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DOFL PROJECT
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WASHINGTON 25, D.C.
20 December 1955

DOFL REPORT
TR-367
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T2060 FUZE PERFORMANCE DURING BIRD DOG ROCKET FLIGHT TESTS

M. R. Schroeder

ORDNANCE CORPS • • • DEPARTMENT OF THE ARMY

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CONTENTS

ABSTRACT (U)

This report presents the results of flight tests of twenty-one T2060 proximity fuzes aboard Bird Dog rockets at the U. S. Naval Ordnance Test Station, Inyokern, California, during the period 9 March to 16 July 1955. These tests were part of a program to determine the feasibility of the Bird Dog rocket as a weapon system.

1. INTRODUCTION

Twenty-one Bird Dog rockets with T2060 proximity fuzes were flight tested as part of a program to determine the feasibility of Bird Dog as an effective, practicable weapon system for interception of enemy bombers. The first 17 of these flight tests (15 with spotting charges and 2 with high-explosive warheads) were made with standard T2060 fuzes on Bird Dog rockets which were fired singly in a tail or beam attack against a QB-17 target drone. In four research tests Bird Dog rockets with special fuzes were used, and three of the fuzed rockets were fired in salvo with nonfuzed rockets. The twenty-one tests were preceded by flight tests of rounds carrying safety and arming devices (S and A's) and dummy fuzes. Information on the early tests is given in Reference [1]*.

The purpose of this report is to present an analysis of the twenty-one tests from data available at the East Coast Field Operations Section of DOFL/DC [8].

For each flight test, the data is tabulated according to a "Fuze Test, Bird Dog (FTBD)" number. The numbering sequence provides an indication of the order of testing, as shown by the dates in Table I. With only twenty-one flight tests, no detailed statistical analyses were made.

Bird Dog is a nonguided, proximity-fuzed missile intended for air-to-air interception of enemy bombers. The rocket is launched at a range of approximately 2,500 to 4,500 feet, and accelerates to the target. The primary function of the fuze is to detonate the rocket warhead at the instant of optimum-kill probability for all angles of attack. The fuze is a fixed-angle, frequency-modulated, microwave, proximity type. For a further description of the Bird Dog rocket and the fuze system, see references [2] and [3].

2. FLIGHT-TEST OBJECTIVES

The complete T2060 fuze system was under test in this group. This fuze system consists of the electronic target-detecting device (TDD) and the safety and arming device (S and A). The fuze system test objectives were to determine flight performance of the fuze as a unit, and as an

* Numbers in brackets indicate references at the end of this report.

integrated part of the weapon system. Test objectives of other agencies were related to performance of the rocket, launchers, warhead, and fire-control systems.

For the special fuzes, additional test objectives included testing fuzes with a larger search angle and extended range, studying operation of the fuze when it is passed by nonfuzed rounds, and gathering flight-vibration data.

3. DESCRIPTION OF THE FLIGHT TESTS

3.1 Preflight Fuze-Handling Procedure

Each fuze was laboratory tested at DOFL/DC and then shipped to the West Coast Field Station located at the Naval Air Missile Test Center (NAMTC) Point Mugu, California, for final acceptance, calibration, and mating to the fuze power supply and inert warhead containing telemeter equipment. The fuze, power supply, and inert warhead sections were shipped to Edwards Air Force Base where a final Go-No-Go acceptance test was performed prior to mating to a rocket for the flight tests at The Naval Ordnance Test Station (NOTS).

3.2 Rocket Launch Data

The interceptor aircraft approached the type QB-17 drone target aircraft in an approximately level tail or level beam attack. All tail attacks were made with an F-86E aircraft using a type A-4 airborne fire-control system. The beam attacks were made with an F-86D aircraft using an E-4 airborne fire-control system. The fire-control systems were modified for use with Bird Dog rockets. Each fighter could carry four rockets.

Range instrumentation was similar to that of the nonfuzed rounds [1], except for equipment added to telemeter fuze-system functions. An FM-FM telemeter unit with three subcarriers and a TM power supply were installed in the warhead section. The TM packs, which normally occupy the warhead section, were not used on the high-explosive tests. Except for these HE tests, kinescore-type, intercept-target optical recorder (ITOR) systems were installed on the drones.

Launch conditions are summarized in Table I.* All rounds prior to Round 34 contained dummy fuzes. Round numbers are not consecutive due to overlapping of the nonfuzed and fuzed rocket groups.

* The launch altitudes were obtained from launch aircraft instrumentation. Launch air speeds were obtained from airborne instrumentation. Drone air speeds were obtained via the remote-control television link. As a test of data correspondence the drone velocities of FTBD 1-15 were compared to those of ground instrumentation. The average of the individual differences is 12.4 knots, or approximately 7 percent.
Tables are at the end of this report.

For launching the four rockets containing special fuzes, a one-hundred-foot-elevation miss bias was set into the airborne fire-control systems to reduce the probability of rocket-drone collision. The rockets of FTBD 19 and FTBD 20 were each launched in separate salvos with two nonfuzed rockets. In each salvo the nonfuzed rockets were launched shortly after the fuzed rocket. To effect passing of the fuzed rounds by inert rounds, the latter were launched using rocket motors of a higher temperature to increase their acceleration. Motors of the inert rounds were temperature conditioned at 120 F for 24 hours prior to loading on the aircraft, while motors of the fuzed rounds were conditionedfor the same time at 70F. In the other two special tests (FTBD 17 and 18) the fuzed rockets were each launched in salvo with one inert rocket. For these launchings passing was not intended, and all the motors were conditioned at the usual 70F.

3.3 Equipment Data

The target-detecting device used was a modified T3002E4 fuze. The S and A device was a MK 502-A mechanism with interim modifications for initial tests. A separate power pack for both the fuze and the TM equipment allowed for interchangeability between a TM pack and a high-explosive warhead. Serial numbers of the rocket equipment used in the respective flight tests are listed in Table II.

The fuze radiation field, or beam, is shaped roughly as a hollow cone, symmetrical about the rocket axis. The leading edge of this beam is considered to be a conical surface 61° from the rocket vertex. At this angle the signal return is approximately 10 decibels below that at the beam center. The fuze is designed to have an effective range out to approximately 75 feet.

The three special fuzes used had been modified to improve weapon-system kill probability. The modified fuzes had a range of approximately 160 feet and a larger beam angle of 78°. No changes were made in the TM equipment except for a modified 40-kc channel in FTBD 19. A fourth special fuze was instrumented to yield flight vibration data.

4. FLIGHT TEST RESULTS

4.1 Fuze-Target Intercept Distances

Basic flight performance of the fuze system is summarized in Tables III, IV, and V. Items of primary importance are fuze locations relative to the aircraft at "triggering" and at "firing", the arming distance, and the self-destruct time. Triggering is considered to occur at the instant the fuze recognizes the signal as a legitimate target. Firing of the fuze occurs a specified time later and was indicated by smokepuffs in these tests.

Because the fuze is the proximity type, spatial relationships of the target and fuze are important. The distances designated "triggering distance" in Table III which are pertinent from an electronics standpoint, are measured from the rocket to the nearest extremity of the illuminated portion of the aircraft at triggering. Although the nominal cutoff range is 75 feet, it is to be noted that the maximum triggering distance is 125 feet. Intercept plots are shown in Figures 1 to 9.

In all tests the aircraft-rocket system carried the fuze within operating range of the target. The closest approach distances of Table III are measured from rocket c.g. to target c.g. On certain indicated rounds ground-camera data,which was referenced to the apparent intersection of the trailing edge of the wing and fuselage, was used in absence of ITOR data.

4.2 Safety and Arming Device Performance

The S and A device should not arm the fuze until it is a safe distance from the launch aircraft but should arm in sufficient time to ensure firing at intercept. This allowable arming distance, as specified by USAF, is 700 to 1,200 feet under all tactical conditions. In addition, the S and A device contains provisions for effecting self-destruction of the rocket in the event that the target is not intercepted. However, in these tests the self-destruct function was indicated only by telemetering, and the rockets were not destroyed. (Figure 10 shows a typical TM record.) Self-destruct time, as specified by USAF, is 8.5 ± 1.5 seconds.

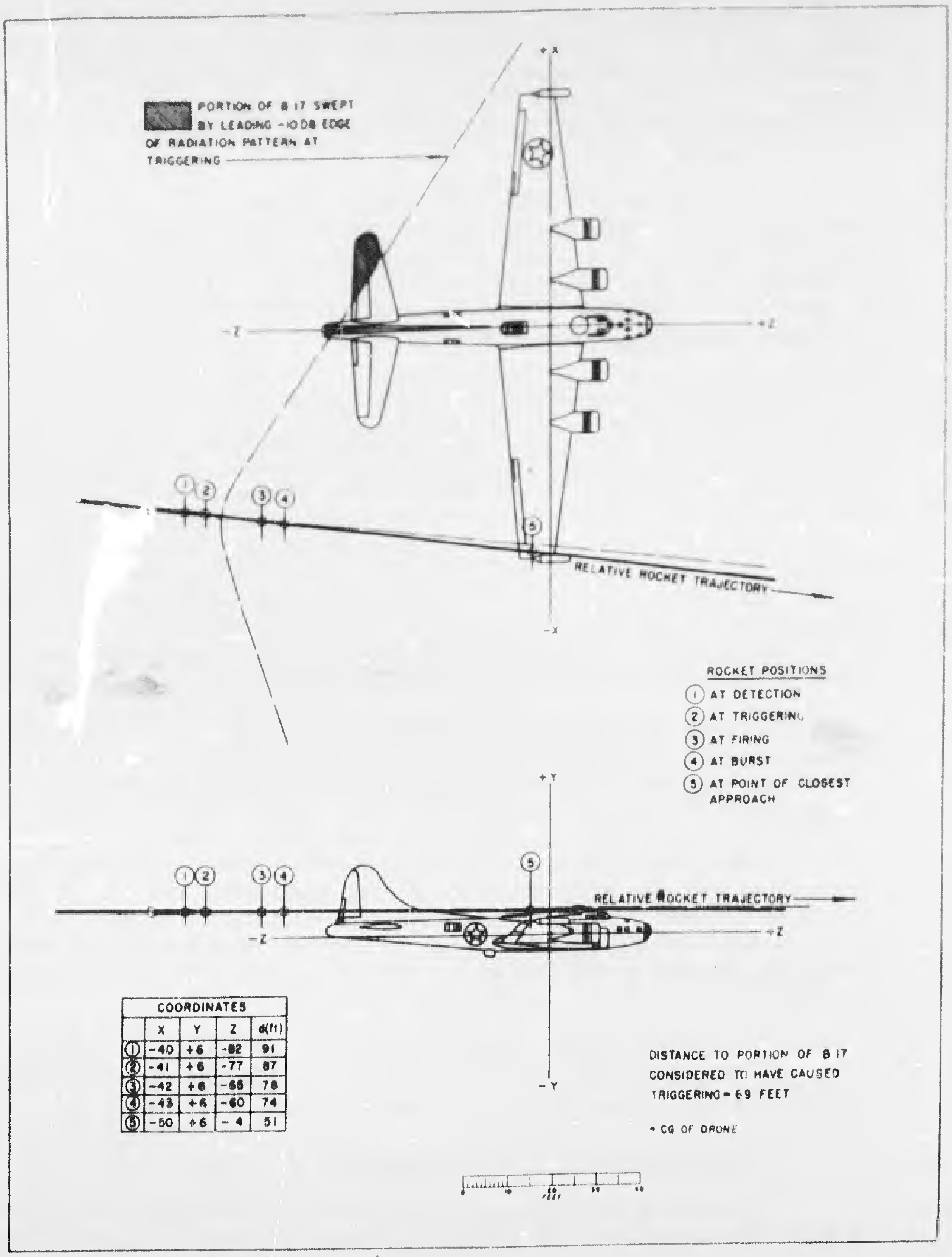
S and A performance is summarized in Table III. The arming and self-destruct times were measured from rocket first motion. Average arming time was 1.46 seconds, and average self-destruct time was 7.90 seconds.

