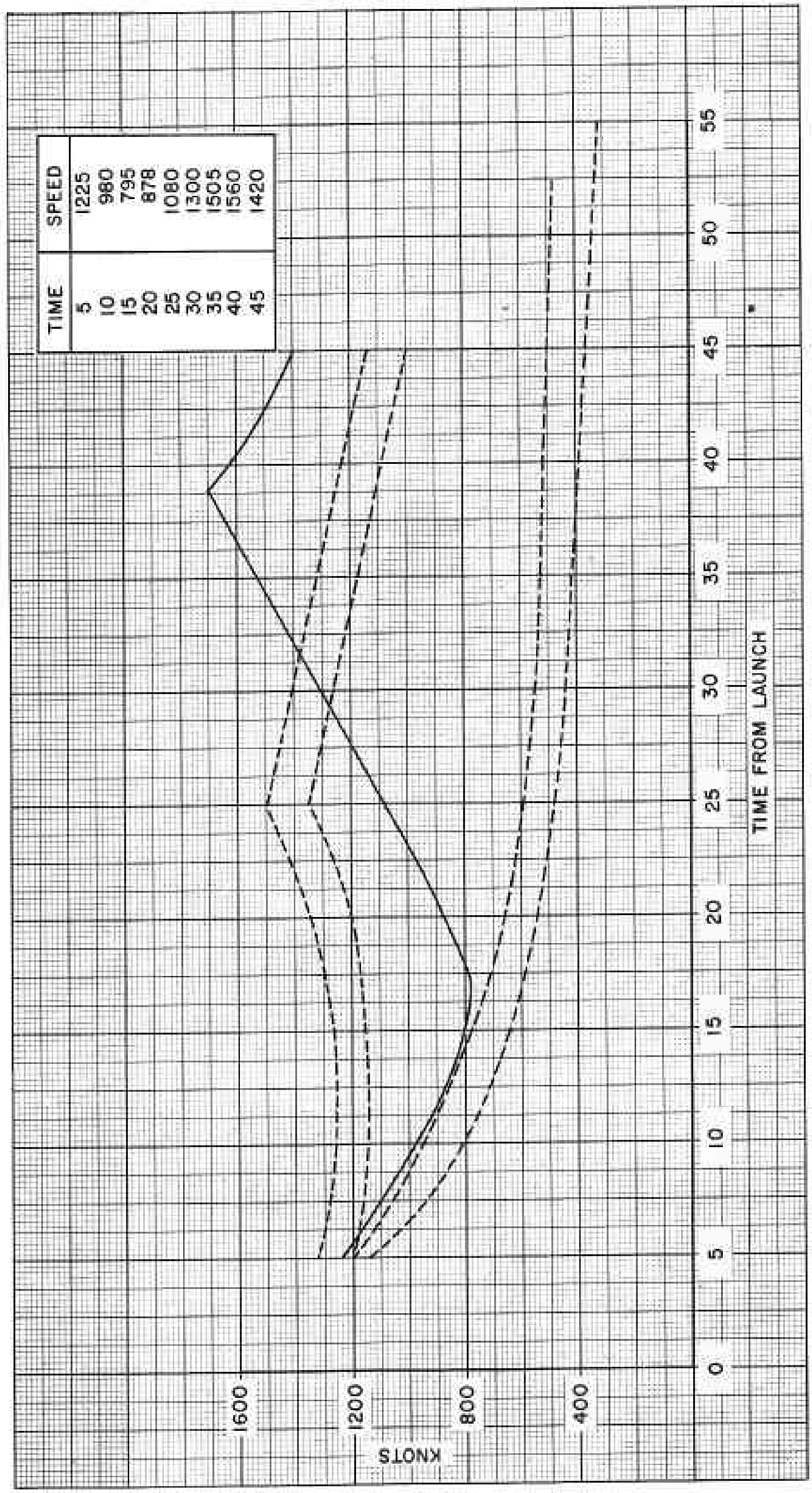

Figure 11. Graph of Speed in Knots Versus Time from Launch

4.2 Missile Breakup

In a breakup all traces except the G_Y and G_P orders, the missile velocities, and the missile AGC will appear normal and follow the same pattern as they do in a successful flight.

On the record in figure 12, the flight is normal up to launch plus 27 seconds. At this time, the missile X and Y velocities fall rapidly to zero. The H velocity shows a slow increase in a negative direction, indicating that the missile is falling. Also, at launch plus 27 seconds, the missile AGC shows a lesser amplitude and becomes cyclic. This is an indication that the guidance section of the missile is tumbling end over end as the missile tracking radar tracks it to earth. During the time the missile is falling, the computer is trying to correct for the fall by issuing G_Y and G_P climb orders. These orders show more and more of an increase until approximately launch plus 54 seconds; the full 5G order is indicated and is continued to the end of the flight.

Note that a burst order was issued; but by checking the missile AGC trace against the missile velocity traces, they terminate simultaneously. This denotes that no burst occurred. The no burst is a sure indication of a breakup. If the missile tumbles but does not break, burst will occur when ordered. When the missile breaks, the pyrotechnic chain is destroyed and burst cannout occur.

