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SUMMARY OF NAVY STUDY PROGRAM FOR F4H-1 WEAPON SYSTEM

(UNCLASSIFIED TITLE)

VOLUME XIV

J. Ryon, C. Loughmiller, M. Schmookler,
R. Lister, and I. Bellavin

RADAR DIVISION

August 1961

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SUMMARY OF NAVY STUDY PROGRAM FOR F4H-1 WEAPON SYSTEM (Unclassified Title)

VOLUME XIV

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RADAR DIVISION

AUGUST 1961

RADAR DIVISION
NAVAL RESEARCH LABORATORY

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ABSTRACT

The U.S. Naval Research Laboratory is serving as technical directors of the Navy's Air-to-Air Missile Study. The results are presented in a series of volumes under NRL Memorandum Report 754. This volume is fourteenth in the series. The study to date has been primarily concerned with the system employing the F4H-1 aircraft, the AN/APQ-72 radar and the Sparrow III-6a missile. This volume represents a continuation of the study results presented in preceding volumes.

The results of a study directed toward describing the capability of the improved Sparrow III6a missile when launched in pull-up attacks against high speed targets are detailed. Miss distance criteria are developed and miss distance results presented. Work in the area of applying these results to the Navy's tactical problem is continuing.

PROBLEM STATUS

This is an interim report; work on the problem is continuing.

AUTHORIZATION

NRL Problem 53R05-04
BuAer No. EL-42001

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Fig. 2b. Sp III Miss Distance (Improved Missile) - Pull-up Attack - X - Z Miss Distance at the Target ($\tau_0 = 0^\circ$, R_{max} Launch, Fighter Course D-2, H_F = 50,000 feet, H_T = 65,000 feet)

Fig. 2c. Sp III Miss Distance (Improved Missile) - Pull-up Attack - Y - Z Miss Distance at the Target ($\tau_0 = 0^\circ$, R_{max} Launch, Fighter Course D-2, H_F = 50,000 feet, H_T = 65,000 feet)

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Fig. 3c. Sp III Miss Distance (Improved Missile) - Pull-up Attack - Y - Z Miss Distance at the Target ($\tau_0 = 0^\circ$, R_{max} Launch, Fighter Course C-5, H_F = 50,000 feet, H_t = 65,000 feet)

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Fig. 4c. Sp III Miss Distance (Improved Missile) - Pull-up Attack - Y - Z Miss Distance at the Target ($\tau_0 = 0^\circ$, R_{max} Launch, Fighter Course D-4, H_F = 50,000 feet, H_T = 75,000 feet)

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Fig. 8c. Sp III Miss Distance (Improved Missile) - Pull-up Attack Against Maneuvering Target - Y - Z Miss Distance at the Target (τ_o = 45°, R_{max} Launch, Fighter Course E-1, H_F = 50,000 feet, H_T = 65,000 feet)

INTRODUCTION

The Bureau of Aeronautics has a project with NRL to conduct system studies directed toward establishing the tactical use capability of the Navy's Air-to-Air Missile Systems. These studies are conducted under the technical direction of the Naval Research Laboratory with all inputs derived from Navy sources. To date, study effort has been primarily directed toward revealing the tactical use capability of the F4H-1 Weapon System. In support of this effort, NRL has contracted with Westinghouse Air Arm Division for analytical services. Recommendations and conclusions to be drawn from analytical results are a Navy responsibility, and in particular the responsibility of the technical directors (NRL). This report is the fourteenth in a series directed toward revealing the tactical effectiveness of the F4H-1 Weapon System.

The Navy Study has been, and will continue to be, a cooperative effort. Wherever possible duplication has been avoided. Input data for the study has been obtained from the government facilities which most logically would cover the particular field. For example, radar test data was obtained from NATC, Patuxent; Sidewinder performance data has been obtained from NOTS, Inyokern; and Sparrow III seeker performance data was obtained from NMC, Pt. Mugu. In addition, the facilities of the various activities have been, in effect, pooled so that special talents and equipments can be employed. The results of NMC, Pt. Mugu simulator studies to ascertain the allowable launch error for Sparrow III, and the effects of hydraulic oil limits have been incorporated in the overall study. In addition, NMC has conducted tests to verify the vectoring accuracies and to determine if the field degradation applied to AI radar detection range in this study is valid. It is very important that everyone concerned recognize that a study such as this must be a team effort. It is just as important to continue this team effort on future studies under the Sparrow III-6b and other programs.

The study results, to date, have been presented in Vols. I, II, III, IV, VII, VIII, IX, X, XI and XIII of this series (references 1 through 11). The study effort covered by the volumes through X carries the system through to Sparrow III-6a missile launch. At this point it is assumed that, if the initial aircraft heading errors can be reduced to an acceptable launch error, the missile will fly perfectly to impact with the target. The probability of arrival to missile launch results presented in these preceding volumes are based upon this assumption.

The study effort covered by this volume is primarily concerned with the launch and missile guidance phases of the attack. The investigation of these phases of the attack has been divided into three parts and will be reported on in the same fashion. These three parts are:

1. Investigation of the tactical effectiveness of the F4H-1 system when employing the Sp III-6a missile as defined at the start of the Navy's

Study. This missile is referred to throughout the study as the unimproved SP III-6a.

2. Investigation of the sensitivity of system performance to Sp III 6a parameter variations.

3. Investigation of the tactical effectiveness of the F4H-1 system when employing the Sp III 6a missile as defined today. This missile will be referred to as the improved Sp III 6a.

The results of the investigation of Parts 1 and 2 above are detailed in Vols. XI, XII & XIII. These results will not be repeated in this volume except where necessary for cross referencing purposes. The results of the investigation of Part 3 above are detailed in this volume.

The material contained in this memorandum is intended primarily for Bureau information. As agreed during the project negotiation phases, except for government activities, all distribution will be handled through Bureau channels.

STUDY PROCEDURE

In preceding volumes through Vol. X, the investigation of the tactical use capability of the F4H-1 Weapon System was restricted to those phases of the attack prior to missile launch. The interceptor aircraft (including pilot, radar operator and displays), target, vectoring environment, and missile launching equations were simulated. Many possible tactical situations were examined. If the F4H-1 Weapon System arrived at a point within the allowable launch ranges and launch error, the missile was assumed to behave perfectly when launched. From the many situations examined, the probability of successful arrival to missile launch was developed for each type of attack. The study effort covered by Vols. XI and XIII (ref. 9 and 11) extends the work described in previous volumes to include missile launching and missile guidance to impact or miss at the target for the unimproved Sp III 6a missile. The results presented previously form the basis for the input conditions of the launch and guidance investigation. Typical attack conditions are examined. The results are then presented in terms of hit or miss at the target for each run examined.

The results of the study of the system utilizing the unimproved Sp III 6a missile were such, particularly in differential altitude attacks, that changes in missile performance were indicated. Further, work going on at Raytheon indicated that such changes were indeed underway. It thus became important at this point in the study program to examine the effect of several missile parameter variations. The results of this investigation are detailed in Volume XIII (ref. 11).

INPUT DATA

In any development program there are, as the result of system analysis and design and development, many changes necessary as the program progresses. Such is the case in this program. Changes have occurred in the basic AI radar and in the F4H-1 aircraft. These changes have been incorporated in the Navy Air-to-Air Missile Study and the resulting effects detailed in earlier volumes of this series. Some of the changes which have occurred during the development of the Sparrow III6a were included at an earlier date. Since this volume is primarily concerned with simulation of the missile itself and the resulting miss distances at the target, it was felt that the last order of business should be incorporation of the latest changes to this missile and associated computer. These changes and the resulting effects on system performance are detailed in the following sections.

Sp III 6a Missile

The Sparrow III missile which has been used to this point in the simulation program of the Navy's Air-to-Air Missile Study is detailed in Appendix I of Volume XI. For the most part, this information is still valid for the latest version (improved) of the Sparrow III 6a. There are areas which have changed and said changes have been included in the Navy Study and reported on in this volume.

Equation 4 of Appendix I (Volume XI) gives the average incremental missile velocity as

$$V_o = 800 \ [1 + 0.41 \ (1 - P/P_{SL})]$$

P = pressure at altitude

P_{SL} = pressure at sea level

This equation has been changed to

$$V_o = 1000 \ [1 + 0.3 \ (1 - P/P_{SL})]$$

Equations 5 and 6 of Appendix I (Volume XI) give the azimuth and elevation steering error equations as

$$\epsilon_a = \frac{57.3 \ [V_o \ \mathrm{Sin} \ \lambda a + R \frac{\omega_K}{1+S}]}{2300}$$

ϵ_a = azimuth steering error
λa = azimuth gimbal angle
R = range
ω_K = azimuth line of sight rate

$$\epsilon_e = \frac{57.3\ [-V_o \text{ Sin } \lambda_e \text{ Cos } \lambda_a - R\,\frac{\omega_j}{1+S}]}{2300} - 0.48\,\alpha_I$$

ϵ_e = elevation steering error
λ_e = elevation gimbal angle
ω_j = elevation line of sight rate
α_I = angle of attack

These equations have been changed to

$$\epsilon_a = \frac{57.3\ [V_o \text{ Sin } \lambda_a + \frac{R\,\omega_K}{1+S}]}{3400}$$

$$\epsilon_e = \frac{57.3\ [-V_o \text{ Sin } \lambda_e \text{ Cos } \lambda_a - \frac{R\,\omega_j}{1+S}]}{3400} - 0.48\,\alpha_I$$

Table I gives the Sparrow III autopilot gains used in the Navy's Study to this point. In the latest version of the Sparrow III6a, τ_3 is changed to 0.3 secs for altitude bands C & D.

The Sparrow III autopilot and seeker block diagram is given by Fig. 1. On this block diagram, Block A is shown to have a transfer equation having the form of

$$\frac{50}{1 + 0.5S}$$

In the latest version (improved) of the Sparrow III6a, this block has been changed to include a shaping network and the resulting transfer equations take the form of

$$\frac{45\left[\frac{P}{50} + 1\right]\left[\frac{P}{266} + 1\right]}{\left[\frac{P}{18.62} + 1\right]\left[\frac{P}{5.81} + 1\right]} \quad \text{(pitch channel)}$$

$$\frac{45\left[\frac{P}{60.7} + 1\right]\left[\frac{P}{292} + 1\right]}{\left[\frac{P}{19.9} + 1\right]\left[\frac{P}{5.8} + 1\right]} \quad \text{(yaw channel)}$$

The block labeled B on the diagram of Fig. 1 represents a limit and has the value of $\pm\ 80^{\circ}$/sec. In the latest version of the Sparrow III6a this limit is changed to $\pm\ 100^{\circ}$/sec. The block labeled E also represents a limit and has the value $1.0^{\circ} \pm 1.25^{\circ}$. This is changed to $0^{\circ} \pm 2.25^{\circ}$.

The above described changes are incorporated in the latest (anticipated as the final version to be studied in the Navy's Study) version of the Sparrow III6a missile. The results on system performance are detailed in the following sections.

TABLE I

SPARROW III AUTOPILOT PARAMETERS

$t \triangleq$ Time from launch (time from end of stroke)

$t_1 \triangleq$ Unlock time = (0.4 - 0.08) sec

$t_2 \triangleq$ End-of-boost time = (2.22 - 0.08) sec

$t_3 \triangleq$ Missile seeker lock-on time = (2.22 - 0.08) sec

Altitude Condition		A	B	C	D
Altitude(ft)		SL-17K	17-32K	32-46K	> 46K
τ_2 (sec)		.15	.15	0.4	0.4
τ_5 (Sec)	Yaw	4.93	3.17	1.70	1.09
	Pitch	3.87	2.49	1.33	.857
K_5 (°/g sec)		3.57	5.56	10.5	16.3
(sec)		0.0063	0.0063	0.008	0.008
G_2 (°/°sec)		$\frac{1.14}{1+25S}$	$\frac{1.14}{1+12.5S}$	$\frac{3.43}{1+25S}$	$\frac{3.43}{1+12.5S}$
K_8 (°/° sec)		0.054	0.110	0.21	0.43

Radar Analysis

The AI radar performance used in this phase of the study corresponds to that predicted for the AN/APQ-72 (XN-3). The 85% probability of detection range for this radar against a B-47 size target flying at M 1.6 at 50,000 ft where V_T/V_F=0.8 is shown by Fig. 1 of ref 9. Head-on, this radar has an 85% probability of detection at approximately 19 n. mi. when the expected 10 db of field degradation is used. The radar has gimbal limits of ±57° in azimuth and elevation. It is currently estimated that these gimbal limits will actually be ±60°. This change has not been incorporated in the study to date. A B-47 size target is used throughout this study.