The arming distance of all rounds, except one, was within specifications; the average arming distance was 841 feet. The standard deviation was 72.7 feet. Because arming distance depends upon rocket acceleration, this deviation is due not only to the inherent variations of design tolerances in the device but also to variations of rocket acceleration that occurred in these tests.

The last column of Table III lists the times from rocket first motion to triggering of the fuze. If no triggering occurred, the times are measured to the beginning of a target-signal return.

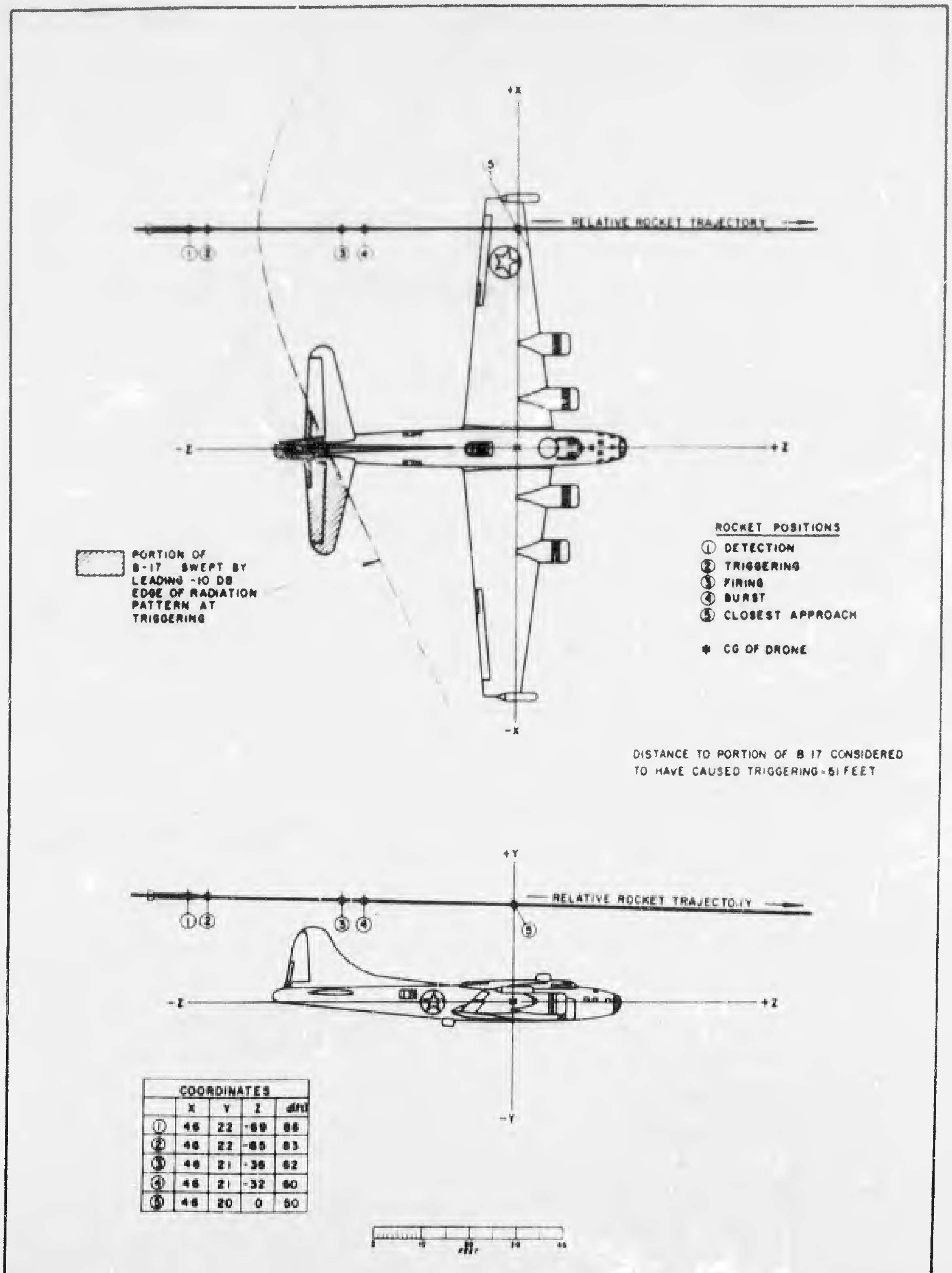
4.3 Analyses of Fuze System Performance

Criteria for performance rating are consistent with those of related fuze projects. If the S and A device did not arm or produce



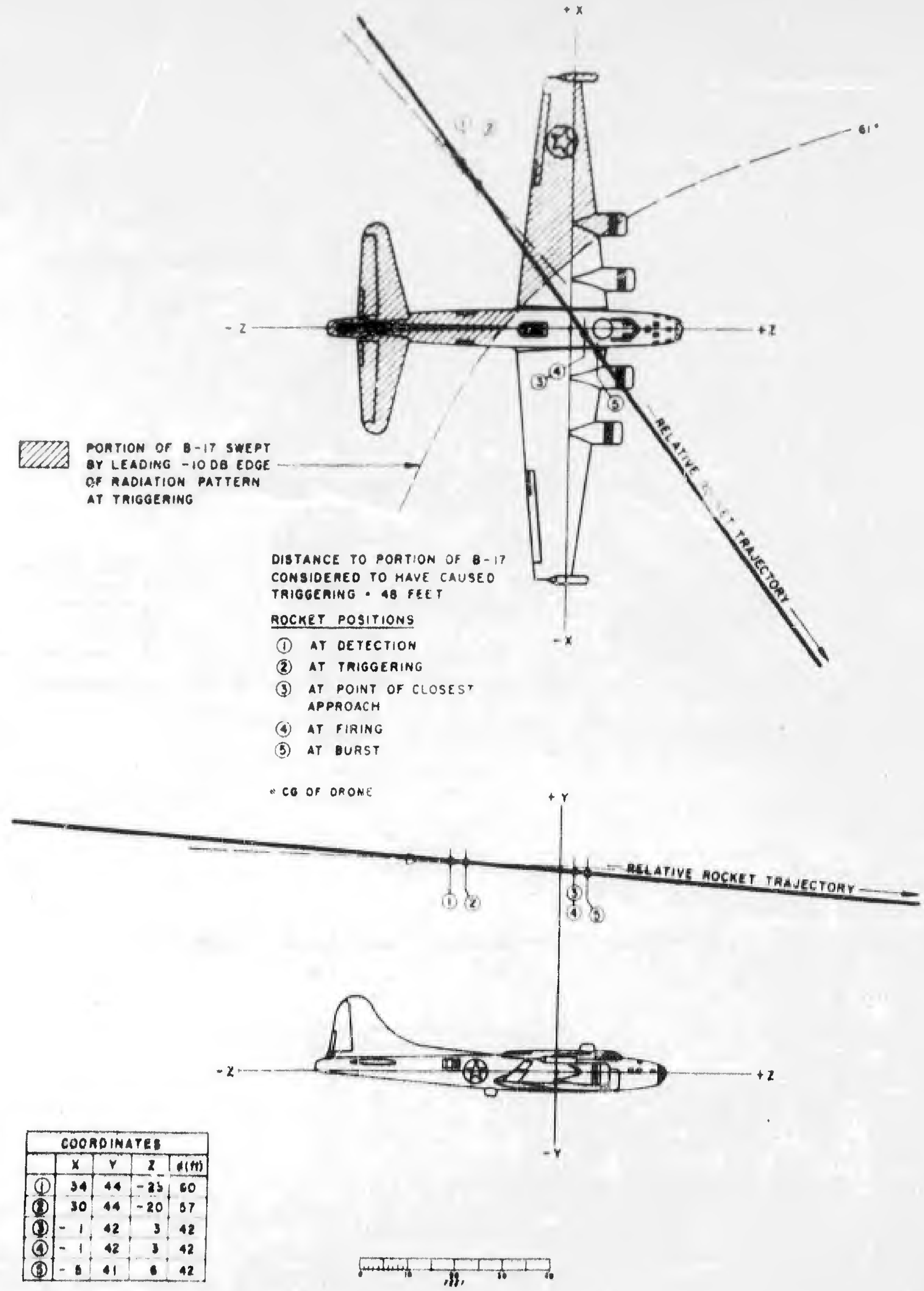
COORDINATES				
	X	Y	Z	d(ft)
(1)	-40	+6	-82	91
(2)	-41	+6	-77	87
(3)	-42	+6	-65	78
(4)	-43	+6	-60	74
(5)	-50	+6	-4	51

Interception of B-17 Drone by Fuze T2060, S/N B-2.
Flight on 9 March 1955. Bird Dog R/N 34.
Figure 1.