4.3 Missile No Burst

Refer to figure 12. This missile did not burst. If burst occurs at the time the order is issued, the missile AGC trace should end at the beginning of the burst order. Since the missile beacon is destroyed by the burst, the beacon is lost immediately and the missile AGC trace goes to zero before the burst order ends. The burst order is only 300 milliseconds and it is difficult to check as the two traces are widely separated. The easiest check on burst is to compare the missile AGC trace to the missile velocity traces. If burst occurs, the AGC trace should drop to zero approximately 300 milliseconds before the missile velocity traces. If these four traces end simultaneously, burst did not occur when ordered by the computer.

It should be emphasized that it is not necessary for the missile to break up for no burst to occur. This example was used only to point out the evidence of such a malfunction. Some missiles do not burst even when the flight is normal.

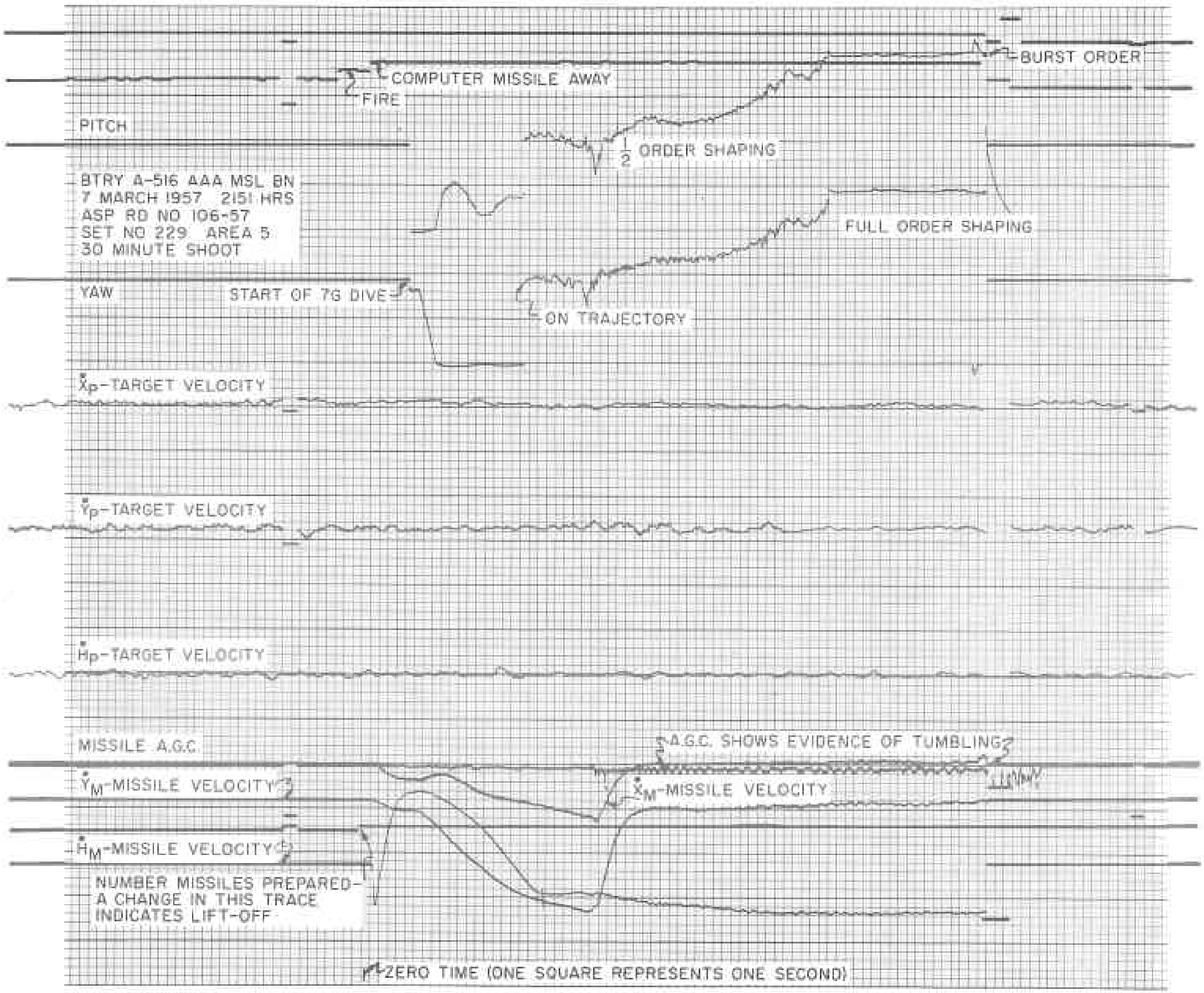

Figure 12. Record of Missile No Burst

When this occurs, the malfunction is shown as "burst hold-off". Burst hold-off is usually confirmed by data from the event recorder once it is suspected by visual observation. The event recorder indicates the time of ordered burst (by the computer) with a very distinct mark on the record. Burst hold-off or no-burst is detected by measuring the time between the ordered burst and the loss of missile AGC. If, instead of dropping to zero, the missile AGC trace continues to show a signal return from the missile for at least 0.3 seconds after the burst order, it is reasonable to assume that the burst order was not properly passed through the guidance section, particularly if fail-safe occurs later. Normally G_Y and G_P orders are removed when a command burst order is sent to the missile. However, the noise level in the G_Y and G_P channel may be sufficient to hold off burst. The noise in the command channels can be picked up from an external source to hold off burst. It is also possible for self-induced noise to be present in the guidance section. Burst hold-off at Red Canyon Range could be due to noise induced in the missile by multiple tracking radars. The multiple tracking problem has been a subject of a study by the contractor earlier in the Nike program.