Aircraft Analysis

The basic performance of the F4H-1 aircraft has been detailed in Vols. I through IV of this series. Changes in this performance have occurred during the study period covered by this report. However, these changes have not resulted in significant changes in system analyses results. Details of the performance changes which have occurred and which are now being used in the simulation program are given in Volume XII of this series (reference 10).

PULL-UP ATTACKS AGAINST NON-MANEUVERING TARGETS - IMPROVED SP III 6a

In this phase of the investigation, six families were selected from those presented previously on Table VIII of Vol. XI for re-evaluation to determine the effects of changes that have occurred in the missile and AN/APA-128 computer. Throughout the remainder of the report this will be designated as the improved Sparrow III 6a. These six families are extracted and presented here on Table II. The target of interest is a non-maneuvering one flying at either 65,000 or 75,000 feet under M 2.0 conditions. The interceptor starts the pull-up attack under V_{max} conditions.

The initial fighter conditions for the investigation of the effects of missile and computer changes are given on Table II. The conditions at launch were approximately the same as those presented for the same families in Volume XI, Table VIII. The small differences are due to missile and computer changes (equations). Thus a direct comparison of unimproved and improved SP III 6a miss distance results can be made. The first column gives the aspect angle with respect to the target nose at the start of the intercept run. The second column of Table II gives the box in the detection and vectoring probability grid (see Fig. 2 of Vol. XI) from which the intercept runs originated. Column 3 gives the fighter altitude at pull-up. The fourth column gives the fighter altitude at launch. The target altitude is given by column five. The sixth column gives the range interlock condition. All launches were made from the maximum aerodynamic range of the missile (R_{max}). The next three columns give the components of range at missile launch. Columns 10 and 11 give the azimuth and elevation steering errors at launch. Column 12 gives interceptor velocity at missile launch.

Table III summarizes the results. Column 1 gives the family number used for reference purposes. This corresponds to the same number used previously in Volume XI. Column 2 gives the figure number used in this report. The next five columns repeat initial condition information which has been given previously on Table II. Column 8 gives the noise sample being investigated and corresponds to the point on the noise spectrum curve at which the run was started. Ten noise samples were investigated for each of the five families. The last four columns of this table give the resulting overall and components of miss distance for the improved

TABLE II

Initial Conditions at Missile Launch for Pull-Up Attacks Against Non-Maneuvering Targets — Improved Sp III6a

$V_T = 1937$ ft/sec

(1) Initial Target Aspect Angle τ_o (Deg)	(2) Fighter Course	(3) Fighter Altitude at Pull-up ($ft \times 10^3$)	(4) Fighter Altitude at Launch Point ($ft \times 10^3$)	(5) Target Altitude ($ft \times 10^3$)	(6) Range Interlock Condition	Range From Target At Launch (7) R_x (ft)	(8) R_y (ft)	(9) R_z (ft)	Steering Error (10) Azimith ϵ_A (Deg)	(11) Elevation ϵ_e (Deg)	(12) Interceptor Velocity V_F (ft/sec)
0	D-2	50	55.156	65	R_{max}	25670	3950	-9844	0.996	8.857	1713
0	C-5	50	56.278	65	R_{max}	34490	10680	-8722	-0.008	0.505	1667
0	D-4	50	59.564	75	R_{max}	33430	3717	-15436	0.399	5.299	1528
45	E-1	50	54.546	65	R_{max}	26580	24520	-10450	-0.019	0.665	1735
45	E-1	40	49.200	65	R_{max}	19890	16980	-15800	-4.743	7.064	1777
45	D-1	50	57.757	75	R_{max}	17060	28050	-17243	-0.058	1.226	1604

TABLE III

Improved SPARROW III 6a Miss Distances - Pull-Up Attacks - Non-Maneuvering Target

B-47 Size Target $V_F = V_{max}$ At Pull-Up $V_T = M\ 2.0$

(1) Family No.	(2) Figure Number	(3) Initial Target Aspect Angle γ_o (deg)	(4) Fighter Course	(5) Interceptor Altitude At Pull-Up (ftx10^3)	(6) Target Altitude (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance At Target (9) R_x (ft)	(10) R_y (ft)	(11) R_z (ft)	(12) Overall Miss Distance R_{MT} (ft)
3	2a	0	-2	50	65	R_{max}	1	3.6	9.5	10.3	14.5
	2b						2	-44.5	-31.4	-107.0	120.0
	2c						3	15.0	-26.8	23.2	38.5
							4	0.6	-5.8	0.0	5.9
							5	-3.0	-44.7	-26.6	52.1
							6	0.4	26.2	9.2	27.8
							7	-4.7	-32.2	-28.9	43.4
							8	12.0	-23.1	17.8	31.5
							9	3.1	-52.9	-19.9	56.6
							10	2.8	4.7	7.4	9.1
										Mean =	39.9
										σ =	31.4
										No Noise =	55.7
4	3a	0	C-5	50	65	R_{max}	1	-1.9	-2.2	-13.3	13.7
	3b						2	12.0	-22.5	20.2	32.5
	3c						3	-38.6	86.5	-42.6	103.9
							4	-28.0	76.1	-22.6	84.1
							5	-10.8	14.9	-25.2	31.2
							6	-3.8	-0.5	-12.8	13.3
							7	-1.3	-25.8	-38.2	46.1
							8	-12.0	3.0	-42.0	43.7

TABLE III (Continued)

Improved Sparrow III 6a Miss Distances - Pull-up Attacks - Non-Maneuvering Target

B-47 Size Target $V_F = V_{max}$ At Pull-Up $V_T = M\ 2.0$

(1) Family No.	(2) Figure Number	(3) Initial Target Aspect Angle τ_o (deg)	(4) Fighter Course	(5) Interceptor Altitude At Pull-up (ftx10^3)	(6) Target Altitude (ftx10^3)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance At Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Distance R_{MT} (ft)
							9	-9.9	12.7	-22.4	27.6
							10	-1.9	6.6	2.4	7.3
										Mean =	40.3
										σ =	29.8
										No Noise =	20.7
7	4a	0	D-4	50	75	R_{max}	1	-12.4	24.1	21.3	34.4
	4b						2	-11.0	-23.7	-25.6	36.6
	4c						3	-35.7	120.1	-44.1	132.9
							4	-20.6	97.7	-19.7	101.8
							5	-41.1	33.8	-78.3	94.6
							6	-11.8	60.7	-8.8	62.4
							7	-27.4	-7.0	-59.2	65.6
							8	-18.4	-10.1	-45.4	50.0
							9	-16.3	8.5	-29.5	34.8
							10	2.7	5.3	8.2	10.1
										Mean =	62.32
										σ =	35.60
										No Noise =	23.9

TABLE III (Continued)

Improved Sparrow III 6a Miss Distances - Pull-Up Attacks - Non-Maneuvering Target

?-47 Size Target $V_F = V_{max}$ At Pull-Up V_T = M 2.0

(1) Family No.	(2) Figure Number	(3) Initial Target Aspect Angle τ_o (deg)	(4) Fighter Course	(5) Interceptor Altitude At Pull-up (ftx10³)	(6) Target Altitude (ftx10³)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distance At Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Distance R_{MT} (ft)
16	5a	45	E-1	50	65	R_{max}	1	-21.9	19.5	-10.7	31.2
	5b						2	-4.2	-10.0	-38.2	39.7
	5c						3	-12.5	0.7	-26.4	29.3
							4	-29.3	5.9	-57.9	65.1
							5	-11.4	0.1	-26.4	28.7
							6	-5.4	5.9	-1.7	8.2
							7	1.0	11.0	30.0	32.0
							8	-30.7	29.7	-6.0	43.1
							9	-7.2	1.8	-15.1	16.8
							10	-9.6	7.7	-12.9	17.8
										Mean =	31.2
										σ =	15.1
										No Noise =	7.0
22	6a	45	E-1	40	65	R_{max}	1	-37.1	-4.5	-49.7	62.2
	6b						2	-75.4	46.3	-39.4	96.8
	6c						3	-73.6	39.6	-47.0	95.9
							4	-67.8	43.9	-36.7	88.7
							5	-72.4	51.6	-33.8	95.1
							6	-31.6	9.8	-28.2	43.5
							7	-50.0	7.8	-53.8	73.9
							8	-39.6	20.2	-25.7	51.4

TABLE III (Continued)

Improved SPARROW III 6a Miss Distances - Pull-Up Attacks - Non-Maneuvering Target

B-47 Size Target $V_F = V_{max}$ At Pull-Up V_T = M 2.0

(1) Family No.	(2) Figure Number	(3) Initial Target Aspect Angle τ_o (deg)	(4) Fighter Course	(5) Interceptor Altitude At Pull-Up ($ft \times 10^3$)	(6) Target Altitude ($ft \times 10^3$)	(7) Range Interlock Condition	(8) Noise Sample	Miss Distances At Target (9) R_X (ft)	(10) R_Y (ft)	(11) R_Z (ft)	(12) Overall Miss Distance R_{MT} (ft)
							9	-57.6	74.7	6.0	94.5
							10	-31.3	7.7	-28.8	43.2
										Mean =	74.52
										σ =	21.4
										No Noise =	38.7
27	7a	45	D-1	50	75	R_{max}	1	-13.4	3.5	-9.5	16.8
	7b						2	-77.8	43.0	-8.3	89.3
	7c						3	-24.2	6.9	-12.7	28.2
							4	-36.3	7.4	-24.6	44.5
							5	1.7	-14.2	-21.0	25.4
							6	-48.4	17.8	-22.8	56.4
							7	-17.2	3.0	-11.8	21.0
							8	-27.9	3.5	-23.7	36.8
							9	-38.4	3.3	-34.6	51.8
							10	-23.7	-11.5	-42.2	49.7
										Mean =	42.0
										σ =	20.4
										No Noise =	22.0

missile against this M 2.0, B-47 size target. At the end of each family, the mean miss distance, 1 σ distribution of miss distance and no noise miss distance are given. The term "no noise" as used here applies only to the missile launch and guidance phase. During the runs involved in this type of investigation, missile launching transients, and radome refraction remained in the simulated missile flights. Target noise effects only were neglected. Noise effects on the interceptor portion of the investigation were also present.

Corresponding results for pull-up attacks against non-maneuvering targets for the unimproved Sparrow III are given on Table X of Volume XI. Comparing the results obtained for the improved Sparrow III with those given in Volume XI it is seen that for essentially the same initial conditions the miss distance is reduced appreciably. For example, referring to noise Sample 7 of Family 3 it is seen that the overall miss distance is reduced from 66.8 feet to 43.4 feet. For this entire family the mean miss distance is reduced from 61.0 feet to 39.9 feet. This same general trend is true for the remainder of the families examined. The results are shown pictorially on Figs. 2a through 7c. On each of these figures the mean miss distances for each launch are plotted with respect to the geometrical center of a B-47 size target. There are three figures corresponding to each of the families of Table III. For example, 2a through 2c represent the resulting miss distance for family 3 of Table III. Figure 2a shows the resulting X - Y coordinates of the miss distances, figure 2b shows the resulting X - Z coordinates of the miss distances, and figure 2c shows the resulting Y - Z coordinates of the miss distances. On each of the miss distance plots of figures 2a through 7c the mean miss distance (mean of 10 shots shown by circles with numbers) is plotted as a black square. The "no noise" results are plotted as black circles.

It is now important to compare the results of using the improved missile and computer with those obtained using the unimproved version using the same lethality criteria as used before in Volume XI (ref. 9). Table IV shows the miss distance results for the improved Sparrow III 6a when these same lethality criteria are used. The first eight columns are repeats of information given on Table III. Column 9 of Table IV shows the percentage of runs where the missile was observed to pass within 25 feet C.G. to C.G. of the target. Column 10 gives the percentage of observed runs which passed within 10 feet (skin-to-skin) of the target. The results are consistently low. Column 11 compares the miss distance results using either of the two lethality criteria used before (25 CG to CG or 10 ft S to S). Referring to this column, it is seen that the percentage of successful missile shots investigated are low. Considering that only those initial conditions which satisfied the criteria for successful missile launch were used for the missile guidance investigation, the percentages resulting are much lower than required.