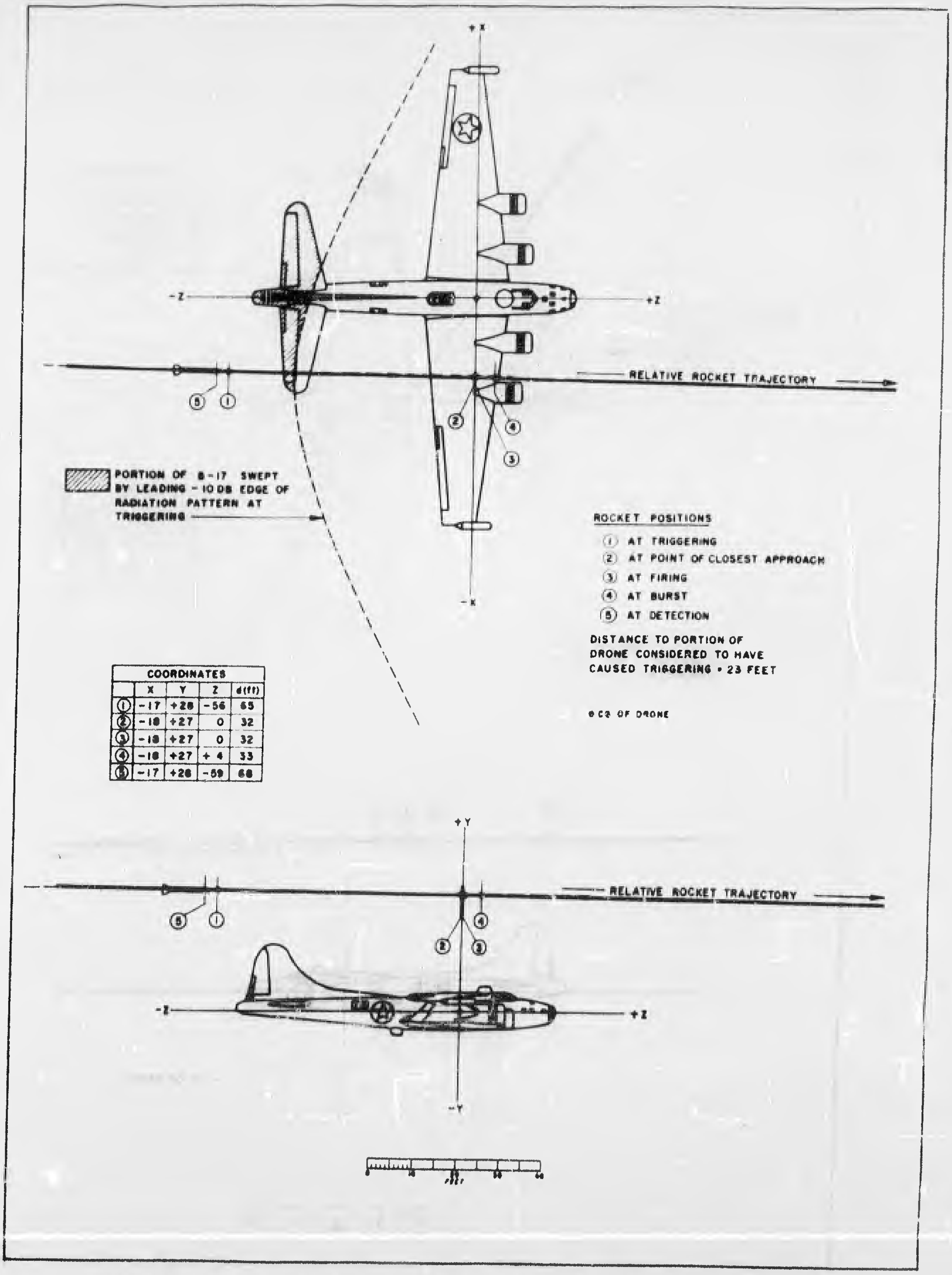
COORDINATES				
	X	Y	Z	d(ft)
①	46	22	-69	86
②	46	22	-65	83
③	46	21	-36	62
④	46	21	-32	60
⑤	46	20	0	50

Interception of B-17 Drone by Fuze T2060, S/N B-5.
Flight on 16 March 1955. Bird Dog R/N 35.
Figure [illegible].



COORDINATES				
	X	Y	Z	d(ft)
①	34	44	-25	60
②	30	44	-20	57
③	-1	42	3	42
④	-1	42	3	42
⑤	-5	41	6	42

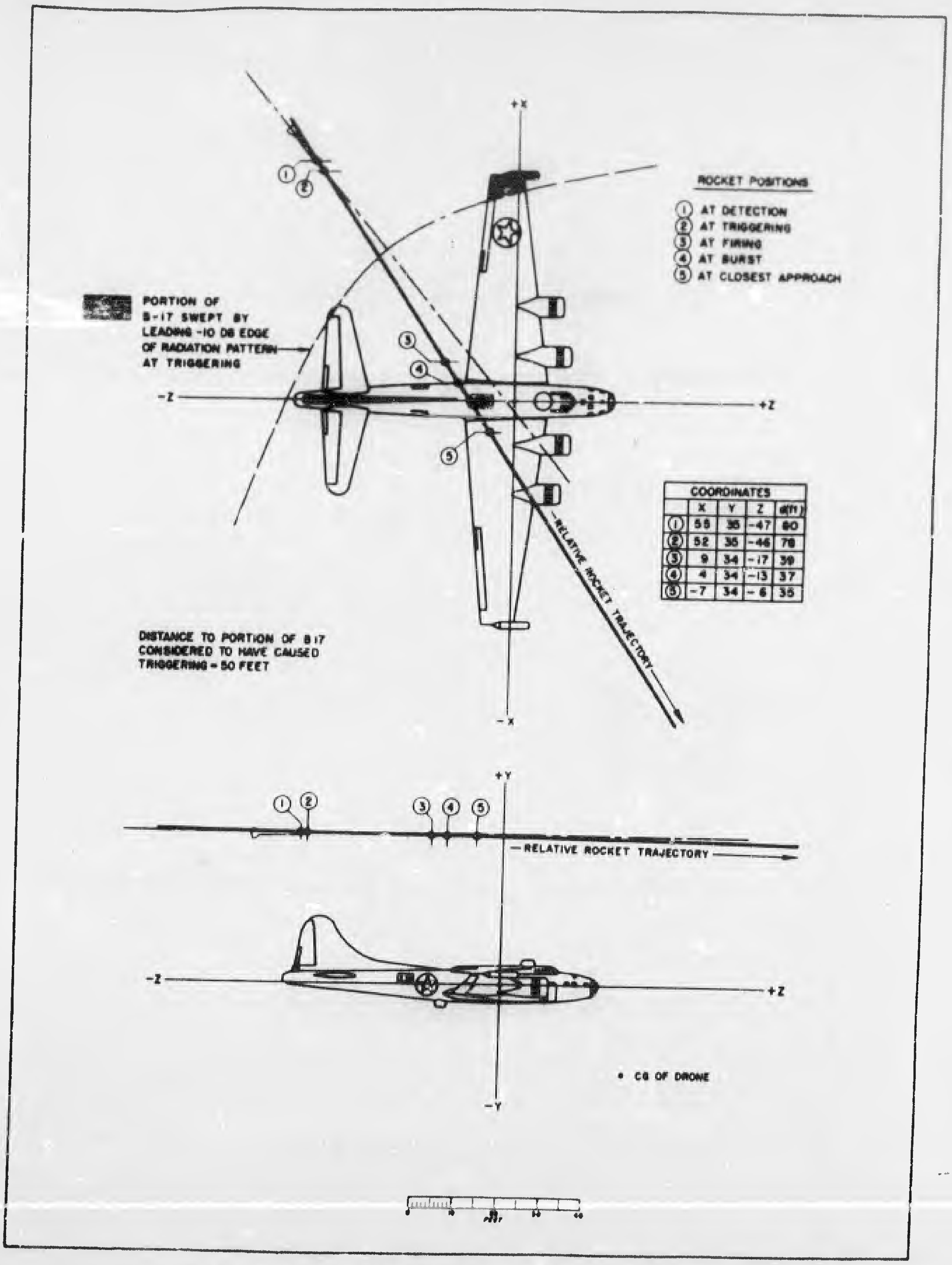
Interception of B-17 Drone by Fuze T2060, S/N B-13.
Flight on 12 April 1955. Bird Dog R/N 56.



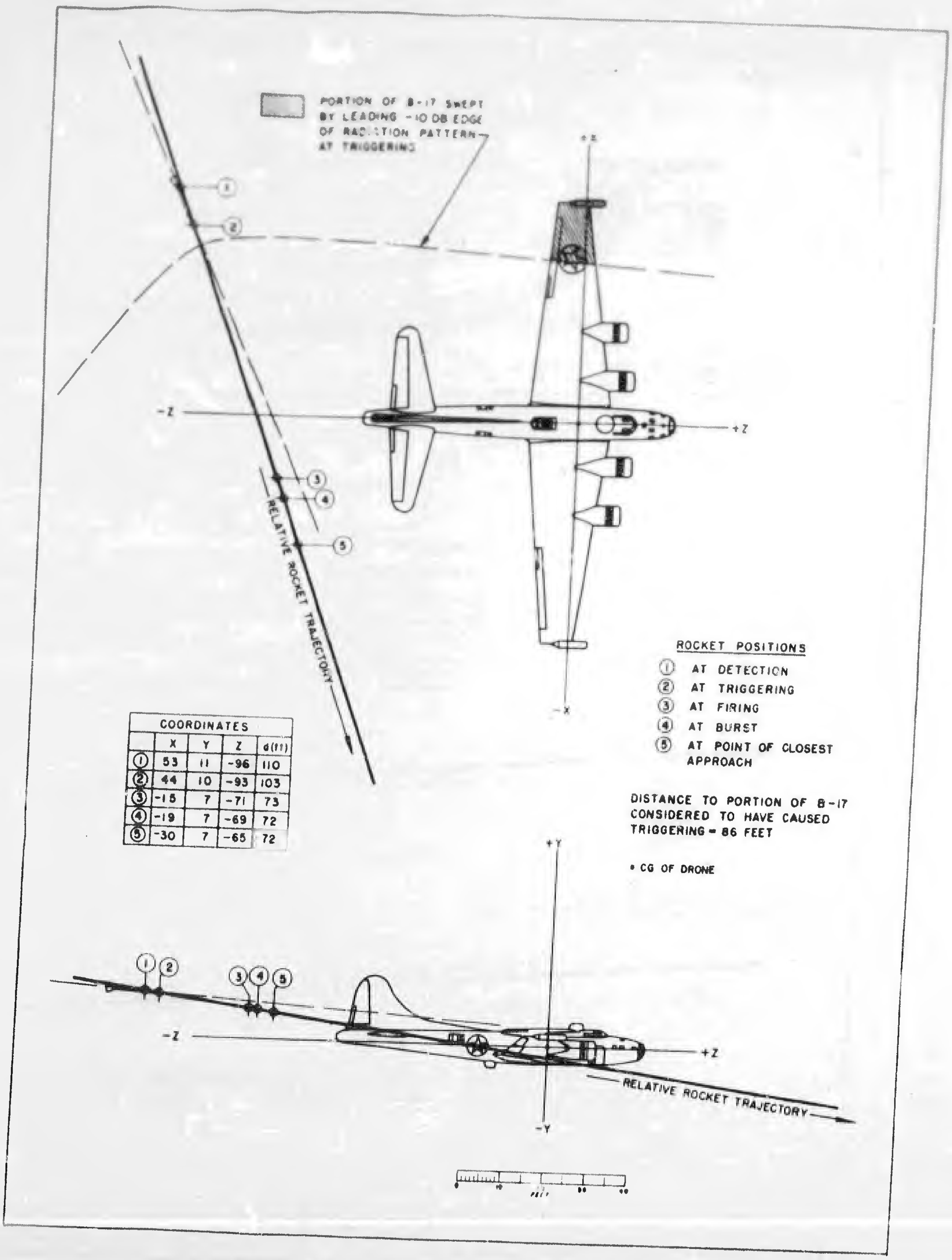
COORDINATES				
	X	Y	Z	d(ft)
①	-17	+28	-56	65
②	-18	+27	0	32
③	-18	+27	0	32
④	-18	+27	+ 4	33
⑤	-17	+28	-59	68

Interception of B-17 Drone by Fuze T2060, S/N B-17. Flight on 29 April 1955. Bird Dog R/N 66.

Figure 4.