4.4 Missile Tumble

Figure 12 is a record from breakup; however, the record of a tumble would be almost identical except that the drop of the missile velocities to zero may not be so abrupt. Breakup is caused by the missile executing so violent a maneuver that the air frame cannot withstand the strain. A tumble may be caused by a missile maneuver (such as climb) that slows the missile to less than the speed necessary to maintain flight, but which does not change direction at a rate that will destroy the structure of the missile. The change in missile velocities may not vary a great deal between breakup and tumble, so this is not a definite distinction. The one definite factor that distinguishes the two malfunctions is the response to the burst order. In a tumble, the missile remains intact, it can and does burst when ordered to do so; whereas a missile that breaks up cannot respond to burst.

Another example of missile tumble is presented in figure 13. The sequence of events through missile-away is in the proper order. Just prior to the 7G dive order, the sine wave in the missile AGC trace indicated that the missile began to tumble. Note the cyclic variation in the trace (1). The computer because of the changing position of the tumbling missile was unable to determine a proper order

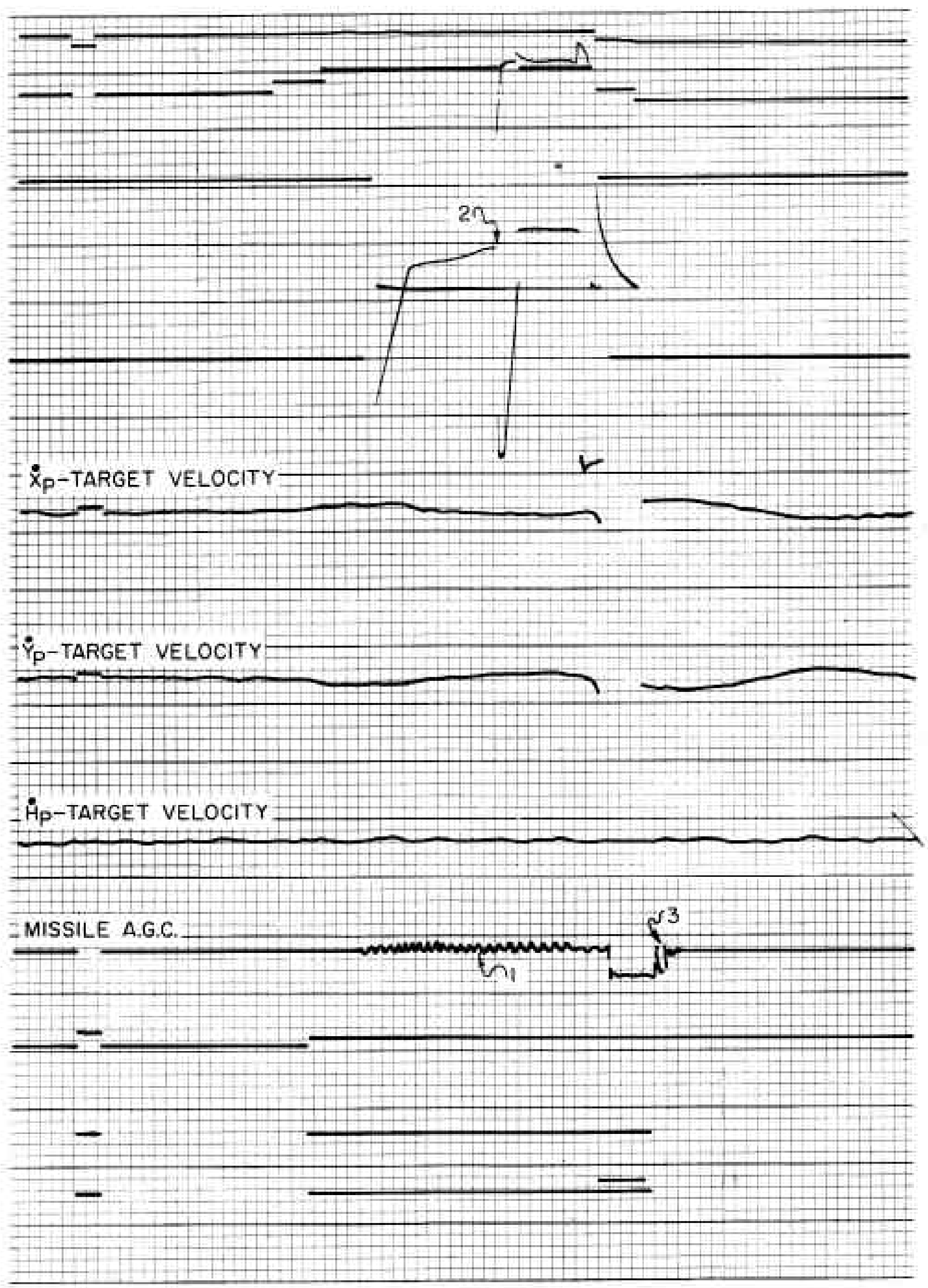

Figure 13. Record of Unsuccessful Flight Caused by Missile Tumbling

to send to the missile (2). The sharp drop and rise in the missile AGC trace (3) is a common oscillation that occurs when the missile tracking radar slews to the test responder.

4.5 Missile Spiral or Roll