Table V compares the miss distance results obtained for the unimproved and the improved Sparrow III6a missiles. The first six columns of this table give initial conditions. Column 7 gives the version of the missile being investigated (either improved or unimproved). Columns 8 and 9 compare the mean miss distance results and the standard deviation

TABLE IV

Improved Sparrow III 6a Miss Distance Results - Pull-Up Attacks

B-47 Size Target $V_F = V_{max}$ At Pull-Up $V_T = M\ 2.0$

(1) Family Number	(2) Initial Target Aspect Angle τ_o (Deg)	(3) Fighter Course	(4) Interceptor Altitude At Pull-Up (ftx10^3)	(5) Target Altitude (ftx10^3)	(6) Range Interlock Condition	(7) Mean Miss (ft)	(8) Standard Deviation σ (ft)	(9) Percent of Runs Within 25 ft G.G. to C.C. (%)	(10) Percent of Runs Within 10 ft Skin to Skin (%)	(11) Percent of Runs Which Satisfy Either 25 ft C.G. to C.G. or 10 ft Skin-to-Skin Criteria (%)
3	0	D-2	50	65	R_{max}	39.4	31.4	30	40	40
4	0	C-5	50	65	R_{max}	40.3	29.8	40	30	40
7	0	D-4	50	75	R_{max}	62.32	35.6	10	20	20
16	45	E-1	50	65	R_{max}	31.2	15.1	30	10	30
22	45	E-[illegible]	40	65	R_{max}	74.52	21.4	0	0	0
27	45	D-1	50	75	R_{max}	42.0	20.4	30	30	40

TABLE V

Comparison of Miss Distance Results For Improved and Unimproved Sparrow III 6a - Pull-Up Attacks

Non-Maneuvering Target   B-47 Size Target V_T = M 2.0 $V_F = V_{max}$ at Pull-Up

(1) Family Number	(2) Initial Target Aspect Angle τ_o (Deg)	(3) Fighter Course	(4) Interceptor Altitude At Pull-Up (ftx10^3)	(5) Target Altitude (ftx10^3)	(6) Range Interlock Condition	(7) Version of Sp III Investigated	(8) Mean Miss (ft)	(9) Standard Deviation σ (ft)	(10) Percent of Runs Within 25 ft C.G. to C.G. (%)	(11) Percent of Runs Within 10 ft Skin-to Skin (%)
3	0	D-2	50	65	R_{max}	Unimproved Improved	61.0 39.4	43.6 31.4	10 30	20 40
4	0	C-5	50	65	R_{max}	Unimproved Improved	71.0 40.3	42.7 29.8	10 30	0 30
7	0	D-4	50	75	R_{max}	Unimproved Improved	131.7 62.32	45.9 35.6	0 10	0 20
16	45	E-1	50	65	R_{max}	Unimproved Improved	31.4 31.2	21.0 15.1	50 30	40 30
22	45	E-1	40	65	R_{max}	Unimproved Improved	73.5 74.52	20.3 21.4	0 0	0 0
27	45	E-1	50	75	R_{max}	Unimproved Improved	112.1 42.0	34.3 20.4	0 20	0 30

of miss. The results for the unimproved missile are copies from those presented in Volume XI (ref. 9). The percent of the missile runs observed to pass within 25 ft CG to CG for the two versions of the Sparrow III6a examined is given by Column 10. The percentage of runs observed to pass within 10 ft skin-to-skin are given by Column 11. This comparison of results indicates that the improved Sparrow III6a does indeed improve the probability of successfully killing the target. However, the improvement is not great. In addition, the end results are still low.

Effect of Target Maneuver

A cursory examination of the effect of target maneuver on system effectiveness when using the improved Sparrow III6a was made. The target maneuver used is the same as that described previously in Volume XI (ref. 9); namely a 1g crisscross maneuver with maximum change of heading relative to the straight line flight path of 30°. For this investigation, only two families were examined. The results are shown in Table VI. The first seven columns of this table give family number, figure numbers and the initial conditions. Column 8 gives the initial target maneuver. For this investigation the target either makes no maneuver or starts a 1g criss-cross maneuver to the right of his initial flight path. The last four columns of this table give the overall miss distance and the components of miss for both of these maneuver conditions. For the first family examined (Family 16) ten noise samples were examined. Referring to the maneuver to the right results, it is seen that the overall miss distances are in some cases decreased by the maneuver of the target. At the end of this family the mean and no noise miss distance are given for both maneuver conditions. Referring back to Volume XI (ref. 9) and comparing the effects of target maneuver (for the same family) obtained for the unimproved Sparrow III6a with those of the improved Sparrow III6a, it is seen that there is a large improvement. Figs. 6a through [illegible] illustrate some of the results of this phase.

REMAINING STUDY EFFORT

The details given in this report describe the concluding phase of the Navy's Air-to-Air Missile Study as related to the system employing the Sparrow III6a. It is anticipated that two additional reports will be issued on the results of this study. The first of these will detail the parameter variations encountered in the missile simulation and the second will be a formal report summarizing the results obtained in the entire study of the system employing the Sparrow III6a. There will be a continuing effort directed toward employing the results in the developing and testing of the system. Where applicable, memorandum reports will be issued detailing this effort.

[illegible]

TABLE VI (Continued)

Improved Sparrow III 6a Miss Distances - Pull-Up Attacks Against Maneuvering Target

$\gamma_F = \gamma_{max}$ at Pull-Up V_T = M 2.0

(1) Family Number	(2) Figure Number	(3) Initial Target Aspect Angle γ_c (Deg)	(4) Fighter Course	(5) Interceptor Altitude At Pull-Up (ftx10³)	(6) Target Altitude (ftx10³)	(7) Range Interlock Condition	(8) Noise Sample	(9 Initial Target Maneuver	(10) Overall Miss Distance R_{MT} (ft)	Miss Distance At Target (11) R_X (ft)	(12) R_Y (ft)	(13) R_Z (ft)
							Mean	None	= 31.2			
								Right	= 35.14			
							σ	None	= 15.1			
								Right	= 16.5			
							No Noise	None	= 7.0			
								Right	= 61.9			
27		45	D-1	50	[illegible]5	R_{max}	1	None	16.8	-13.4	3.5	-9.5
								Right	237.2	75.3	-175.7	-140.4
							2	None	89.3	-77.8	43	-8.3
								Right	305.7	58.7	-215.3	-208.9
							3	None	28.2	-24.2	6.9	-12.7
								Right	184.5	16.1	-122.6	-136.9
							4	None	44.5	-36.3	7.4	-24.6
								Right	98.0	-20.6	70.6	64.8
							5	None	25.4	1.7	-14.2	-21
								Right	166.1	28.0	-113.8	-117.7

CONCLUSIONS AND RECOMMENDATIONS

1. When the improved Sparrow III6a (all changes anticipated for the missile to be employed in the final system) is used in pull-up attacks against high speed, high altitude targets (M 2.0 at 65,000 ft and above) on intercept runs conducted in a region of highest conversion to missile launch potential, the miss distance results are marginal.

2. When pull-up attacks are made against a non-maneuvering M 2.0 target flying at 65,000 ft, the miss distances are decreased from those achieved with the unimproved missile. However, the results are still far too low. For example, when these pull-up attacks are made head-on, the percentage of runs observed to pass within 25 ft CG to CG of the target was 30%. When the aspect angle (Γ_0) is increased to 45° the probability results obtained were 0% and 30% (see Table IV).

3. When the target is allowed to start a simple 1g criss-cross maneuver at AI radar lock-on the improved Sparrow III6a miss distances against this high altitude, high speed target are excessive (see Table VI).

ACKNOWLEDGEMENTS

The data presented in this report represents the results, to date, of the Navy's Air-to-Air Missile Study Program. The analytical results, including those from which the figures were derived, are the results of the computational work underway at Westinghouse Air Arm Division. A large portion of the data reduction required for material presented in this volume was actually accomplished at Westinghouse and reviewed for accuracy by the Technical Directors. In addition, results of analysis underway at NMC, Pt. Mugu are included. The data from which the definition of the Sparrow III missile and the AN/APA-128 computer resulted were obtained from the Raytheon Mfg. Co. Definition of the aircraft performance resulted from the cooperative effort of the McDonnell Aircraft Company. Test data on AI radar performance was obtained from NATC, Patuxent. The authors would like to thank members of these activities for their cooperation.

This report was prepared by the following members of the System Section - Equipment Research Branch.

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M. Schmookler I. Bellavin

R. Lister

REFERENCES

1. "Summary of Navy Study Program for F4H-1 and F8U-3 Weapons Systems, Volume I", NRL Memorandum Report 754, Nov 1957, Confidential.

2. "Summary of Navy Study Program For F4H-1 and F8U-3 Weapons Systems, Volume II, Appendices to NRL Memorandum 754", Confidential.

3. "Summary of Navy Study Program For F4H-1 and F8U-3 Weapons Systems, Volume III", NRL Memorandum Report 754, May 1958, Confidential.

4. "Summary of Navy Study Program For F4H-1 and F8U-3 Weapons Systems, Volume IV, Appendices to NRL Memorandum Report 754", Confidential.

5. "Summary of Navy Study Program For F4H-1 and F8U-3 Weapons Systems, Parameter Plots for Co-altitude Attacks, Volume VII", NRL Memorandum Report 754, Confidential.

6. "Summary of Navy Study Program For F4H-1 and F8U-3 Weapons Systems, Parameter Plots for Pull-Up Attacks, Volume VIII", NRL Memorandum Report 754, December 1958, Confidential.

7. "Summary of Navy Study Program For F4H-1 Weapon System, Volume IX", NRL Memo Report 754, November 1959, Confidential.

8. "Summary of Navy Study Program for F4H-1 Weapon System, Parameter Plots for Pull-Up Attacks, Volume X", NRL Memo Report 754, In Preparation, Confidential.

9. "Summary of Navy Study Program for F4H-1 Weapon System, Volume XI", NRL Memo Report 754, In Preparation, Confidential.

10. "Summary of Navy Study Program for F4H-1 Weapon System, Volume XII, Appendices to NRL Memorandum 754", Confidential.

11. "Summary of Navy Study Program for F4H-1 Weapon System, Volume XIII", NRL Memo Report 754, In Preparation, Confidential.