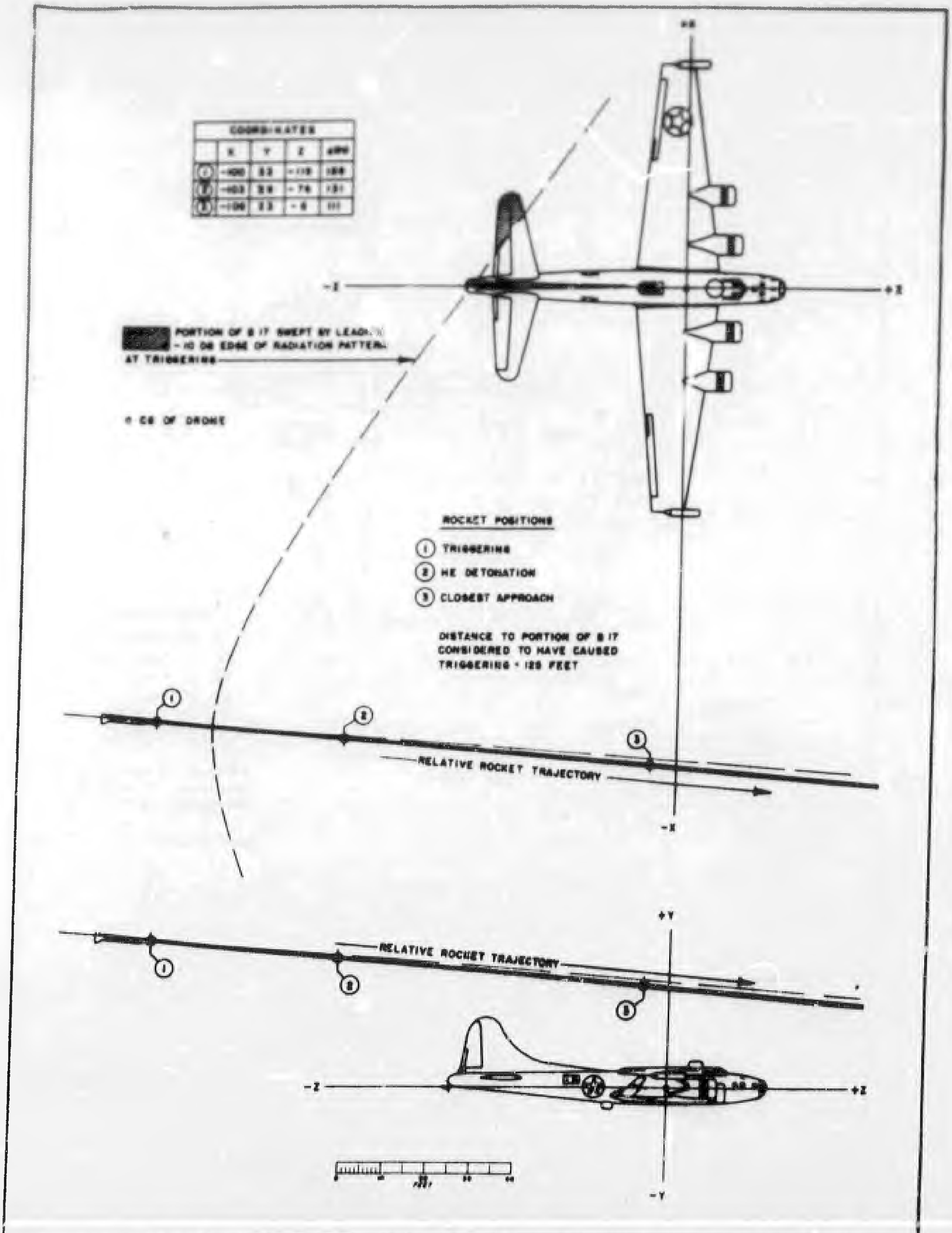


Interception of B-17 Drone by Fuze S/N B-11.
Flight on 25 May 1955. Bird Dog R/N 72.
Figure 5.

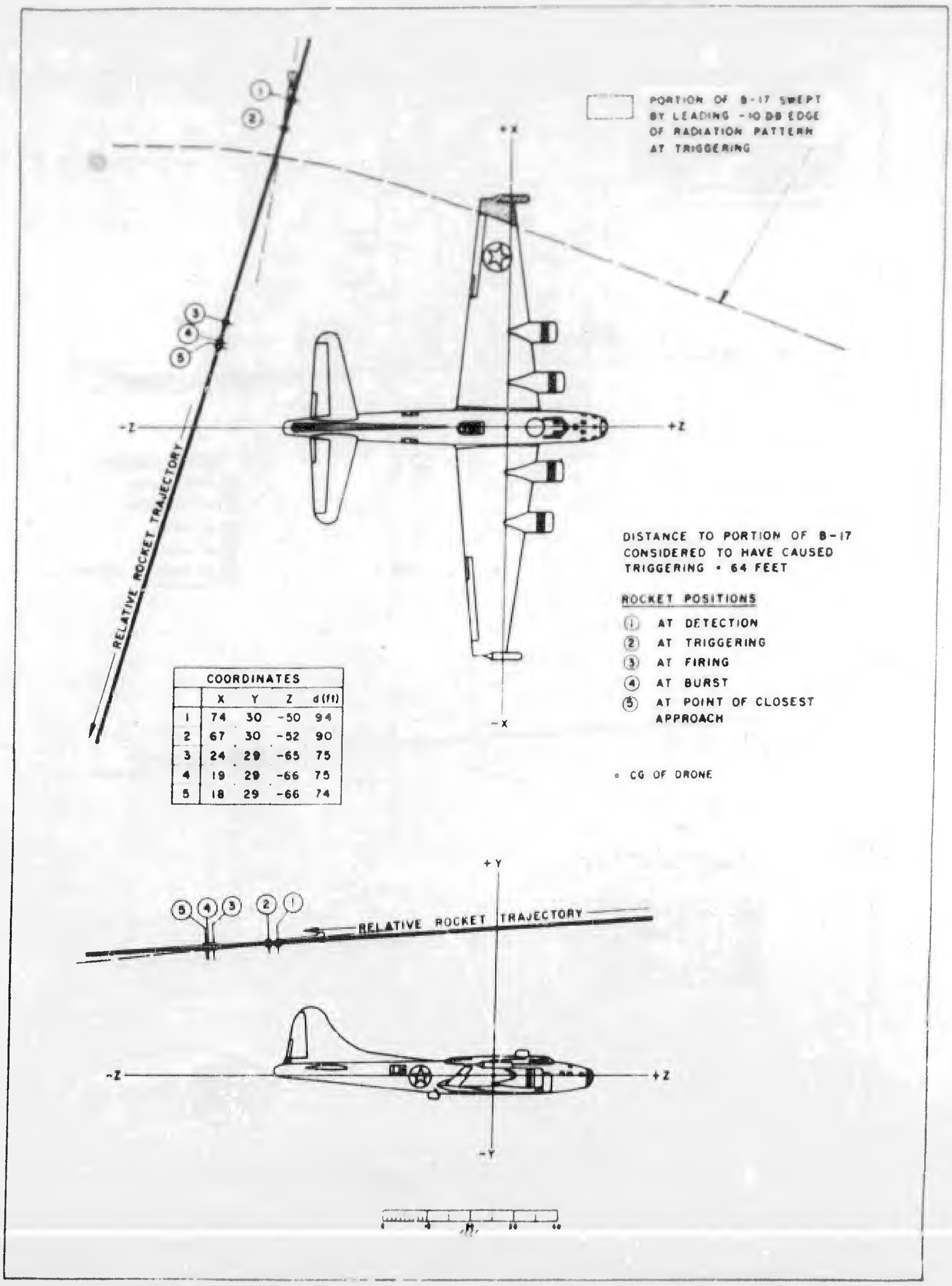


Interception of B-17 Drone by Fuze T2060, S/N B-6. Flight on 25 May 1955. Bird Dog R/N 73.

Figure 6.

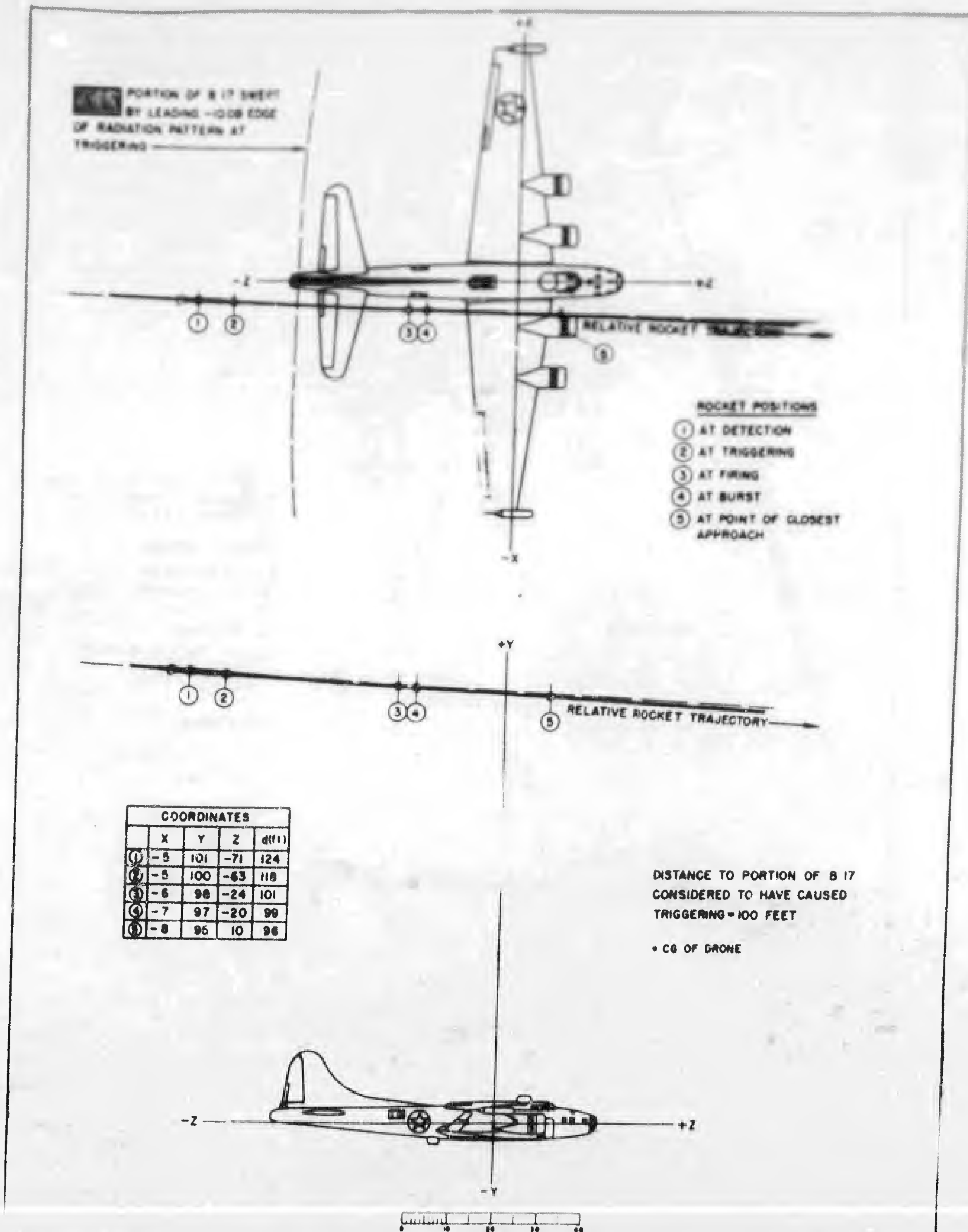


Interception of B-17 Drone by Fuze T2060, S/N B-21.
Flight on 25 June 1955. Bird Dog R/N 81.