The spiral is caused by roll stabilization being lost shortly after launch which results in the missile spiraling straight up. The roll is the result of losing roll stabilization after the 5G dive is completed and the missile is in horizontal flight. The cause for both is the same, differing only in the time at which it occurs. Figure 14 presents a record of a missile that spiraled and went straight up. Note the G_Y and G_P orders (1). The length of the 7G dive order trace indicates that the missile did not respond. At (2), the missile reached an altitude of 30,000 feet, and order limiting is shown on the -5G G_Y order; since the G_P order is only -2G, it is not yet affected. At (2A), the rate of order limiting on the G_Y fin decreases. The G_P order is still less than the maximum limit for this altitude. This change in order limiting rate occurs at 50,000 feet. At (3), limiting occurs on the G_P order and both G_Y and G_P are limited until (3A). At this time, the 7G dive order has been limited to zero. The missile continued until it reached about 98,000 feet where the manual burst was ordered. The missile AGC trace (4) is erratic through the entire flight. The oscillations, resembling the normal boost phase noise, could have been caused by the aspect of the missile antennas during vertical flight. The missile tracking radar slewed back to the test responder (5), but the test responder probably was turned off. This would explain the oscillation after burst.

4.6 Excessive Indicated Miss Distance

Figure 15 presents a record of an unsuccessful engagement resulting from excessive miss distance.

The 7G dive order, on-trajectory timing, and steering orders (1) appear normal. The rough tracking in X, Y, and H velocity (2) is very noticeable; however, negative pips in X show up as positive pips in Y, indicating that the target made a violent movement, probably caused by a sudden gust of wind. Note that in the G_Y and G_P channels (3), the last order sent to the missile was a +5G G_Y and a -5G G_P, which sums up vectorially to a 7G right turn. The indicated miss distance