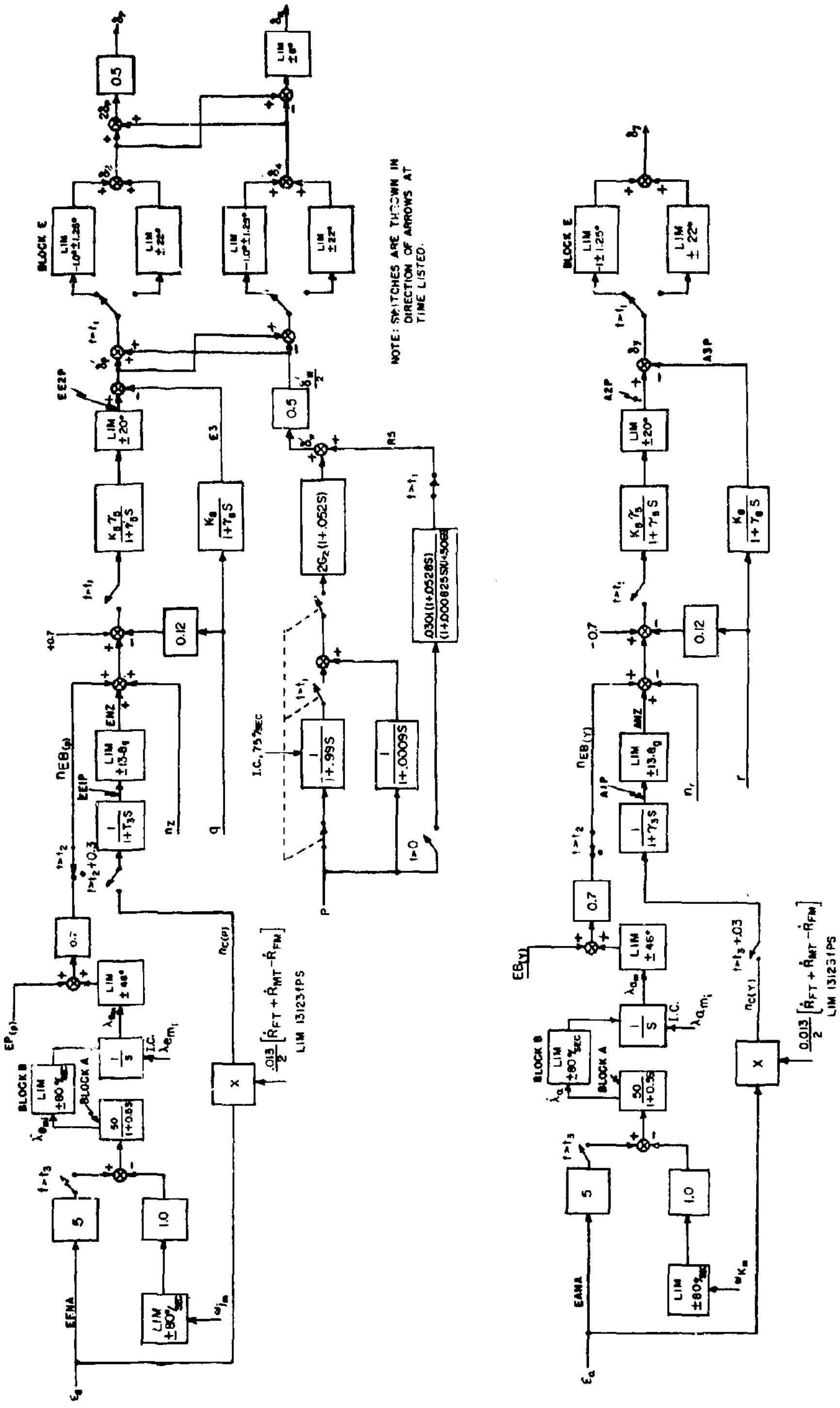

Fig. 1 - Sparrow III Autopilot and Seeker Block Diagram

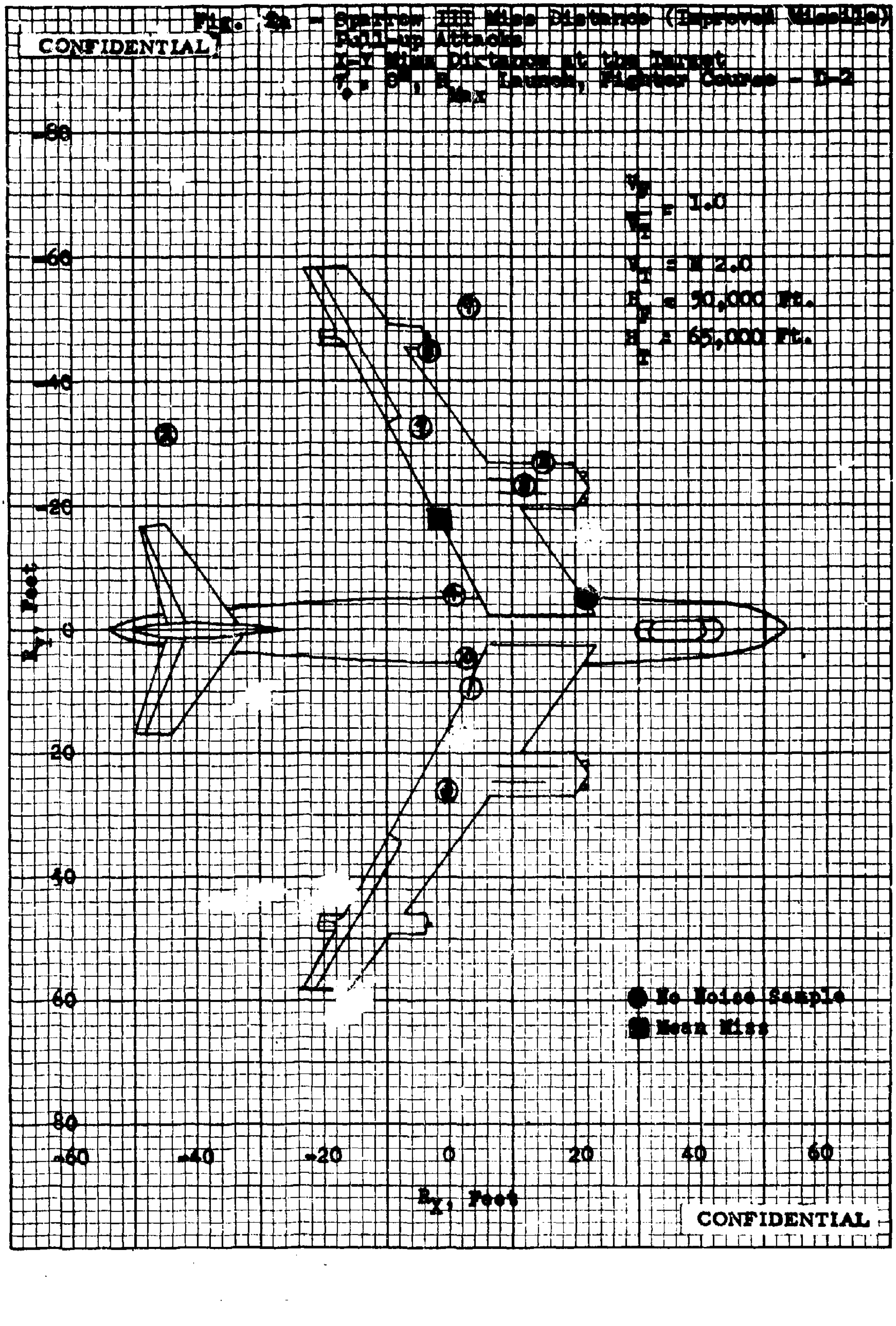
Fig. 2a - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_\phi = 0°$, R_{Max} Launch, Fighter Course - D-2
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$V_F / V_T = 1.0$
V_T = M 2.0
H_F = 50,000 Ft.
H_T = 65,000 Ft.
No Noise Sample
Mean Miss
R_Y, Feet
R_X, Feet
-80
-60
-40
-20
0
20
40
60
80
-60
-40
-20
0
20
40
60
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Fig. 2b - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
X-Z Miss Distance at the Target
$\gamma_o = 0°$, R_{max} Launch, Fighter Course - D-2

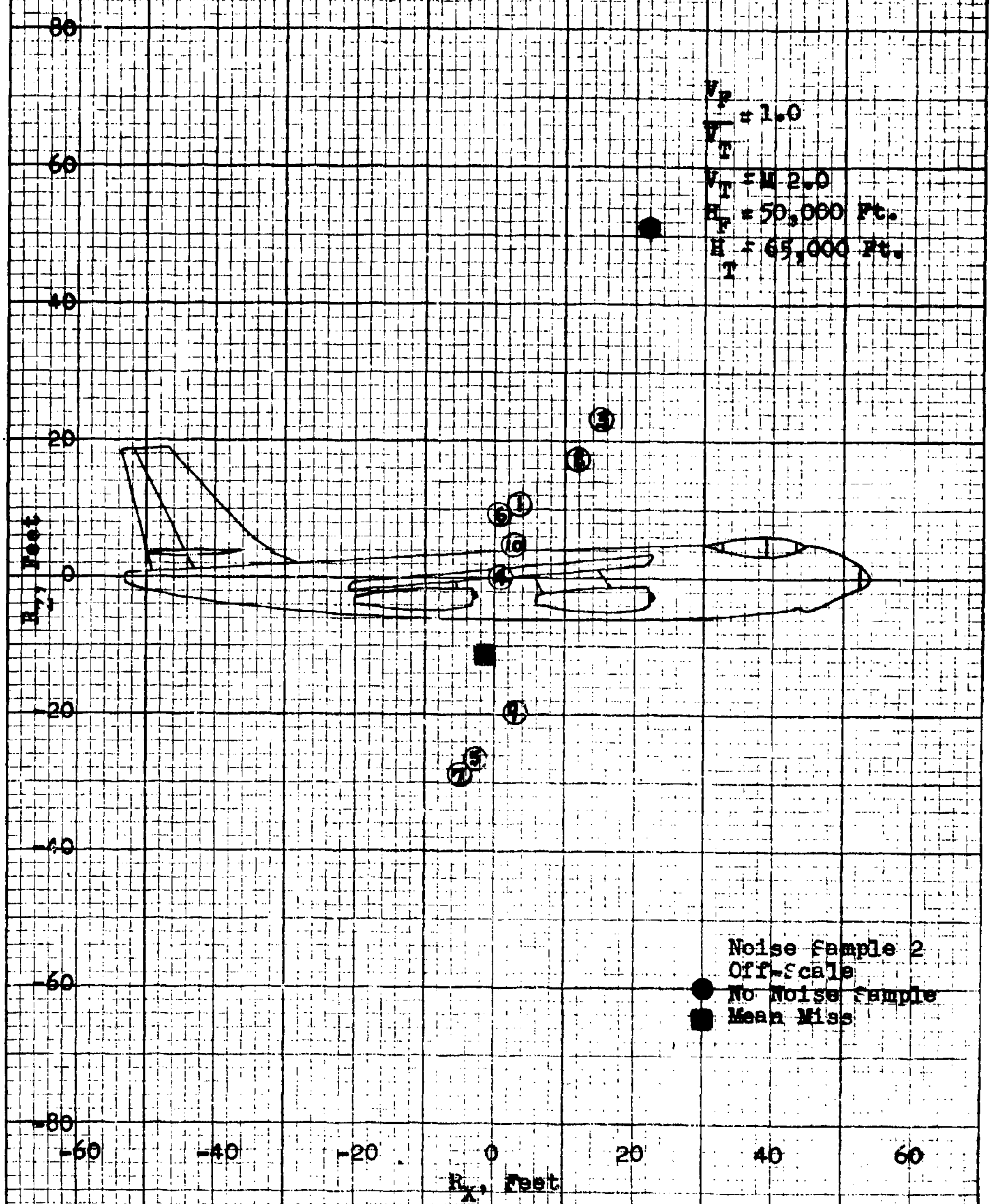

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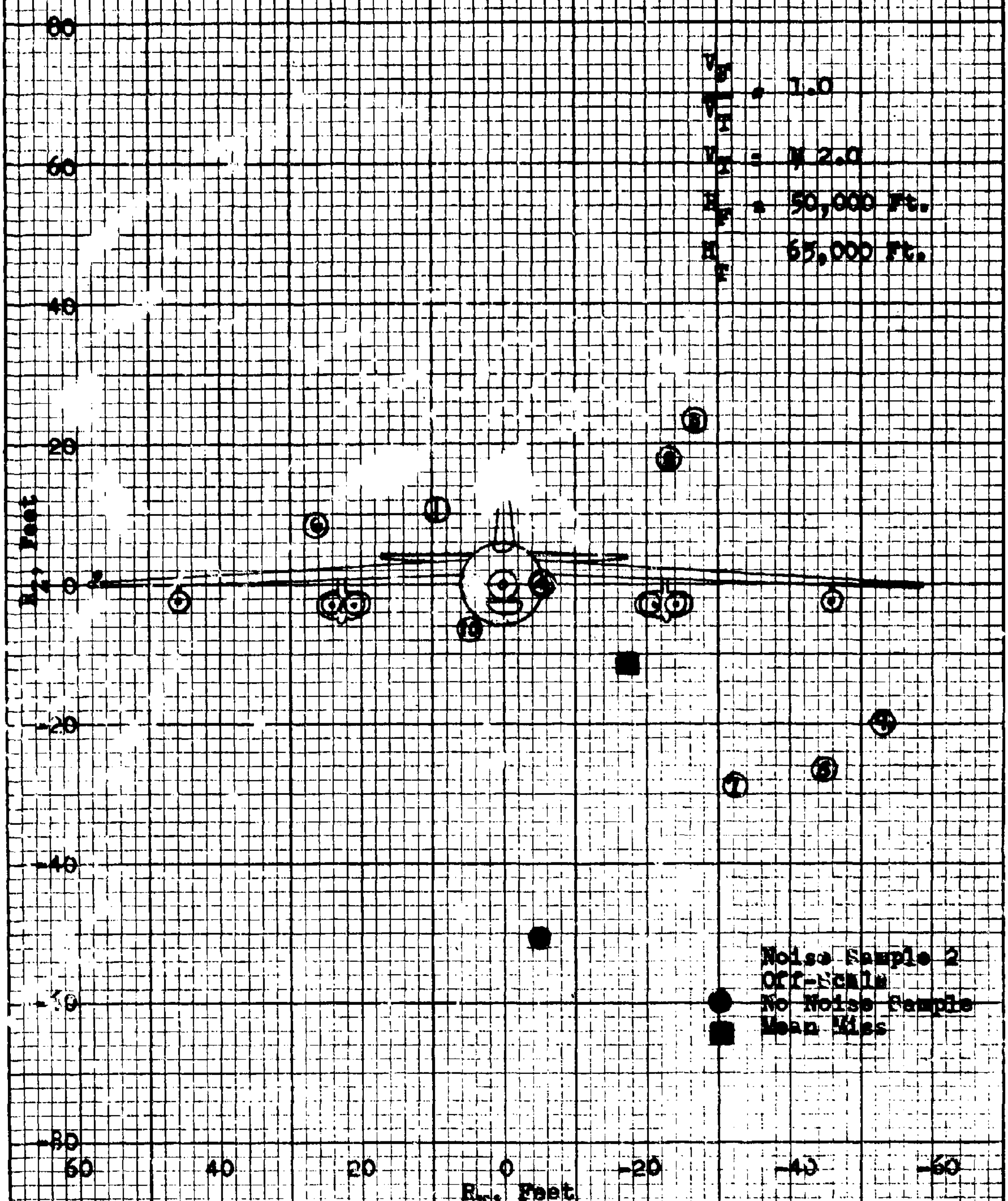
Fig. 29- Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
Y-Z Miss Distance at the Target
$\tau_g = 0°$, R_{Max} Launch, Fighter Course - D-2