COORDINATES				
	X	Y	Z	d (ft)
1	74	30	-50	94
2	67	30	-52	90
3	24	29	-65	75
4	19	29	-66	75
5	18	29	-66	74

Interception of B-17 Drone by Fuze T2060, S/N B-38.
Flight on 1 July 1955. Bird Dog R/N 82.
re 3.



COORDINATES				
	X	Y	Z	d(ft)
(1)	-5	101	-71	124
(2)	-5	100	-63	118
(3)	-6	98	-24	101
(4)	-7	97	-20	99
(5)	-8	95	10	96

Interception of B-17 Drone by Fuze T2060, S/N B-34. Flight on 8 July 1955. Bird Dog R/N 87.

Figure 9.

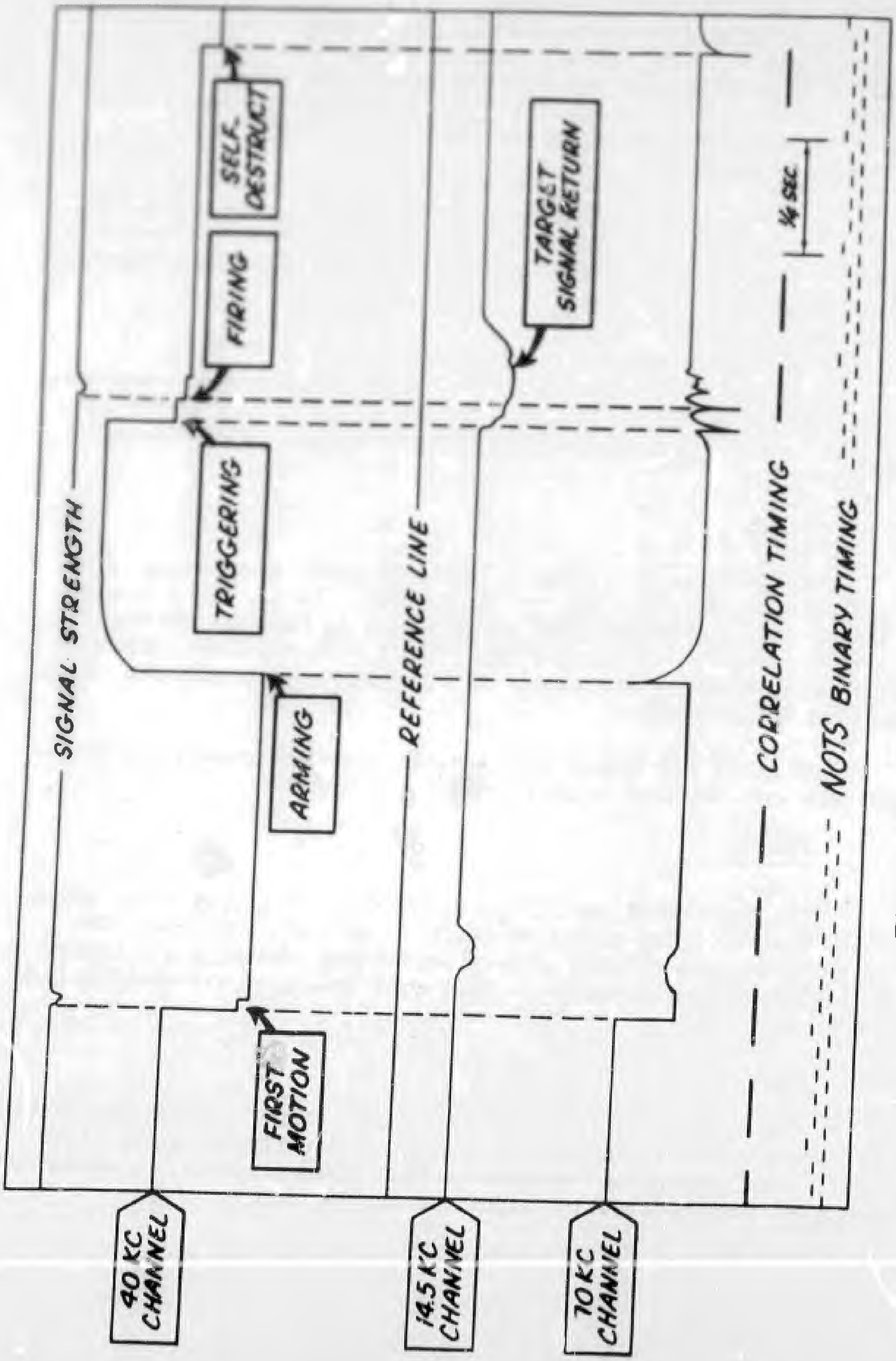


Figure 10. Typical telemetered flight record.

the self-destruct function within the specified limits, the respective function was considered improper. If the fuze armed and did not fire for triggering distances within the nominal cutoff range of 75 feet, operation of the TDD was considered improper. Beyond 75 feet firing or nonfiring of the fuze was considered proper. Although an operative fuze cutoff range is desired to prevent triggering on distant objects, no criterion has yet been established for judging distant firings as improper.

The flight-test performance of the fuze is summarized in Table IV. Details of the results listed in Table IV with respect to "no tests," "impropers," and performance which could not be categorized are given below.

FTBD 3

The fuze functioned properly. The self-destruct function was not simulated because of an inadvertent omission of a ground lead in the fuze. No intercept plot is presented because of a failure of the ITOR system.

FTBD 4

The fuze was electrically disarmed prior to intercept and the self-destruct function was not indicated. Laboratory investigation showed that the trouble was probably due to improper mating of the connector pins which connect the S and A with the fuze electronics section (TDD). Mating difficulty resulted from a pin material change by the plug manufacturer.

TM records indicate that the TDD operated properly, and the fuze should have fired if arming had been maintained.

FTBD 5

The fuze fired early, approximately 0.27 second after arming and 2,260 feet from the target aircraft. Analysis indicated that firing resulted from extreme voltage variations caused by a malfunction in the high-frequency circuits. Smokepuff operation was observed but was beyond the range of the ITOR cameras.

FTBD 6

The fuze did not fire. Later laboratory tests showed that the failure was due to an experimental change in the firing circuit (see page 24). All other fuze components functioned properly, as shown by a satisfactory target-detection signal on the TM record.

FTBD 7

The self-destruct function failed to occur. This failure may have been caused by either an S and A malfunction or the omission of a ground lead as in the case of FTBD 3.

FTBD 8

A relative trajectory plot could not be made because of failure of the ITOR system.

FTBD 9

The TDD operated properly, but arming failed to occur. This failure may have been due to the electrical plug difficulty which occurred in FTBD 4, rather than to a malfunction of the S and A device. The arming failure prevented simulation of the self-destruct function.

FTBD 11

The TDD failed to operate because of a lack of filament voltage. This was determined later by bench tests simulating the TM record. No explanation could be found for the filament-voltage failure. The presence of B+ voltage in the fuze indicated that the power supply had been properly switched to internal fuze power. Records of checkout tests were satisfactory on filament circuitry, which extends from the fuze power supply to the TDD and the TM power supply. Because the preheating filament voltage obtained from the launch aircraft prior to the switch to the fuze power supply was missing, the trouble was probably in fuze circuitry common to both voltage sources.

Arming distance could not be determined because of insufficient correlation between TM records and trajectory data.

FTBD 14

The firing pulse was delivered to a short circuit instead of to the spotting-charge detonators, precluding spotting-charge operation. It was not possible to determine where the short occurred. It could have occurred in any one of the following: the TDD, the S and A, the fuze power supply, the TM pack, or the separate conductor which is wired from the TM pack to the detonator during rocket assembly. No short was found during the fuze checkout tests.

The ITOR pods were inadvertently jettisoned just prior to the test.

FTBD 15

Fuze operation was proper. Rocket impact with the drone caused loss of telemetering 19 milliseconds after triggering. (See Figure 11.) With the triggering-to-firing interval set at a nominal value of 26 milliseconds, impact occurred approximately 7 milliseconds prior to the expected time of fuze firing. It is possible that the spotting charges detonated inside the drone.

The approximate center of the fuselage was struck by the rocket, resulting in loss of control and crashing of the drone. No intercept plot is presented because the camera pods were inadvertently jettisoned just prior to FTBD 14. Arming distance could not be computed because data on the down-range position of the drone was not available.

FTBD 16

Proper fuze operation is indicated by the eventual destruction of the target and by the location of the high-explosive burst relative to the target as shown in Figures 7 and 13. Photos of the HE bursts were enlarged from 35-mm film from the ground camera system. The two views were obtained from successive frames separated by an interval of approximately 15 milliseconds.

FTBD 17

The inert round, launched in salvo with the fuzed round, was not close enough to create a fuze-signal return.

FTBD 18

Fuze-test objectives were not attained. A probable malfunction in the power supply for the special instrumentation amplifiers prevented obtaining the desired vibration information.

FTBD 19

Although fuze operations were proper, not all of the test objectives were accomplished. The fuzed rocket was not passed by the inert rockets until approximately one second after drone intercept. The rockets were launched in the order intended, with the fuzed round first, followed by two inert rounds approximately one-tenth second later.

TM records indicate a fuze signal return which was apparently caused by the passing inert rockets. Even if the fuze had not fired at intercept, it theoretically would not have fired on signal return from the rockets because of the signal amplitude and frequency characteristics. Detector signal return varied up to 2.5 volts peak-to-peak at 500 to 600 cycles per second.