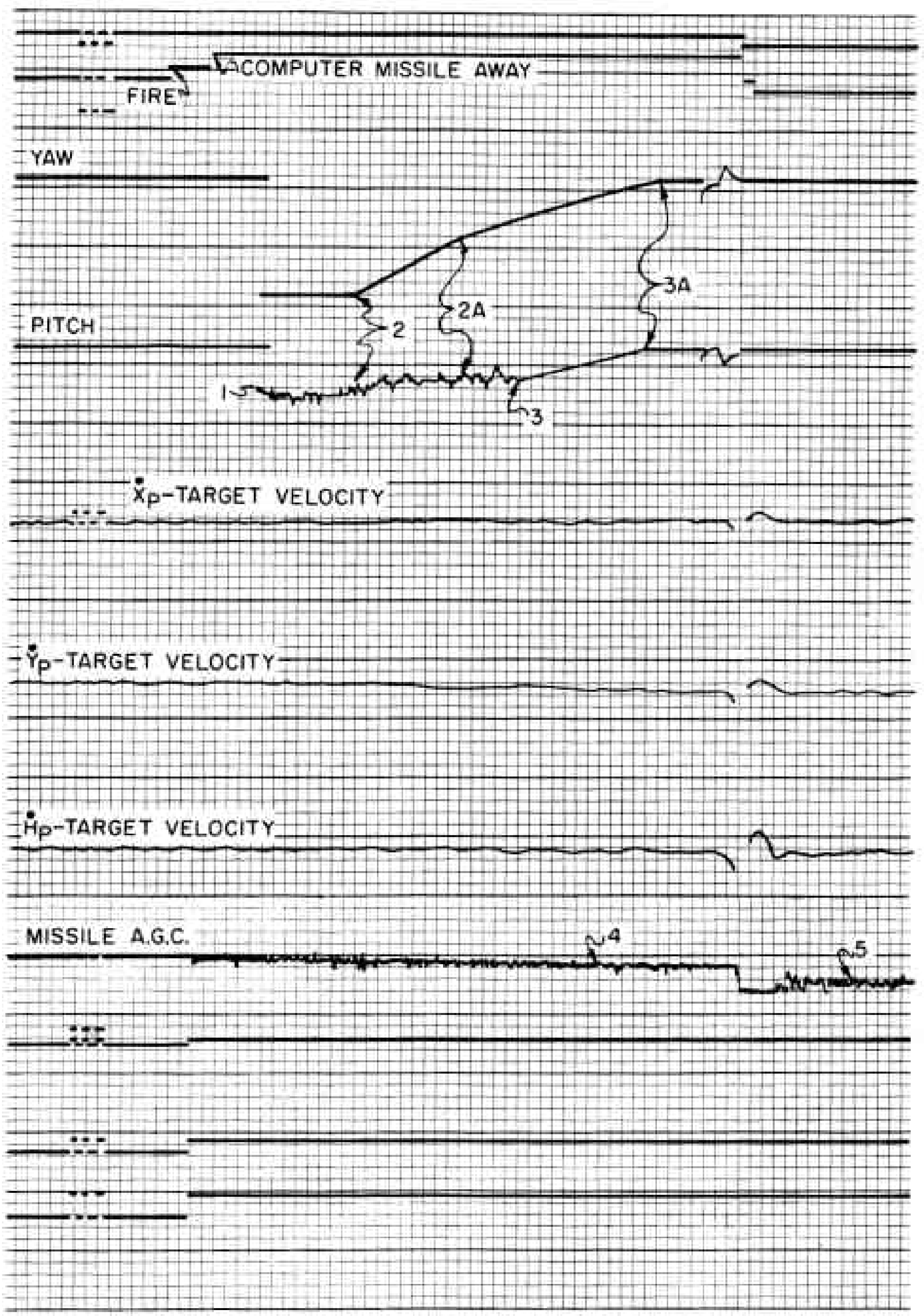

Figure 14. Record of Unsuccessful Flight Caused by Missile Spiraling Upward

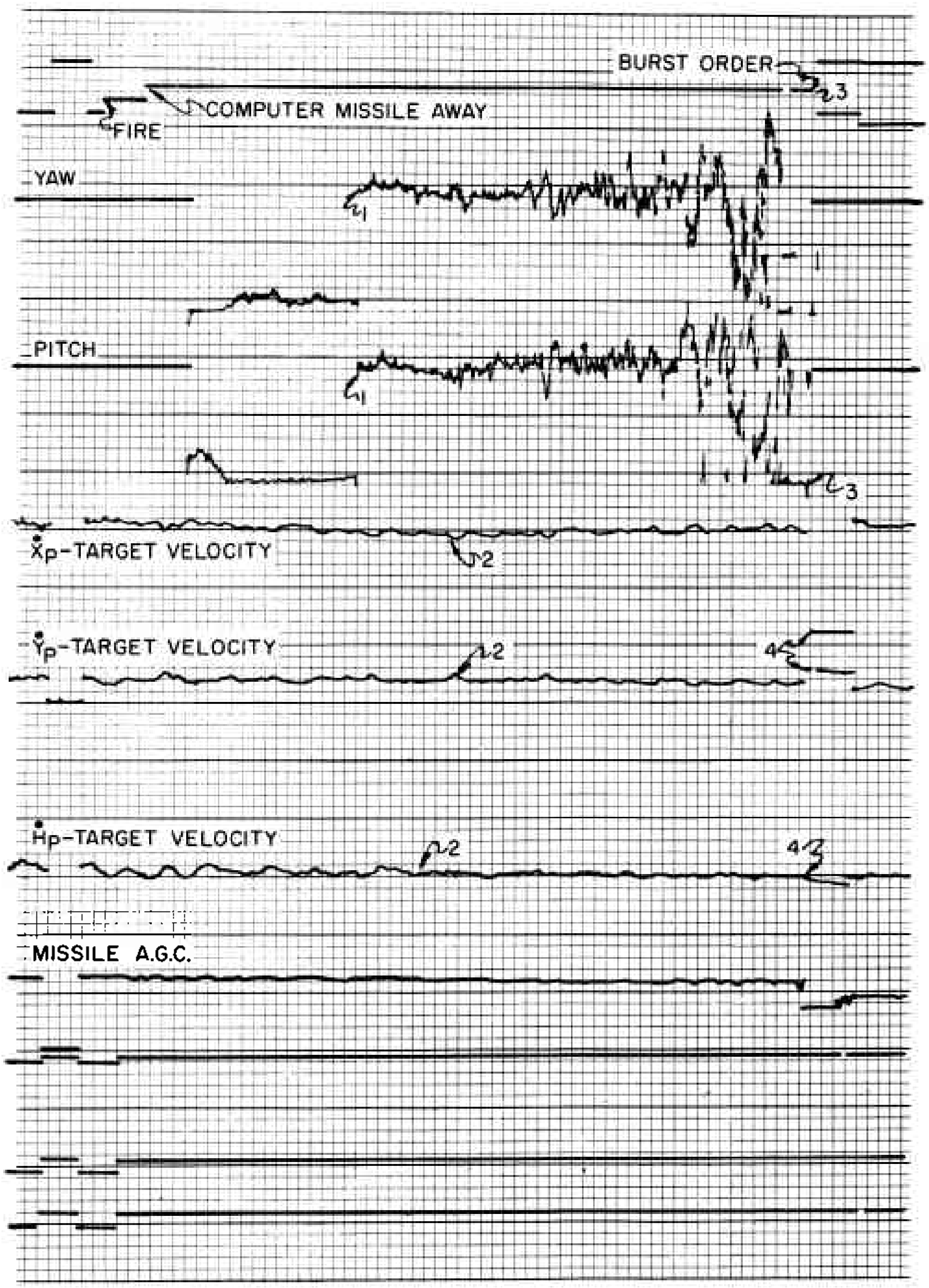

Figure 15. Record of Unsuccessful Flight Caused by Excessive Miss Distance

is measured from the leading edge of the waveforms (4) to the zero trace. Each grid line on this figure represents 10 yards, thus, the distance from the missile to the target X, Y, and H is: X = -81, Y = +33, and H = -1. The radial miss is:

$$\sqrt{(X)^2 + (Y)^2 + (H)^2} \text{ or}$$

$$\sqrt{(-81)^2 + (33)^2 + (-1)^2} = \sqrt{7651}$$

$$= 87.5 \text{ yards}$$

A few misses are a result of the circuits used to record the miss distance. The printed miss indication represents a charge on a capacitor that is collected in the last 0.25 second of the missile flight. A small but rapid change in one of the target velocities in the last 0.25 second will build up a charge on the capacitor in that channel of such magnitude that the indicated miss exceeds the actual miss. When this occurs, one or more of the target velocities will show a short, rapid change that was not completed due to the transfer from target velocity to the indicated miss circuits.

There are some excessive indicated misses that are a result of a malfunction, such as no-response of the missile to orders in end game. In fact, the no-response accounts for the greater part of excessive misses. There are a number of causes for this malfunction. Some missiles expend all of their hydraulic oil before intercept; others fail to respond due to electrical difficulties. The indication of no-response is that one or more of the missile velocity traces show a slow, steady decrease with no change during end game. It is possible that these traces may show very little change and there is no difficulty; however, if there is an indication in the G_Y and G_P orders that a maneuver was called for in end game and the missile shows little or no response to the order, then a malfunction likely did occur.

Very few missile flights result in excessive miss distance without any cause. Some missiles tumble or break up just before intercept. The evidence of these is not as easily interpreted as one that occurred earlier; however, by careful analysis of the G_Y and G_P orders and the missile velocity traces, the cause of an excessive miss can usually be determined.