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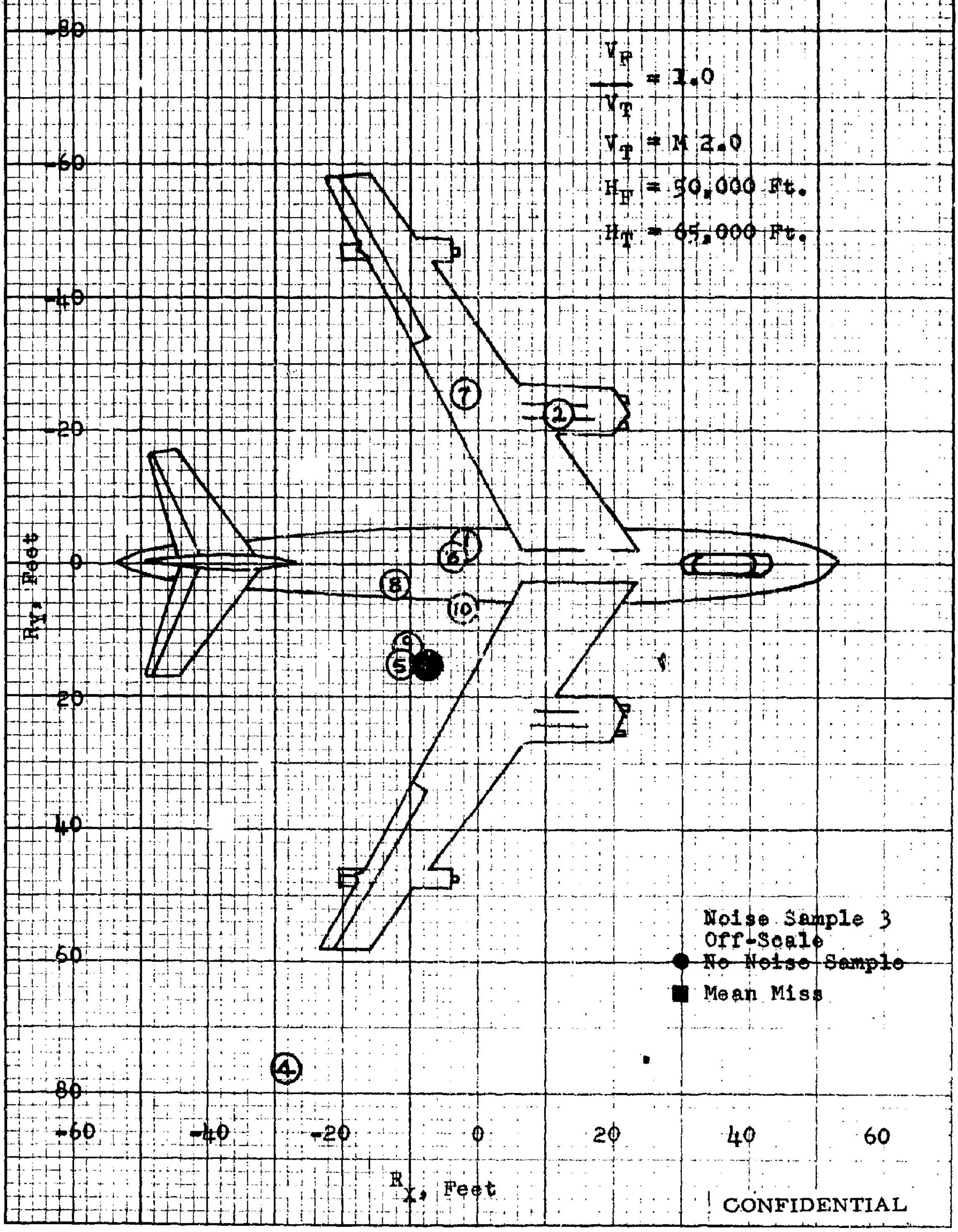

Fig. 3a - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
X-Y Miss Distance at the Target
$\tau_o = 0^\circ$, R_{Max} Launch, Fighter Course - C-5

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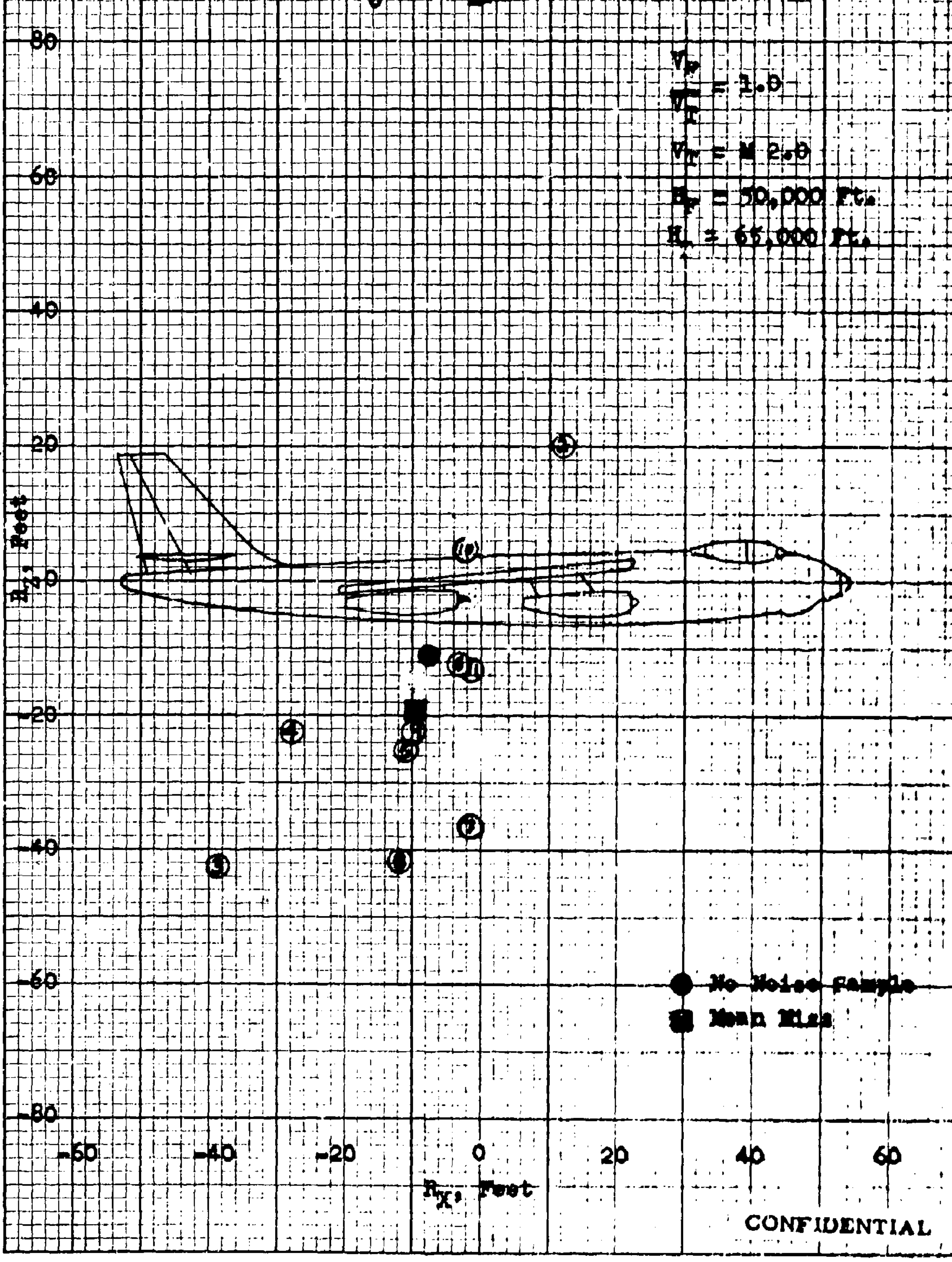

Fig. 3b - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
X-Z Miss Distance at the Target
$\Gamma_o = 0^\circ$, R_{max} Launch, Fighter Course - C-5

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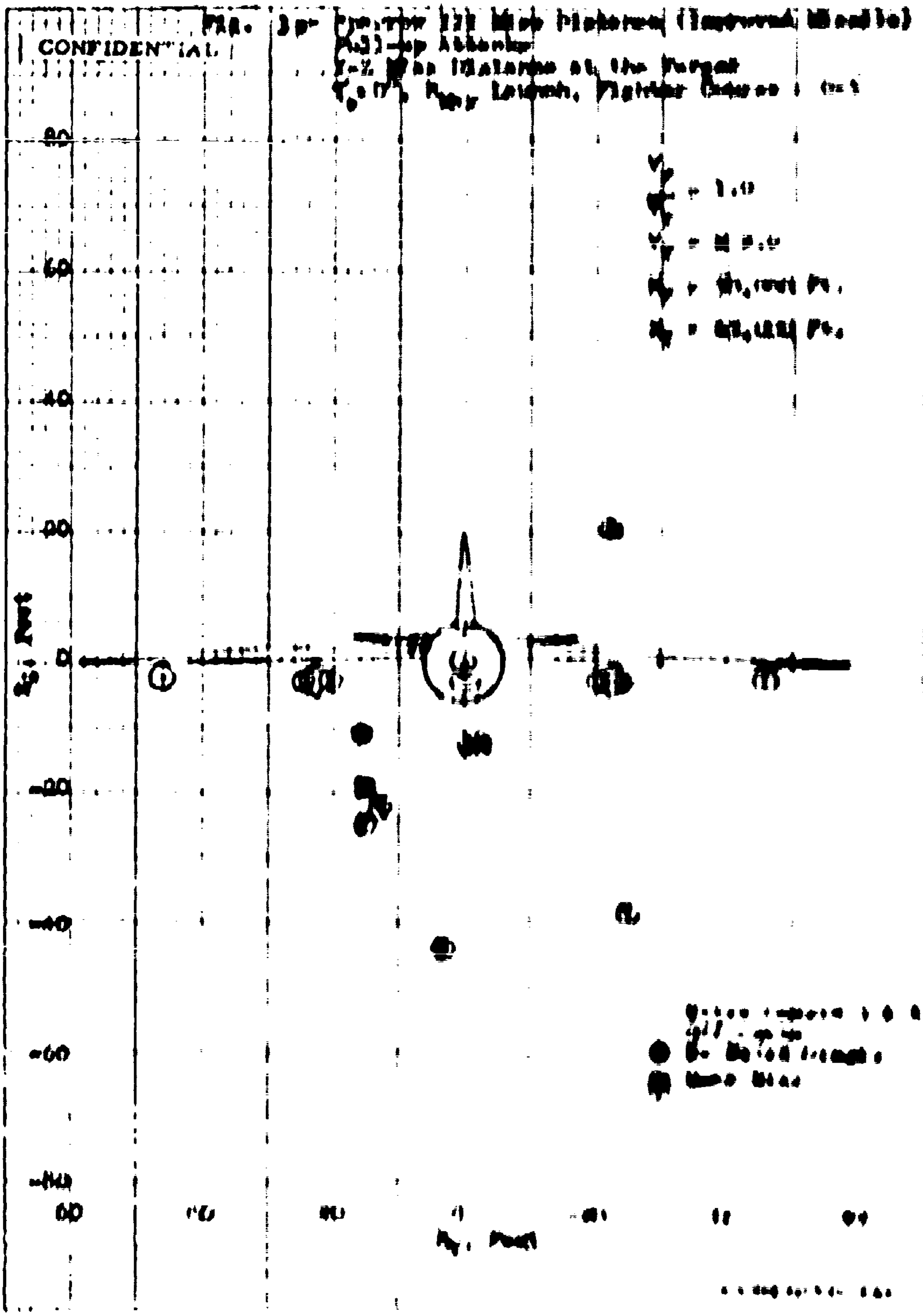