Numerals are FTBD designations

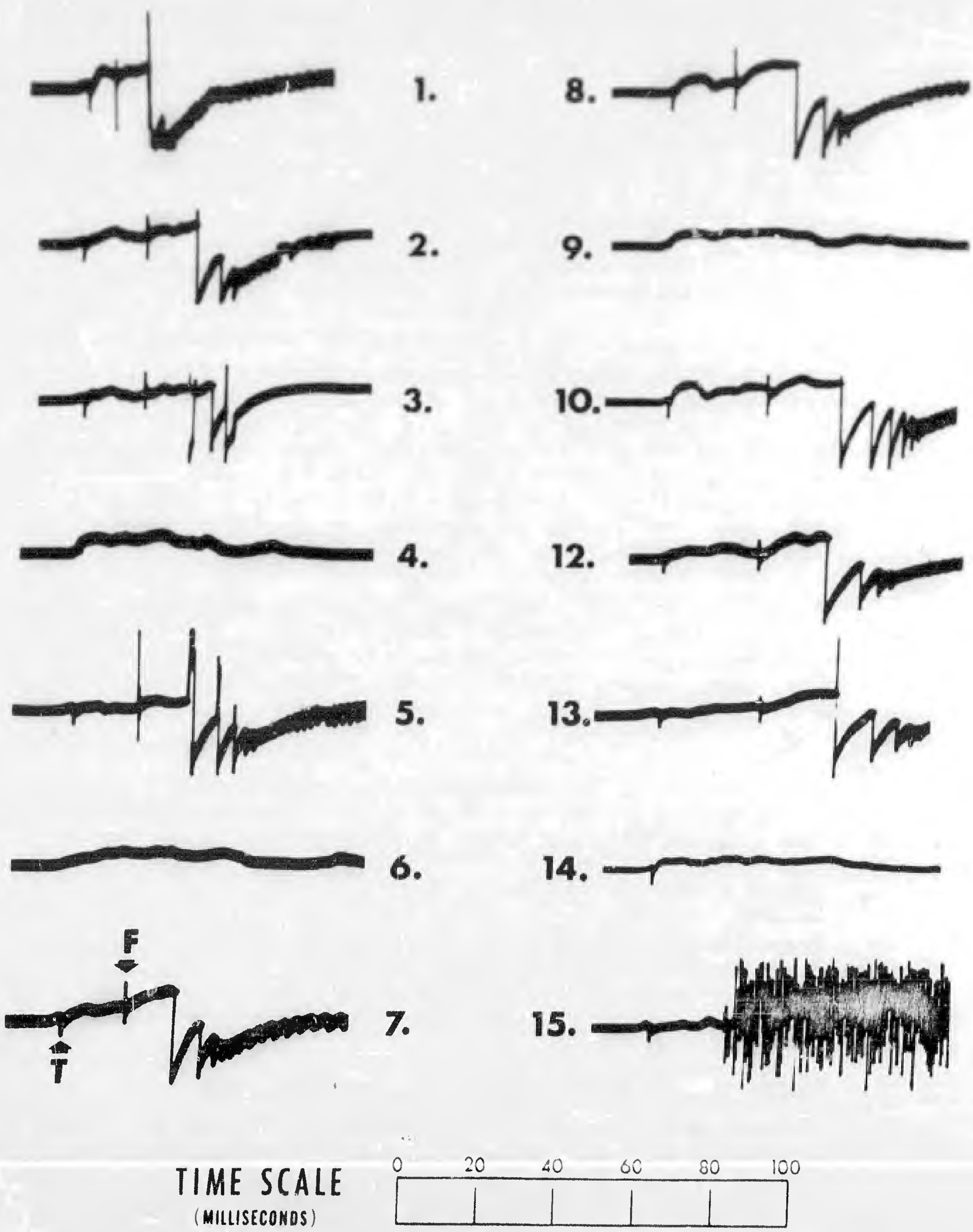


Figure 11. [illegible]0-kc TM traces about firing pulse.

FTBD 20

The fuze fired early, approximately 0.3? second before intercept. Investigation indicated that the early firing was probably due to malfunction of the fuze, despite the proximity of a passing inert rocket. The early smokepuff was beyond the range of the TTCR cameras.

The three rounds of the salvo were launched in the order intended. Rocket-motor first-flame of the inert rounds was visible approximately 0.11 second after that of the fuzed round. At fuze firing, inert round number 89 was at a position approximately 8 feet to the left and 0 feet ahead of the fuzed round. Velocity of the inert round relative to the fuzed round was approximately 35 feet per second. The other inert round, number 91, did not pass the fuzed round until approximately two seconds after intercept.

TM records indicate that the fuze TDD was in an abnormal state during flight. Residual detector voltage was approximately -10 volts, whereas normal voltage ranges from 0 to -1 volt. This voltage varied abnormally for 0.2 second after first motion. The firing-circuit voltage, which should represent in part the approximate integral of the detector signal was also abnormally high in numerical value and showed an abnormal waveshape after triggering. Although the fuze normally triggers on a negative-going signal, TM records indicate that triggering occurred while the signal was positive-going.

A signal return, presumably from the passing inert rocket, began 0.1 second prior to arming and extended through firing. The frequency of this return is comparable to that which would be produced by the relative velocity of the inert rocket. If this signal triggered the fuze, the question arises why triggering did not occur on the similar signal just after arming.

Discrepancies in the instrumentation records prevent a positive conclusion as to the reason for fuze triggering. Some discrepancies are evident in the playback TM oscillograph of Figure 12 when it is compared to the typical TM record of Figure 10.

FTBD 21

Proper fuze operation is indicated by the location of the high explosive warhead relative to the target as shown in Figure 14 and by the eventual destruction of the target. No intercept plot is presented for this test because of difficulties in reconciling rocket trajectory data with the specified miss distance.

4.4 Engineering Changes Consequential to Flight Tests

Several changes in the fuze system which were made as a direct result of the prior flight tests are listed in the following paragraphs.

In order to insure against the type of self-destruct failure that occurred in FTBD 3, a pin in the power plug of each of the subsequent fuzes was grounded.

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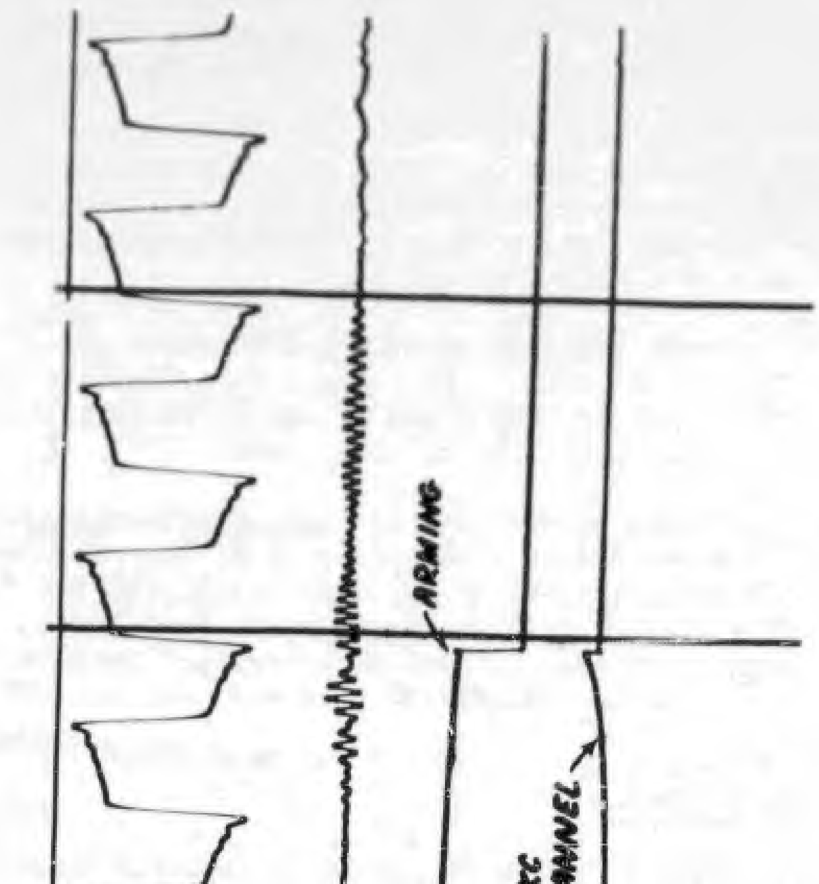

Figure 12. TM record of FTBD20.

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Lack of a first-motion indication in the first three tests resulted in wiring one of the existing inertia switches in the TM power supply into the TM input circuit for FTBD 4 through 11. In addition, the TM input circuit was changed for indication of first motion by shearing of the umbilical cord for FTBD 4 and subsequent tests.

Failure of the fuze to fire on FTBD 4 resulted in the decision to replace plug inserts on the remaining fuzes. Laboratory tests showed the original inserts were sufficiently incompatible to produce an 'open' from flight vibrations.

Vibration tests were included as standard checkout procedure on fuzes for FTBD 6 and above. This was a result of the improper operations of the fuzes of FTBD 4 and 5, and of TM indications of abnormal residual voltage variations on other tests.

In FTBD 6, the firing circuit was altered experimentally by replacing one of the capacitors with a capacitor of different value. The failure was attributed to this change because units with the same change tested later would not fire under certain tests more rigorous than those used in standard checkout procedure. Because the fuze failed to fire, the original capacitor value was used in subsequent fuzes.

4.5 Intercept Trajectories

Rocket trajectories relative to the target aircrafts are shown in Figures 1 through 9. The shaded portion of the aircraft indicates target illumination by the fuze-radiation field at triggering. Some tests lack illustrations due to improper operation of either the fuze or the drone cameras.

Positioning of the rocket c.g. along the relative trajectory at instants of fuze functions depended upon an assumed two millisecond delay between fuze firing and detection of the smokepuff. (See paragraph 5.1, "Instrumenting with Smokepuffs" for further details.)

The relative trajectories do not normally indicate rocket heading because these trajectories are relative to the moving target rather than to the surrounding air mass. True headings are indicated separately in the figures. Because Bird Dog is a nonguided rocket, not subject to guidance control deviations, the attitude is assumed to be along the true rocket trajectory. This trajectory was determined by vector addition of the relative rocket velocity and the drone velocity (TAS). Fuze information from TM records and the drone aircraft velocities are combined with ITOR data. This data is then refined graphically by the processes of analytic geometry at DOFL/DC to produce the results illustrated.

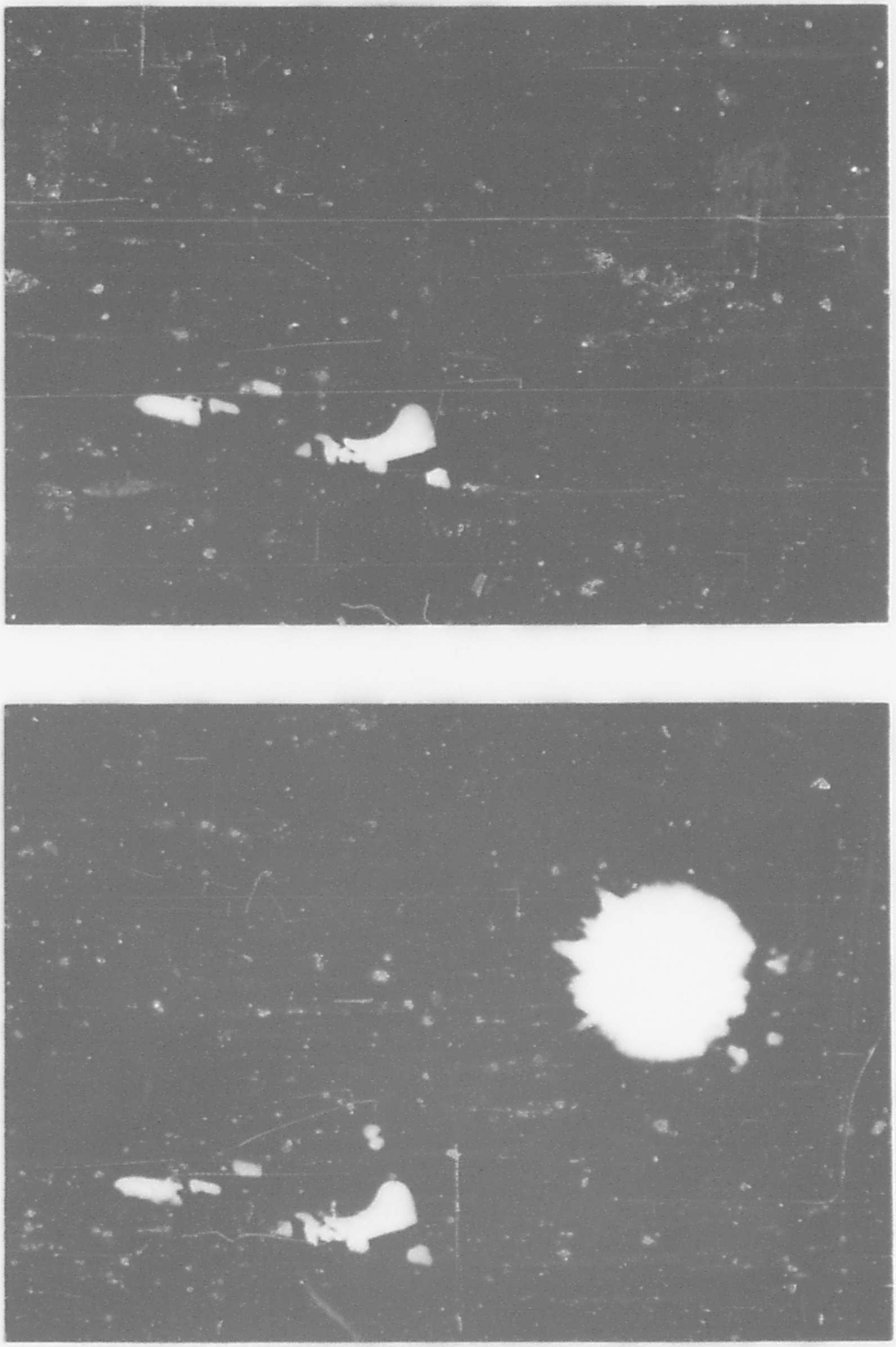

Figure 13. Target interception during FTBD 16.