4.7 Lost Beacon

See figure 16. All action is normal until launch plus three seconds (1). At launch plus 3 seconds, the missile AGC drops to zero, and the missile velocities go awry. After launch plus 3 seconds, the missile velocities have no real meaning. The missile tracking radar antenna is coasting, and may go in any direction. Note that the G_Y and G_P orders did start but were chopped off when "missile tracked" was lost.

Some of the reasons for a lost beacon may be:

1. Failure of missile internal (battery) power.
2. Failure due to electrical trouble in the missile.
3. Misadjustment of missile tracking radar AGC.
4. Misadjustment of missile tracking radar AFC.
5. Misadjustment of the missile range unit (MTR) such as the range zero or slope adjustment.
6. Misadjustment of code spacing.
7. Low sensitivity in the MTR azimuth or elevation channel.

In the case of figure 16, an eye witness in the radar van reported that the MTR range notch jumped 2000 yards shortly after the missile was launched. This evidence pointed to a maladjustment of the MTR range unit SLOPE control, and the failure was charged to this.

With a few exceptions, the cause of a lost beacon within the early part of a flight is usually due to difficulty in the missile tracking radar rather than in the missile. Experience at Red Canyon Range Camp has indicated that beacons lost within the first ten or twelve seconds are a result of radar misadjustments, and those that are lost later in flight are the result of missile malfunctions.

One type of lost beacon that may be analyzed easily is the one that is lost at launch. The tape for this will have no missile velocities, indicating that the MTR antenna did not move when the missile was launched. There are two reasons for this happening: (1) the MTR may be locked on a reflection of the missile beacon, and (2) missile internal power is lost at launch. The first reason is usually correct since internal power is checked at the Launcher Operating Position (LOP) before launch.

All available evidence should be carefully considered when trying to determine the cause of a malfunction. This is particularly true for lost beacons, since the event record tape shows only that it was lost, but gives very little evidence as to why.