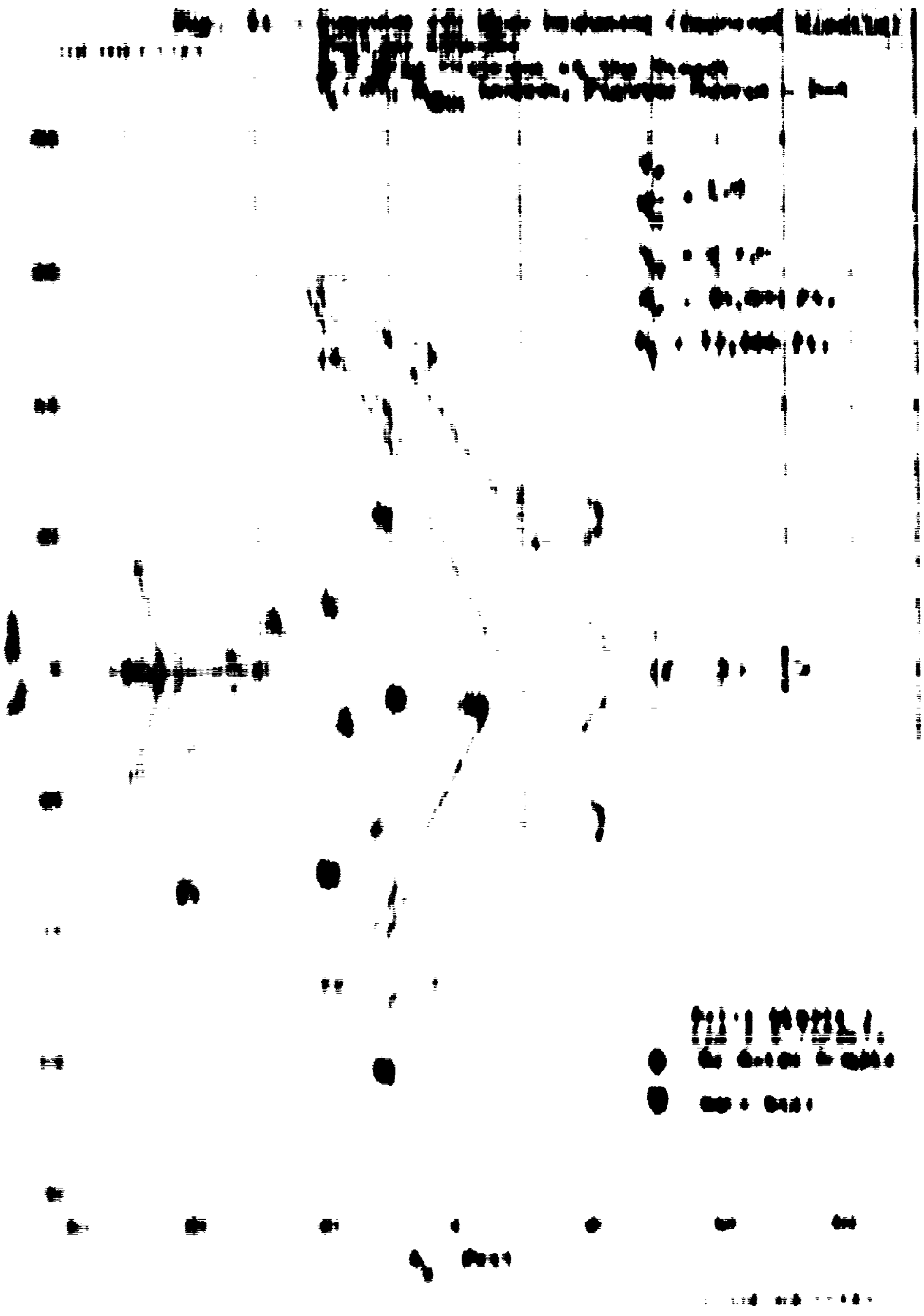

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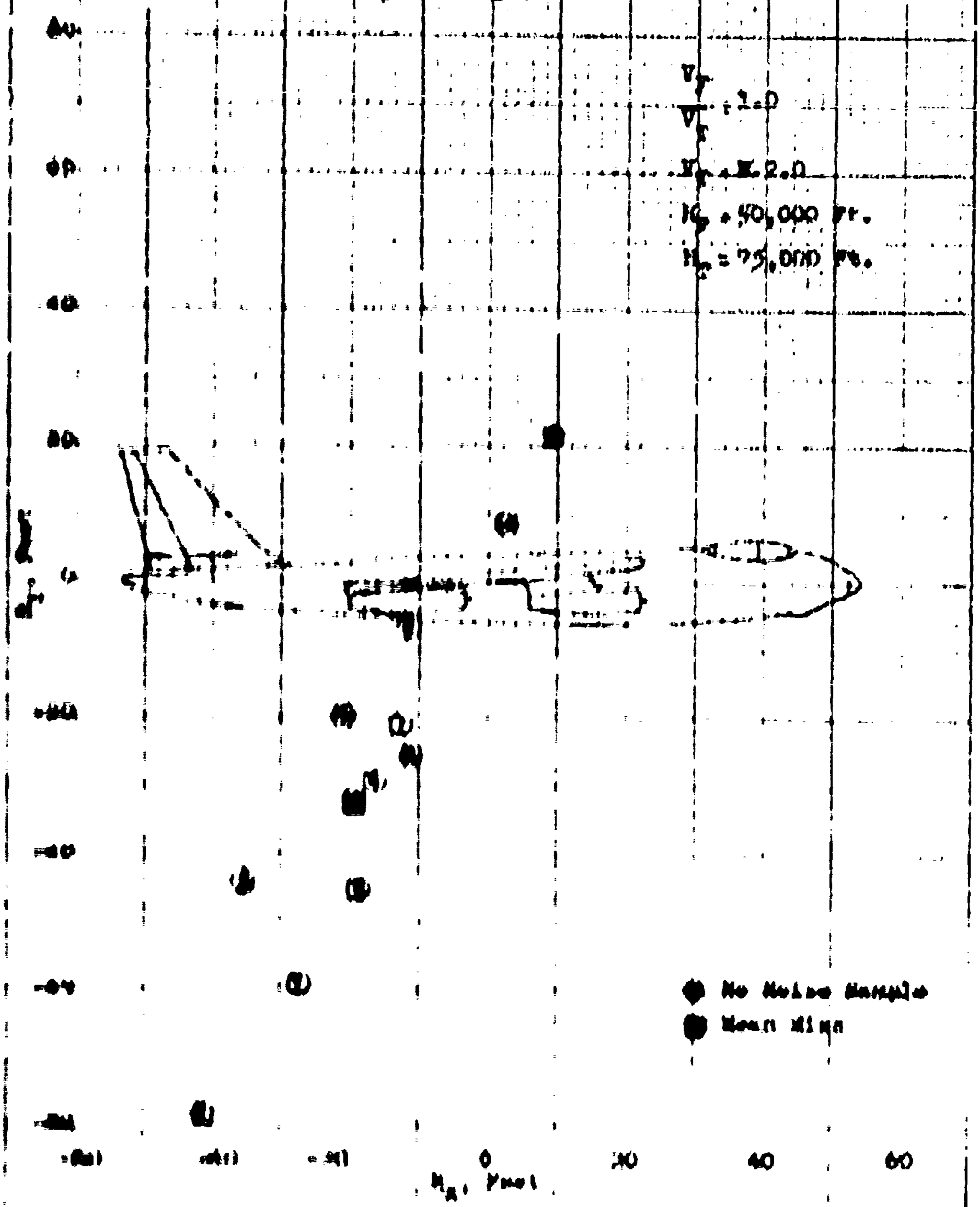
Fig. 4b - Sparrow III Miss Distance (Improved Missile) Pull-up Attacks
X-Z Miss Distance at the Target.
τ_0 = [illegible], R_{max} Launch, Fighter Course - D-4



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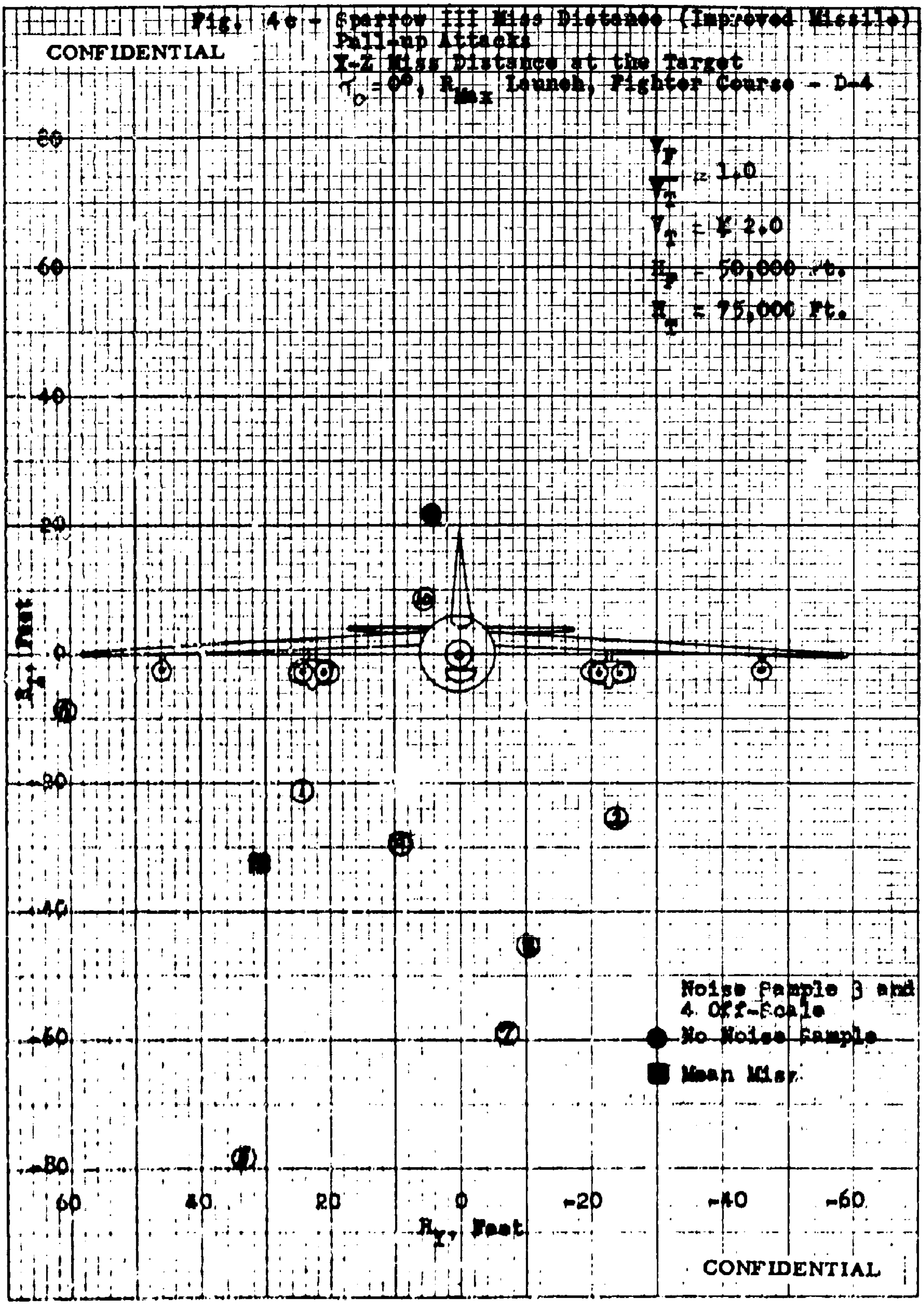