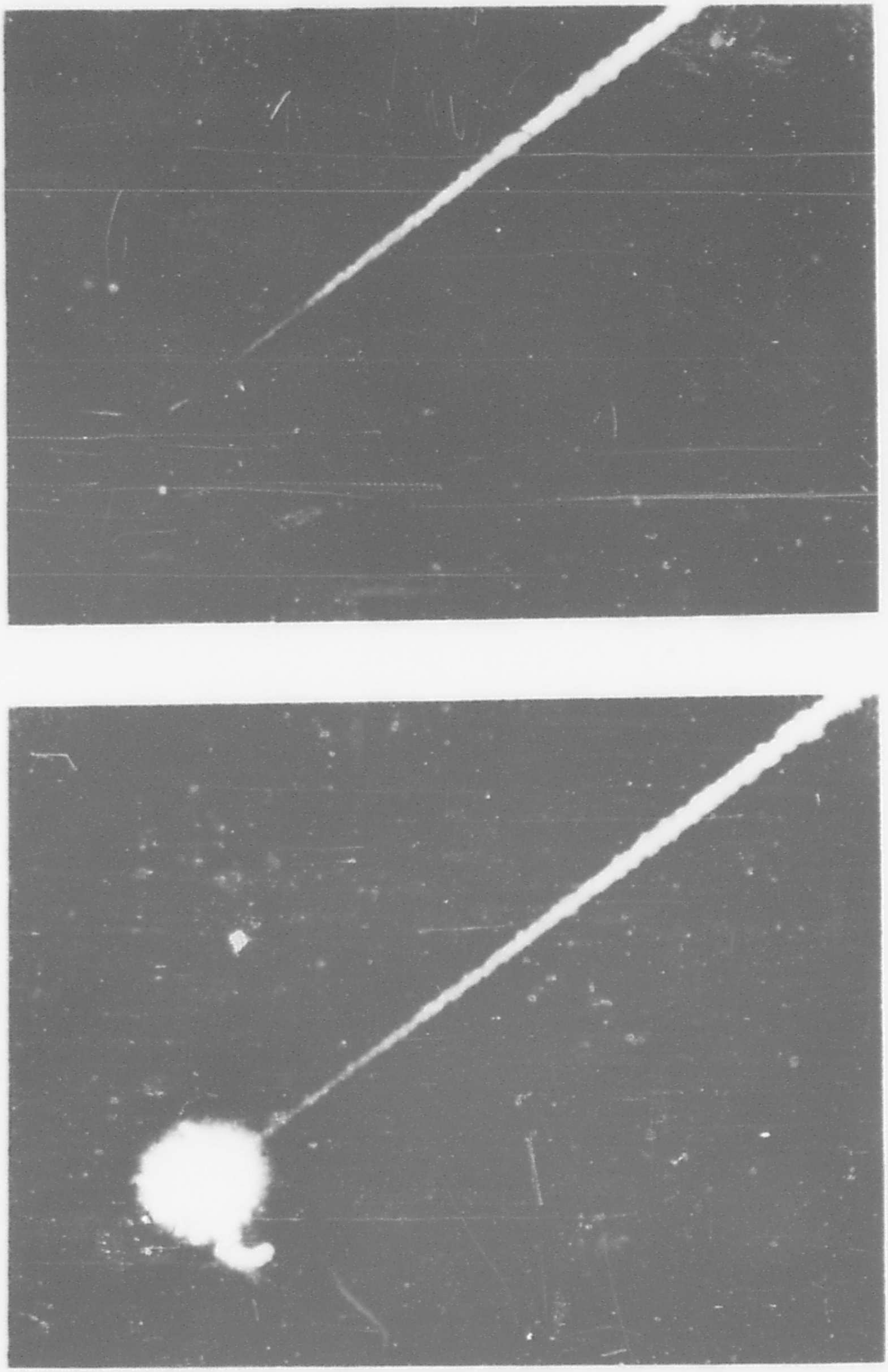

Figure 14. Target interception during FTBD 21.

Table V includes a tabulation of the rocket attitudes of Figures 1 through 9. The angles are referenced to the drone heading in each view, with clockwise angles labeled minus. These angles, plus the relative rocket velocities, are included for any probable damage analysis.

4.6 Fuze Time Delays

A time delay was set in to produce a fire signal at a predetermined interval after fuze triggering. The settings and measurements of these delays are summarized in Table VI. It is assumed that the differences in the time delays measured at NAMTC compared to measurements at DOFL/DC are due to different measuring methods. The delays were measured from the TM pulses shown in Figure 10.

4.7 Variation of Integration Period

Several milliseconds elapse between the instant that a signal return is first evidenced at the firing-circuit input and the instant of fuze triggering. This period, arbitrarily called the integration period, occurs during circuit recognition of the return as a legitimate target. (The interval is not related to the preset time delay between triggering and firing.)

In these tests this period was between 1 and 4 milliseconds. This period depends on many flight parameters, and on somewhat indeterminable variables such as the strength of the radar echo and the phase of residual voltages in the fuze-electronics section. Conclusions from fuze-flight test results are in Section 6.

5. FUZE INSTRUMENTATION ACCURACIES

5.1 Instrumenting with Smokepuffs

Certain errors are introduced by the use of the charges which mark the position of the rocket at fuze firing. The spotting charges, located close to the rocket c.g. were detonated by a fuze firing signal. The puff, visible in ITCR films, was then located on the intercept curve by film-data analysis. The stated-error tolerance for this data is less than 10 percent out to 200 feet [4]. Rocket locations for other fuze functions, such as triggering and detection, had to depend on a precise location of this smokepuff; the locations were obtained by using the fuze TM record and "working back" timewise from the smokepuff along the relative trajectory.

The interval between the instant of fuze firing, as clearly indicated on TM records, and the instant of photographic detection of the smokepuffs could be significant when locating fuze functions with high relative rocket intercept velocities around 2,300 feet per second. An interval of two milliseconds was judged to be reasonable on the basis of available data.

Two factors contribute toward this interval - the ignition delay and the photographic delay. Ground tests on new spotting charges of similar type have shown that an ignition delay of approximately one-half millisecond occurs between electrical detonation and first visibility of the smokepuff [5]. The delay may be longer and less consistent on older spotting charges and the photographic delay may also vary. The drone cameras operate at approximately 200 frames per second, and use a rotary shutter opening of 72 degrees [6], which produces an exposure from each camera of about 1 millisecond every fifth millisecond. The random-time relationship between frame exposures and smokepuff ignition could produce, under poorest conditions, a delay of approximately 4.5 milliseconds.

5.2 Time Correlation Between Instrumentation Systems

Obviously it is desirable to time-correlate records from all flight-test instrumentation systems. From the standpoint of fuze instrumentation, a precise correlation (±.002 second) of TM records and ITOR data is very useful. Such correlation was not successful in these tests. This correlation would have enabled critical determination of the rocket locations for various fuze functions independent of the smokepuff. The correlation would provide a double check on the smokepuff instrumentation and would have made practical the inclusion at intercept plots for FTBD 4, 5, 6, and 9. In these tests, smokepuffs did not occur at intercept. A second correlation is desirable between fuze TM records and ground-camera trajectory data to relate fuze functions to rocket locations. This could be effected by specification of rocket-first motion on the time scale of the trajectory data. This correlation was not possible except for special data which enabled determination of first motion for FTBD 6, 8, 9, and 10. A partial correlation was achieved, but only within any quarter-second interval. These intervals were indicated on the trace of NOTS binary timing on fuze TM records (see Figure 11.) The beginning of the 25-millisecond pulse marking each quarter-second interval indicates the simultaneous occurrence of some entry in the trajectory tables, for this pulse also synchronizes the shutters of the range-theodolite cameras which are used to produce the trajectory data.

5.3 Measurement of Arming Distance

Compared to the nonfuzed rounds, accuracy in measuring arming distances was probably improved because TM pulses instead of smokepuffs were used to detect arming. However, the lack of complete fuze TM correlation with NOTS trajectory data necessitated correlation by a circuitous method. An assumption was made that fuze firing occurred at the instant the rocket and target were the same distance down-range as shown on trajectory curves. The instant of arming could then be located on the curves using the TM records. Arming distance was measured at this point.

5.4 Typical Telemeter Record

A telemetered-flight record which is typical for the test group appears in Figure 10. For illustration purposes, time progresses toward the right and a positive voltage input to the airborne TM pack results in upward movement of the traces. The three TM channels with their respective subcarrier frequencies are indicated.

The 40-kc channel was used to detect steady fuze conditions as indicated by the level shifts. The 70-kc channel, with a proportionately higher frequency response, was used to check the transient action and voltage levels of the fuze-firing circuit. (See Figure 11 for time-expanded firing pulses.) The 14.5-kc channel monitored the detected and amplified fuze-signal return.

The 14.5-kc channel shows a signal return from the target aircraft at intercept and also shows a return approximately 190 to 250 milliseconds after first motion. This additional return is caused mostly by the effect of the fire-control-system radar on the back lobe of the fuze-radiation field.[7] The 70-kc channel also indicates this influence.

The trace at the top of the figure is a measure of the received TM-signal strength. It is normally constant for a particular flight except for physical-radiation interference caused by the launch and target aircraft. The binary-timing traces provide a correlation of fuze functions to the NOTS timing system. A correlation-timing system was used by the prime contractor.

5.5 Indications of Rocket-First Motion

Two methods provided accurate indication of rocket-first motion on fuze TM records. One method depended upon shearing of the rocket umbilical cord and a second method used the closing of an inertia switch in the TM pack. TM-trace deflections from both methods appear in Figure 10. Umbilical shearing appears in the 40-kc channel and switch closing in the 70-kc channel.

On the six records indicating first motion by both methods, indications were not over eight milliseconds apart with the inertia switch closing earlier. The inertia-switch indication was used for time measurements when a choice existed.

Although the self-locking inertia switches were set at a seemingly high value of 11 g (±2 g), they were closed properly by the high acceleration following rocket-motor ignition. (Average accelerations for the Bird Dog rocket was about 24 g). The value of 11 g was set to provide a safe margin above accelerations due to rocket-handling and launch-aircraft maneuvers.