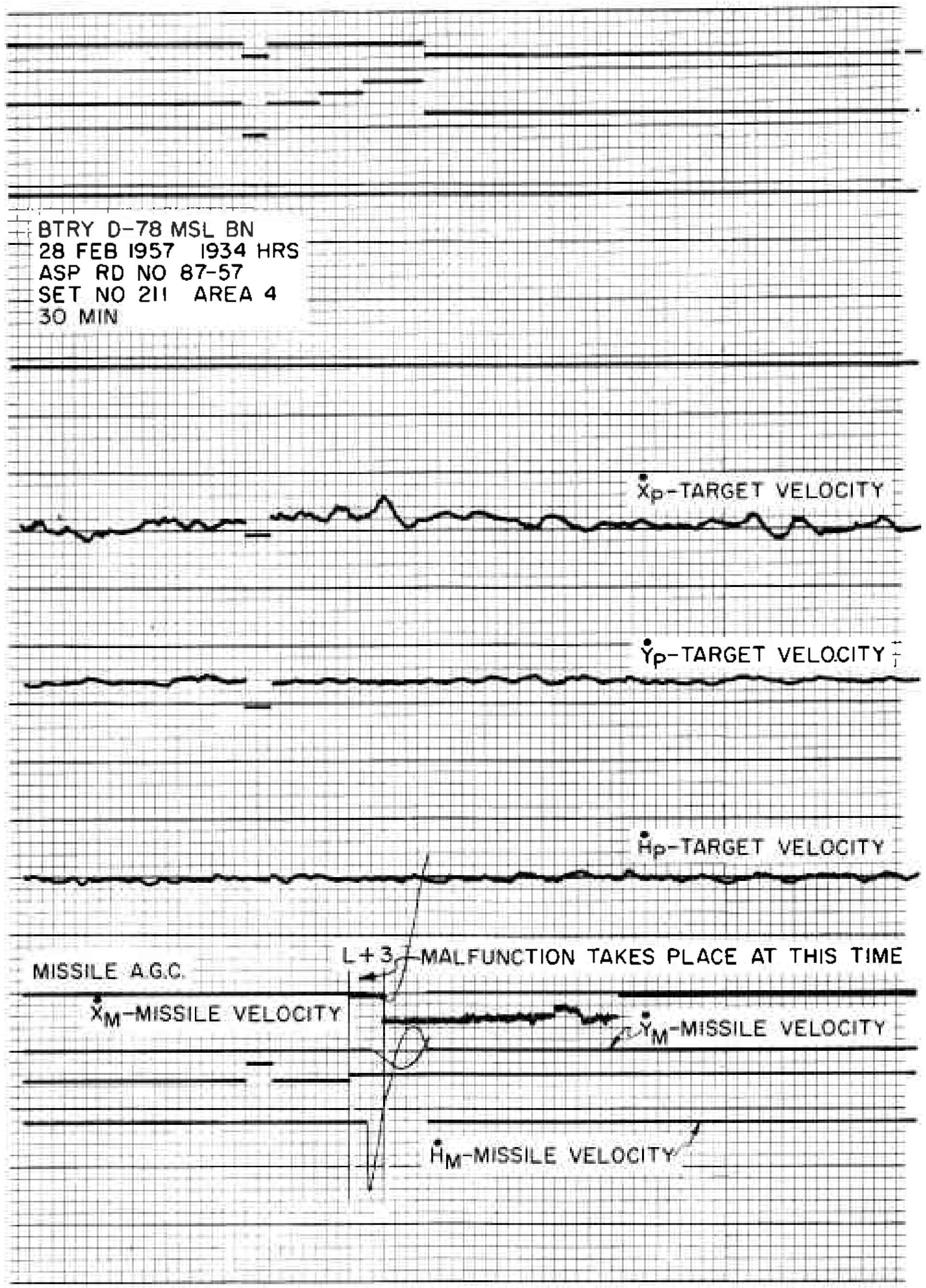

Figure 16. Record of Missile Lost Beacon

4.8 Data Potentiometer Discontinuities

Bats, as discontinuities are commonly known, are interruptions in one or more of the missile or target velocity traces. These interruptions may be very small, less than a second, or quite long - 10 seconds or more. The actual bat has no relation to time except as the length of interruption shown on a tape. A bat results when the brush in the data potentiometer is separated from the card on which it normally makes contact. Separation may be caused by foreign materiel on the contact edge of the card, misadjustment of the brush, etc. The result of the discontinuity is a change in voltage being sent to the computer; this, in turn, causes a change of the voltage being presented as a velocity trace on the event tape.

Position data discontinuities may be grouped into three different classes:

Class A: Greater Than 1,000 Yards. These cause overloads in the computer differentiators. They cause increasing miss distances if they occur during the final 15 seconds of missile flight.

Class B: From 100 to 1,000 Yards in Magnitude. These do not cause amplifier overloads, but increase the miss distance if they occur at times less than approximately 1-10 seconds.

Class C: Less Than 100 Yards in Magnitude. These cause trouble only if they are present in the final two seconds of flight.

As mentioned in section 3 above, a secondary purpose of the simultaneous tracking test is to check for data discontinuities. In the records presented, (figures 7 and 8) no bats or discontinuities were present during the tracking test. Should they have been present on the record, their location could have been determined vary effectively from the chart presented as figure 17.

As an example, suppose a positive bat appears on the Y_T trace. The tracking test was made in the third quadrant. Look at the 3rd Quad section and follow the Y trace out until a positive bat is found with no bats in X or H at the time of the one in Y. The bat falls under the heading Ym; at the bottom of the chart this is labeled M AZ COS CARD which means the bat is on the cosine card of the missile tracking radar azimuth data unit. By looking at the horizontal plot of the computer and finding the approximate azimuth at the time the bat occurred, it should be easily located in the data unit.