Fig. 4e - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_o = 0°$, R_{Max} Launch, Fighter Course - D-4

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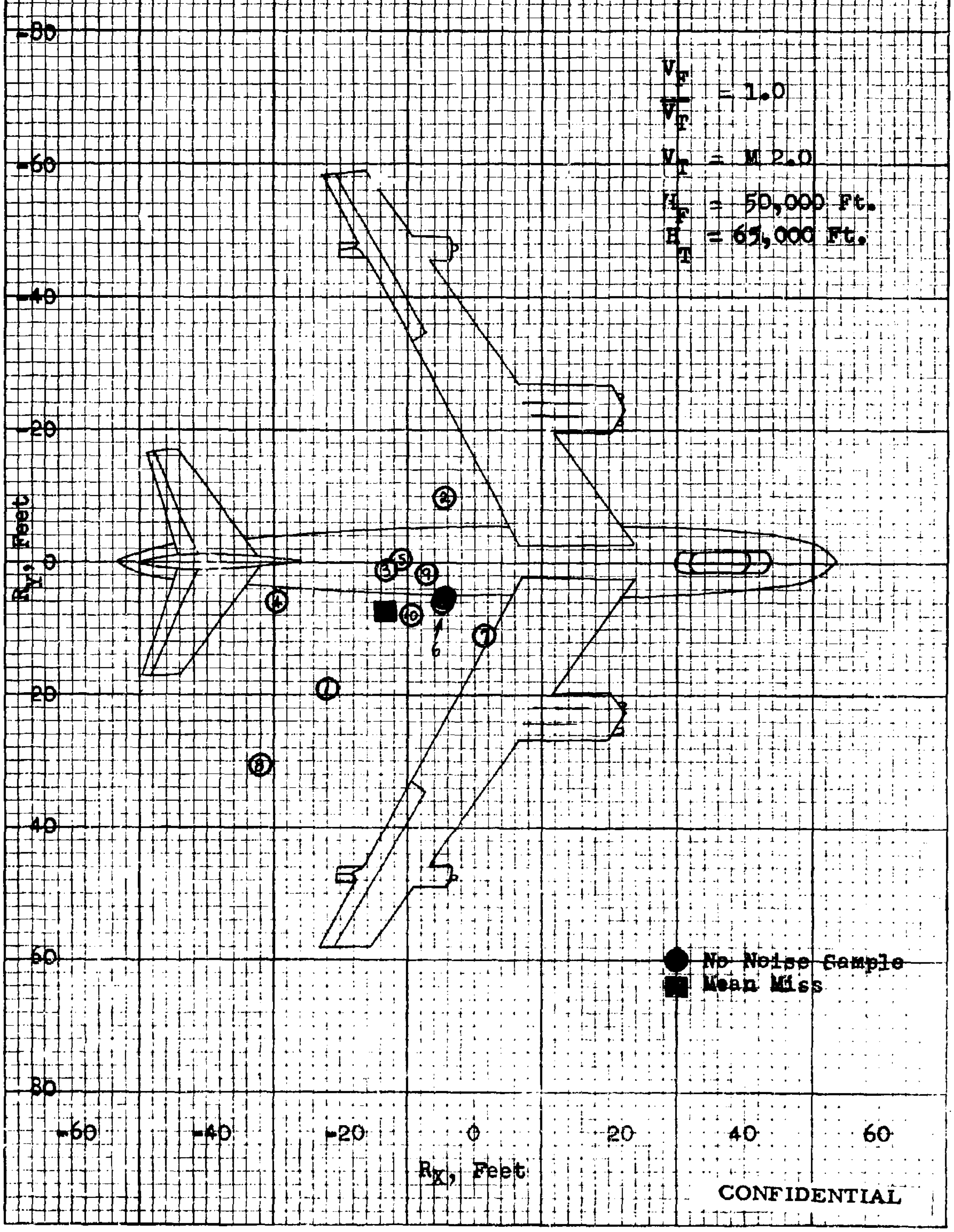
Fig. 5a - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
X-Y Miss Distance at the Target
$\Gamma_o = 45^o$, R_{Max} Launch, Fighter Course - E-1



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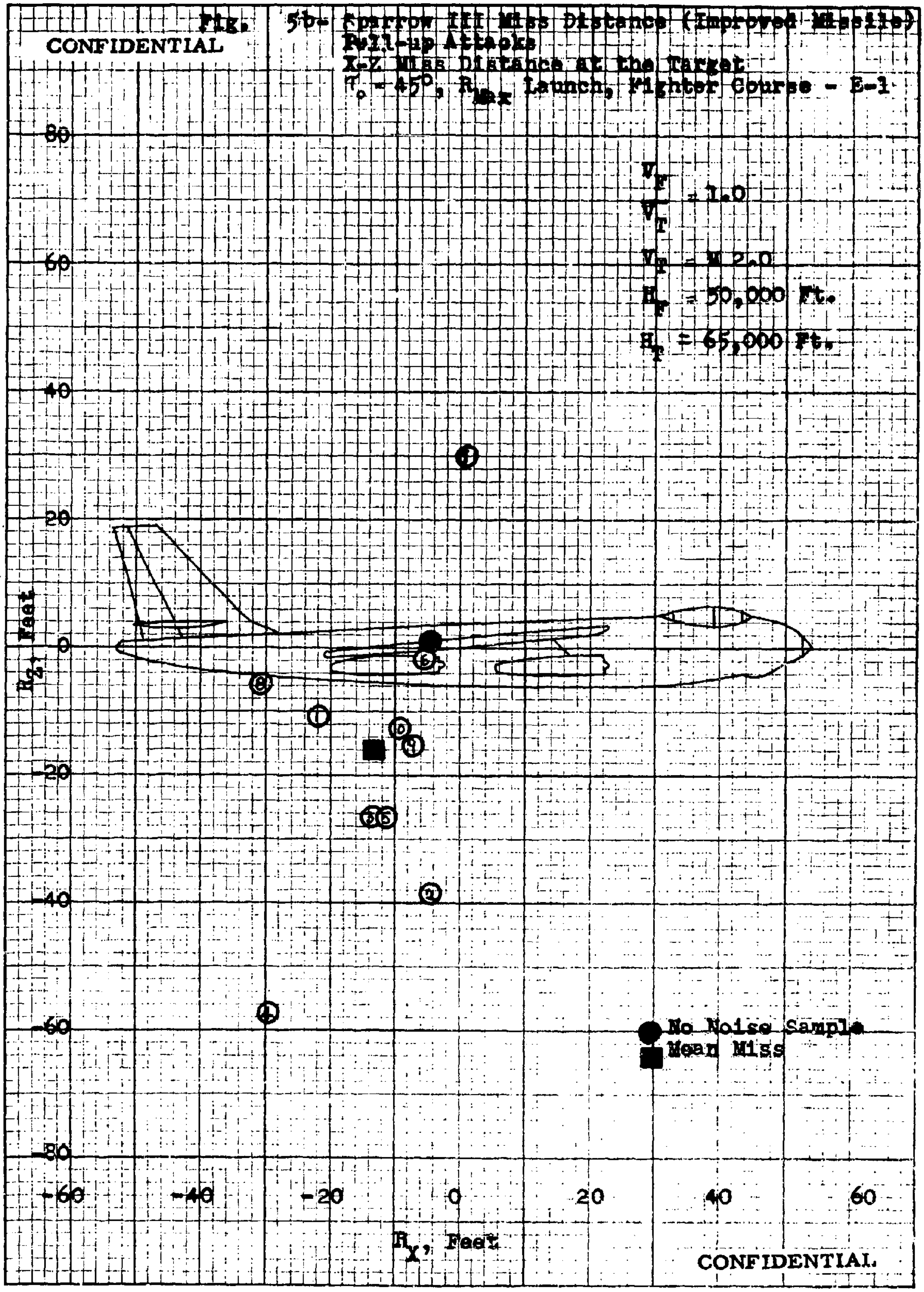

Fig. 5b- Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
X-Z Miss Distance at the Target
$T_o = 45°$, R_{Max} Launch, Fighter Course - E-1

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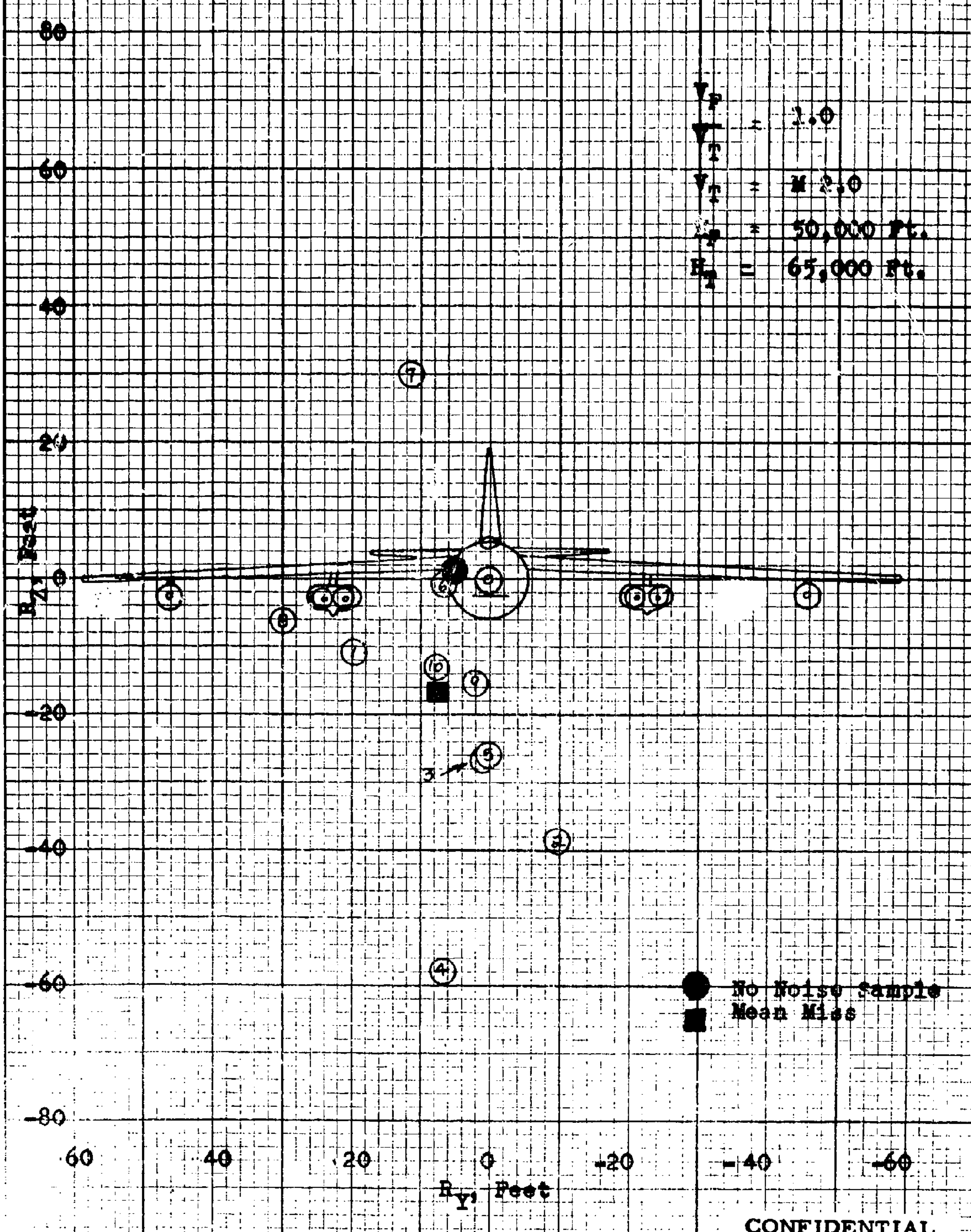
Fig. 5a - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
Y-Z Miss Distance at the Target
$\lambda_o = 45^\circ$, R_{Max} Launch, Fighter Course - E-1