A short step on the 40-kc trace is assumed to result from circuit changes during shearing. The knife-action shearing was caused by a shear knife combined with motion of the rocket.

5.6 Telemeter Traces of Fuze Firing

Telemeter traces from the 70-kc channel about the instant of firing are shown in Figure 11. The traces illustrate the accuracy with which fuze detection, triggering, and firing is indicated. Observe that the traces from tests with proper fuze electronic operation are consistent. The "T" and "F" labels on the trace of FTBD 7 mark typical indications for triggering and firing, respectively. The traces were enlarged, with some loss of detail, from camerascope 35-mm film records, with the expanded time scale produced by a film rate of approximately 20 inches per second.

The large pulse and the smaller pulses following the firing pulse are caused by resistor-capacitor action with gas tubes in the fuze-firing circuit. This pulse was originally thought to be a result of shock of the spotting-charge explosion on fuze or telemetering circuitry. Laboratory tests at DOFL/DC showed that the firing traces, especially those on the 40-kc channel, could be closely duplicated with certain electrical loading of the firing circuit, independent of any physical shock. This explanation is supported by observations that the time between firing pulse and the large pulse appears related to the delay between triggering and firing, which is an r-c function in the same circuit.

6. CONCLUSIONS

6.1 Fuze Performance

Except for circuit malfunctions in FTBD 11 and 20, apparently all of the targets were detected properly, as indicated by smokepuffs or by normal intercept signals on TM records. Lack of spotting-charge detonation was due to a disarmed fuze in two tests, an unsuccessful design change in the firing circuit in one test, and a shorted spotting-charge circuit in a fourth test. Two early firings occurred. The improper operations resulted from miscellaneous causes commensurate with an initial flight-test program. No improper operations, except self-destruct, appeared to be a result of inherent design limitations. Improvements were made during the test program which remedied some of the consequences of the rapid schedule of the feasibility program.

6.2 Instrumentation

Instrumentation was sufficient to derive conclusions on fuze-system performance. The availability of information from several sources proved extremely valuable for decisive performance evaluation.

7. RECOMMENDATIONS

Recommendations within the scope of this report are those regarding test instrumentation and evaluation.

(1) Establish a precise time correlation between ITOR and fuze TM equipment. This could be accomplished during intercept by exposing the flash of an event lamp on the drone-camera film, and sychronizing the flash with a signal fed into the fuze TM equipment.

(2) Incorporate an exact time correlation between fuze functions and trajectory data. This could be accomplished by the specification of rocket-first motion in terms of the trajectory-data-time base, to an accuracy of within ± .01 second.

(3) Continue the use of back-up instrumentation.

(4) Conduct further studies for the determination and the improvement of test-data accuracies.

(5) In range data refer miss distance and rocket positions to a common point on the target aircraft. This will facilitate construction of intercept plots when ITOR data is not available.

(6) Due to the inconclusive results of the tests involving passing, it is recommended that more tests of the same nature be conducted. Such tests should be instrumented to obtain an accurate time correlation of fuze operation and rocket positions.

8. REFERENCES

[1] Safety and Arming Device Performance During Flight Tests of Bird Dog Rockets with Dummy Fuzes, DOFL Report TR-366, Secret.

[2] T2060 Fuze for the Bird Dog Rocket, Phase 1 Summary Report, DOFL Report PR-56-16, 25 April 1956, Secret.

[3] Safety and Arming Device for the T2060 Fuze, DOFL Report TR-191, 10 July 1955, Confidential.

[4] Reduction of Scoring Camera Data, Scoring Camera System, Douglas Aircraft Company, Inc. Report SM-14624, 1 October 1952.

[5] MK 31 MOD 0 Spotting Charge Time Delay Tests, DOFL/NAMTC Technical Memorandum 42.5-8, 28 June 1955, Confidential.

[6] Traid High Speed and Data Recording Cameras, Brochure by Traid Corporation, Sherman Oaks, California.

[7] T2060 Fuze Radar Interference Test, DOFL Technical Memorandum 42.5-9, 31 August 1955, Secret.

[8] Logbooks on the fuze, fuze power supply, and TM pack. Fuze TM records, NOTS trajectory data, final data sheets and weekly reports by Douglas Aircraft Company, DOFL/NAMTC monthly progress reports and memos, and special correspondence.

9. ACKNOWLEDGMENT

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TABLE I. LAUNCH DATA

Round Number	Fuze Test (FTBD) Number	Test Date 1955	Altitude (Ft above m.s.l)	Launch Aircraft True Air Speed (Knots)	Target Aircraft True Air Speed (Knots)	Type of Attack
34	1	9 Mar	12,830	485	172	Tail
35	2	16 Mar	18,000	505	185	Tail
36	3	16 Mar	18,440	510	187	Tail
51	4	29 Mar	8,360	520	161	Tail
52	5	29 Mar	8,460	525	162	Tail
53	6	8 Apr	18,460	448	188	Beam
56	7	12 Apr	18,350	490	190	Beam
62	8	21 Apr	8,280	477	161	Tail
63	9	21 Apr	7,400	510	156	Tail
66	10	29 Apr	28,560	503	216	Tail
69	11	20 May	14,220	517	181	Tail
72	12	25 May	18,540	479	192	Beam
73	13	25 May	18,610	479	192	Beam
79	14	14 June	18,510	479	192	Beam
80	15	14 June	18,470	479	192	Beam
81	16	25 June	8,690	532	164	Tail
82	17	1 July	11,310	453	172	Beam
84	18	1 July	11,500	467	172	Beam
87	19	8 July	18,750	503	194	Tail
90	20	8 July	18,540	470	194	Beam
100	21	16 July	18,320	500	193	Beam

TABLE II. EQUIPMENT DATA

Fuze Test (FTBD) Number	Round Number	TDD	S and A	Serial Numbers Fuze Power Pack	TM Pack	Rocket
1	34	B-2	F-75	8	6	86
2	35	B-5	F-76	1	8	87
3	36	B-4	F-135	7	14	89
4	51	B-9	F-145	6	10	90
5	52	B-8	F-140	12	12	91
6	53	B-12	F-165	31	11	94
7	56	B-13	F-166	28	13	93
8	62	B-14	F-171	33	3	92
9	63	B-1	F-164	2	2	95
10	66	B-17	F-162	14	7	96
11	69	B-27	F-146	13	18	99
12	72	B-11	F-136	9	16	88
13	73	B-6	F-154	24	15	100
14	79	B-30	F-168	20	9	98
15	80	B-20	F-167	19	5	97
16	81	B-21	F-143	34	None	102
17	82	B-38	F-155	29	1	1 spare
18	84	Spec	None	Spec	Spec	4 spare
19	87	B-34	F-161	27	17	3 spare
20	90	B-35	F-169	22	4	2 spare
21	100	B-29	F-149	36	None	101

TABLE III. FUZE SYSTEM PERFORMANCE

Fuze Test (FTBD) Number	Triggering Distance (Feet)	Closest Approach (Feet)	Arming Time (Seconds)	Arming Distance (Feet)	Self-Destruct Time (Seconds)	Triggering (or Target Detection) (Seconds)
1	69	50.4	1.49	900	7.56	1.96
2	51	49.9	1.51	910	7.97	1.95
3	-	17.	1.50	770	-	1.88
4	-	25.5	1.52	880	-	2.75
5	-	55.6	1.54	880	7.83	2.75
6	-	64.5	1.46	800	7.95	1.95
7	48	42.1	1.46	850	-	1.92
8	-	43.*	1.52	830	8.26	2.45
9	-	32.6	-	-	-	2.64
10	23	32.1	1.48	880	8.08	2.84
11	-	48.7	1.48	-	7.86	-
12	50	35.6	1.24	640	7.91	1.95
13	86	72.2	1.38	760	7.69	1.93
14	-	53.*	1.44	910	7.94	1.95
15	-	18.*	1.48	-	-	1.98
16	125*	131.*o	-	-	-	-
17	64	73 99□	1.47	850	7.92	2.08
18	-	75 31□	-	-	-	-
19	100	96 8□	1.42	870	7.81	2.91
20	-	166 152□	1.45	880	-	1.59
21	-	84*o	-	-	-	-

Refer to text for definition of headings.

* Data from ground cameras.
□ Less 100 feet in elevation.
o Burst to target c.g.

TABLE IV. FLIGHT-TEST PERFORMANCE OF FUZE

Fuze Test (FTBD) Number	Visible Smoke Puff	Fuze Electronics Section (TDD)	S and A		Remarks
			Arming	Self-Destruct	
1	Yes	Proper	Proper	Proper	-
2	Yes	Proper	Proper	Proper	-
3	Yes	Proper	Proper	Improper	No self-destruct indication
4	No	Proper	Improper	No Test	Disarming prior to intercept
5	Yes	Improper	Proper	Proper	Early firing
6	No	Improper	Proper	Proper	No firing due to experimental change
7	Yes	Proper	Proper	Improper	No indication of self-destruct
8	Yes	Proper	Proper	Proper	
9	No	Proper	Improper	No Test	No arming or self-destruct
10	Yes	Proper	Proper	Proper	-
11	No	Improper	Proper	Proper	No filament voltage
12	Yes	Proper	Proper	Proper	-
13	Yes	Proper	Proper	Proper	-
14	No	-	Proper	Proper	Shorted Smokepuff detonator circuit
15	-	Proper	Proper	No Test	Rocket struck drone after fuze triggering
16	HE burst	Proper	Proper	No Test	Target destroyed
17	Yes	Proper	Proper	Proper	Special fuze
18	None used	No test	None used	None used	Special fuze
19	Yes	Proper	Proper	Proper	Special fuze
20	Yes	Improper	Proper	No Test	Special fuze early firing
21	HE burst	Proper	Proper	No Test	Target destroyed

TABLE V. ROCKET ATTITUDES AND RELATIVE VELOCITIES AT FUZE FIRING

Fuze Test (FTBD) Number	1	2	7	10	12	13	16	17	19
Velocity relative to target (ft per sec)	2,300	2,000	2,400	2,200	2,500	2,480	2,100	2,370	2,000
Attitude (in plan view)	-6.0	0	-47	-1	-51	-65	-4	-99	-2
Attitude (in side view)	0	0	-4	-1	-1	-4	-4	-174	-4

TABLE VI. FUZE TIME DELAYS

Fuze Test (FTBD) Number	Time Delay Position Setting	Nominal Time Delay (millisecs)	Bench Measurement (millisecs) DOFL/DC	NAMTC	Time Delay During Flight (millisecs)
1	3	8	9.1	No record	7
2	5	18	17.5	No record	17
3	5	18	17.5	No record	15
4	5	18	19.2	No record	-
5	5	18	20.1	No record	17
6	5	18	17.9	15.0	-
7	5	18	16.1	No record	17
8	5	18	18.7	No record	16
9	5	18	18.2	16.4	-
10	6	26	25.4	No record	25.5
11	6	26	24.7	26.0	-
12	6	26	25.2	24.2	24.5
13	6	26	25.9	24.2	26
14	6	26	24.7	No record	-
15	6	26	25.6	No record	-
16	6	26	24.4	No record	-
17	1	20	21.0	No record	19
18	None	-	-	-	-
19	1	20	20.7	No record	20
20	1	20	20.6	No record	19
21	5	18	17.5	No record	-

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