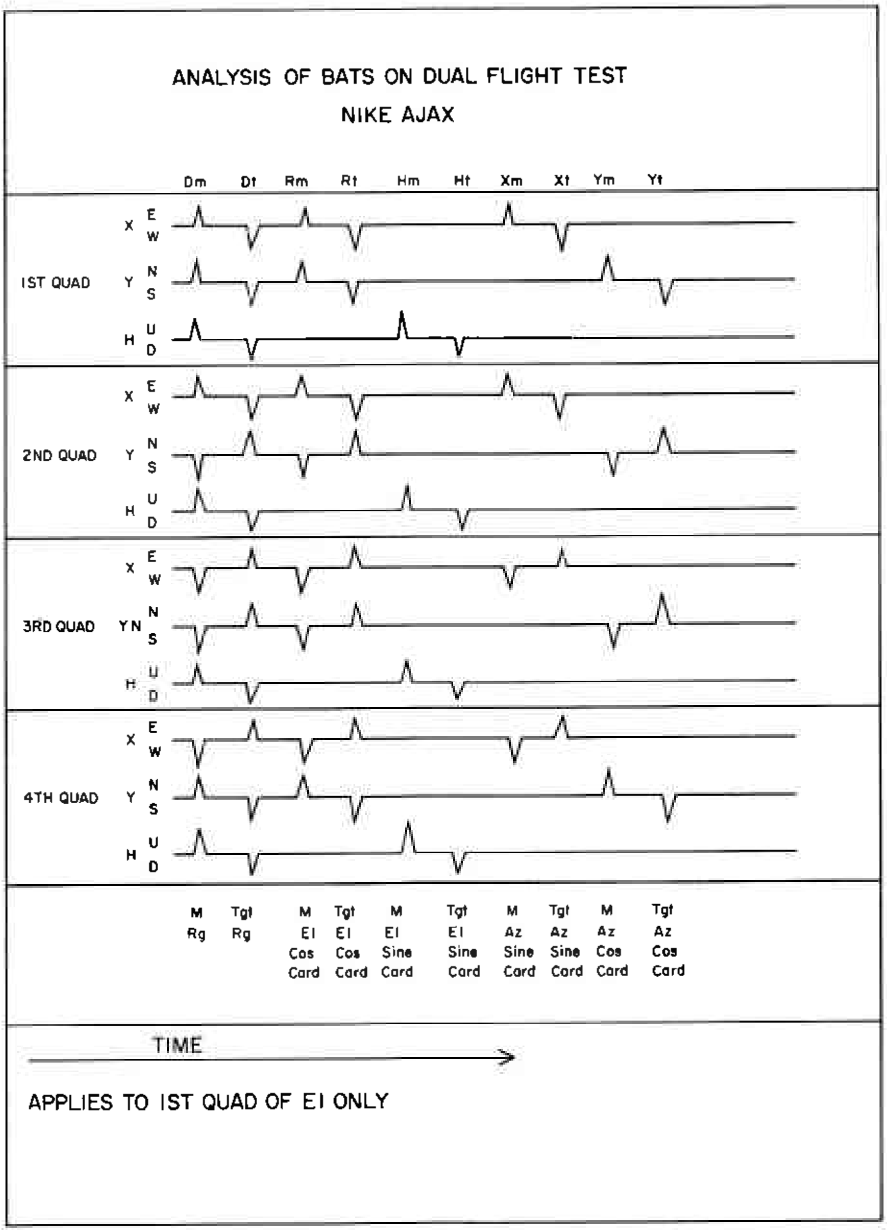

Figure 17. Chart of Bats on Dual Flight Test

The chart (figure 17) is divided into columns, with the proper heading at the top to denote the function of the card on which discontinuities may be located. All the bats shown are uniform; however, these are only for illustration. The actual bats that occur will vary in width and amplitude, depending on their location and the voltages present. For instance, a discontinuity in one of the range units will result in bats on all three components, X, Y, and H, of the same width. The amplitudes, however, will differ. One may be of low amplitude, one high, and one of medium amplitude or some combination of these. The size and shape of the bats is not important, but their relation to each other in time determines the column in which they fall. Suppose a test that was made in the third quadrant has a positive bat on the X trace and at a later time a positive bat on the Y trace; these indicate two separate discontinuities. The first one, positive on X, comes under Xm indicating a discontinuity on the missile azimuth sine card; the second one, positive on Y, comes under the heading Ym and indicates a discontinuity on the missile azimuth cosine card.

5. SUMMARY

This memorandum has presented a detailed discussion Nike-Ajax engagement records and their analysis. An attempt has been made to clarify the role of the event recorder and its associated horizontal and vertical plotting board records in the evaluation of system performance during an engagement. It should be empahsized, however, that proper interpretation of the data found on these records requires considerable experience plus a sound technical knowledge of the Nike system. It should further be emphasized that these records alone may not in every case offer conclusive evidence to determine the results of an engagement. In some instances observations and reports of personnel present, Army firing reports, etc. may be found useful in collaborating the data presented on the engagement records.

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