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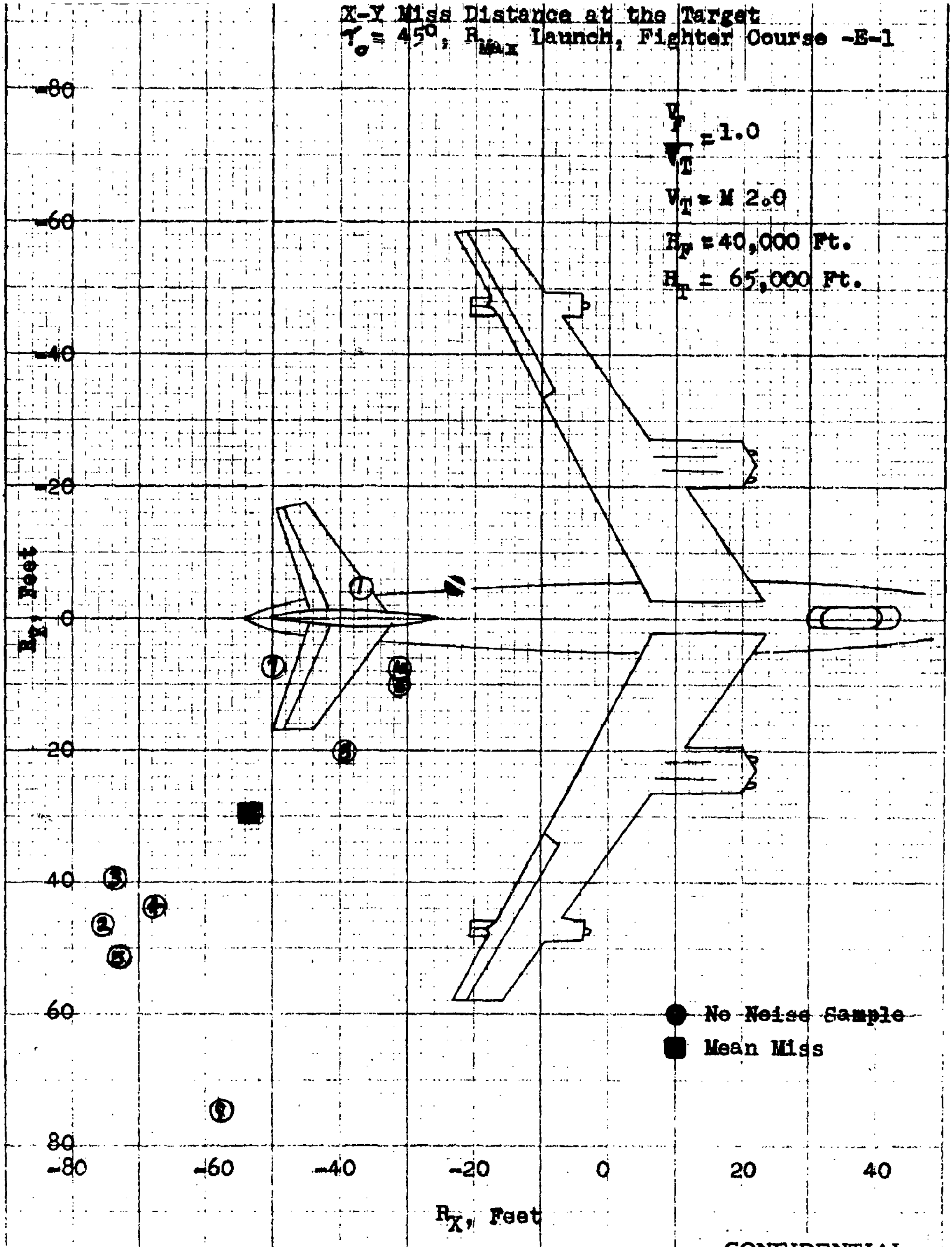

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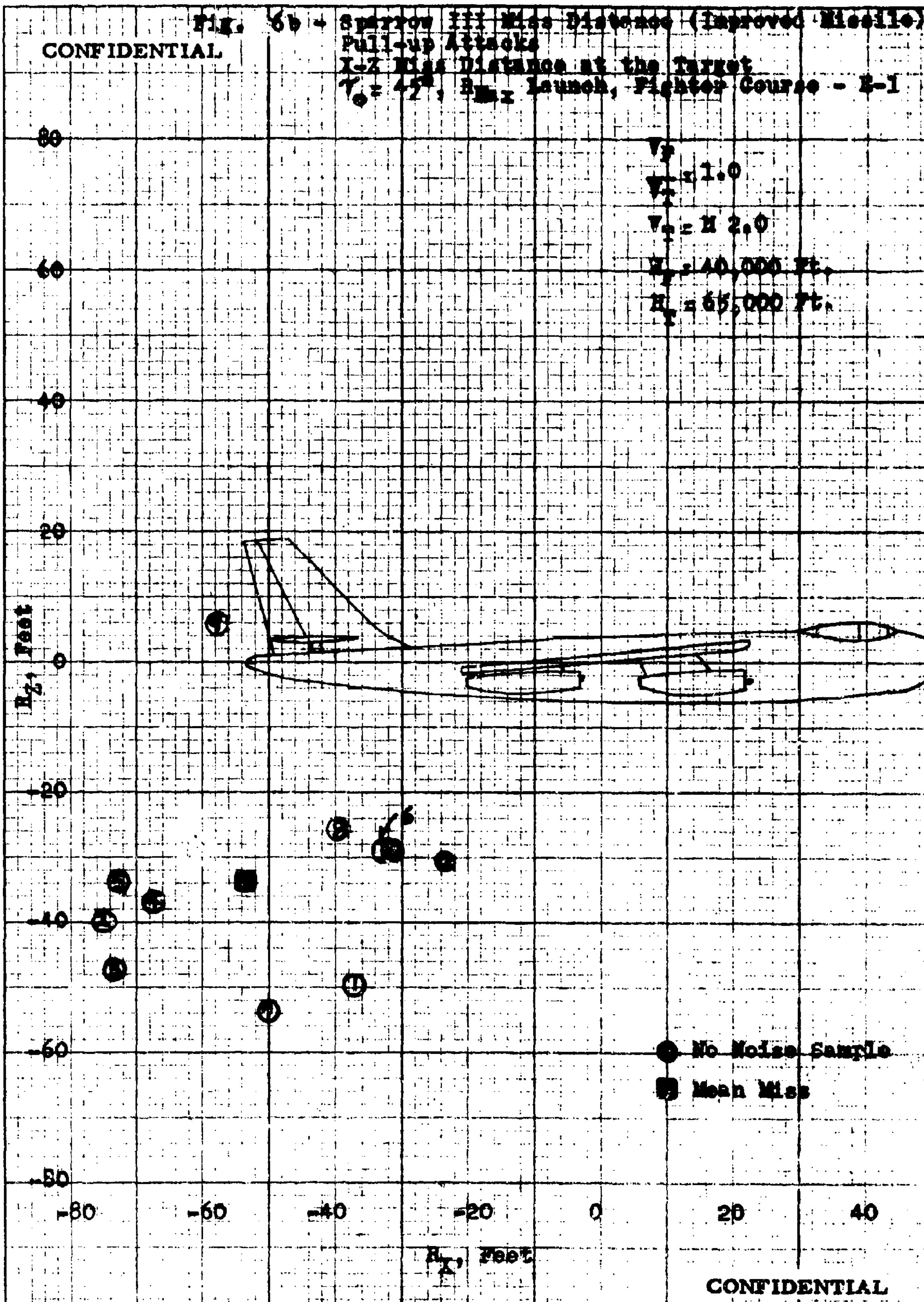

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Fig. 6c - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
Y-Z Miss Distance at the Target
$\gamma_o = 45°$, R_{Max} Launch, Fighter Course E-1

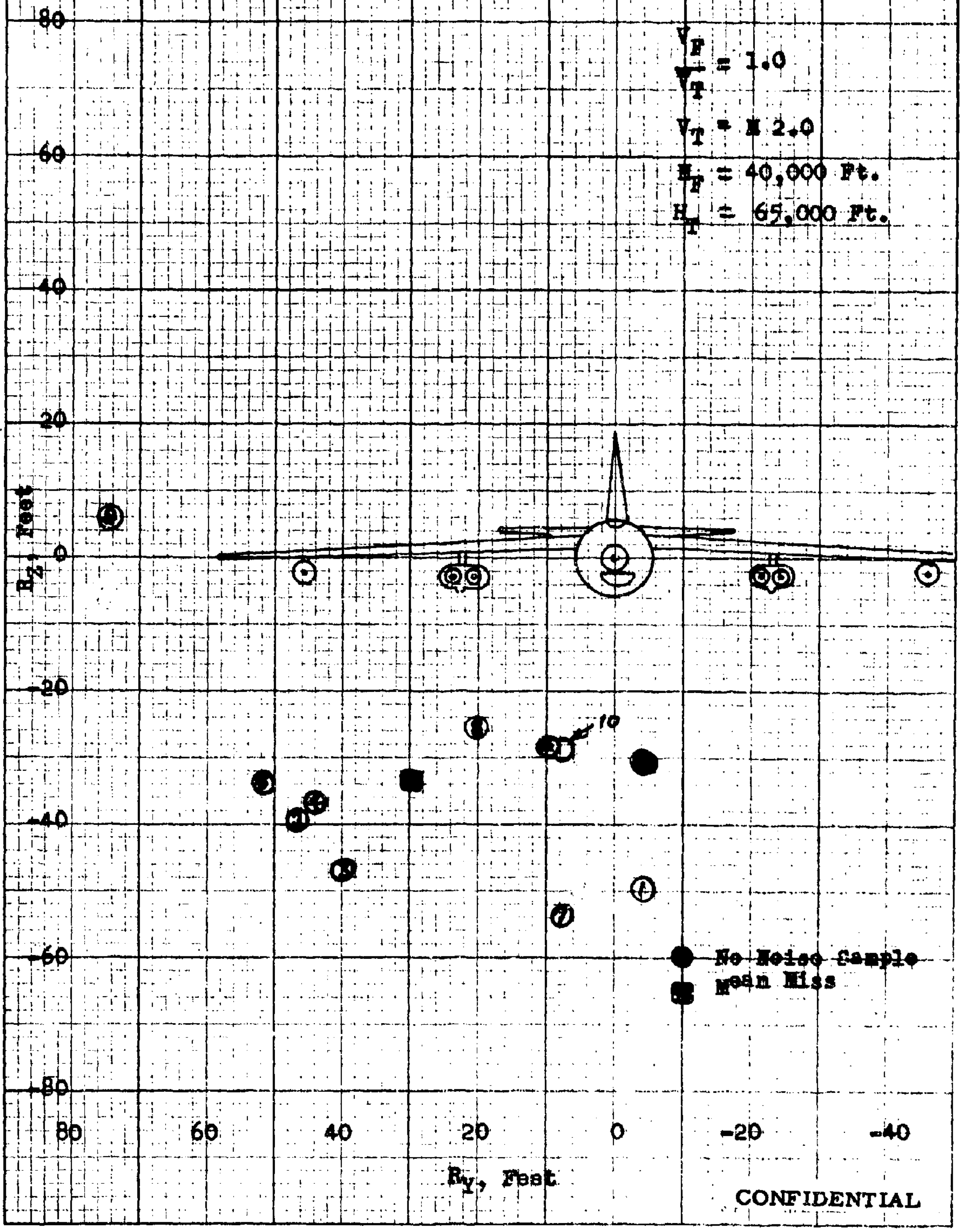

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Fig. 7a - Sparrow III Miss Distance - (Improved Missile)
Pull-up Attacks
X-Y Miss Distance at the Target
$\gamma_o = 45°$, R_{Max} Launch, Fighter Course - D-1

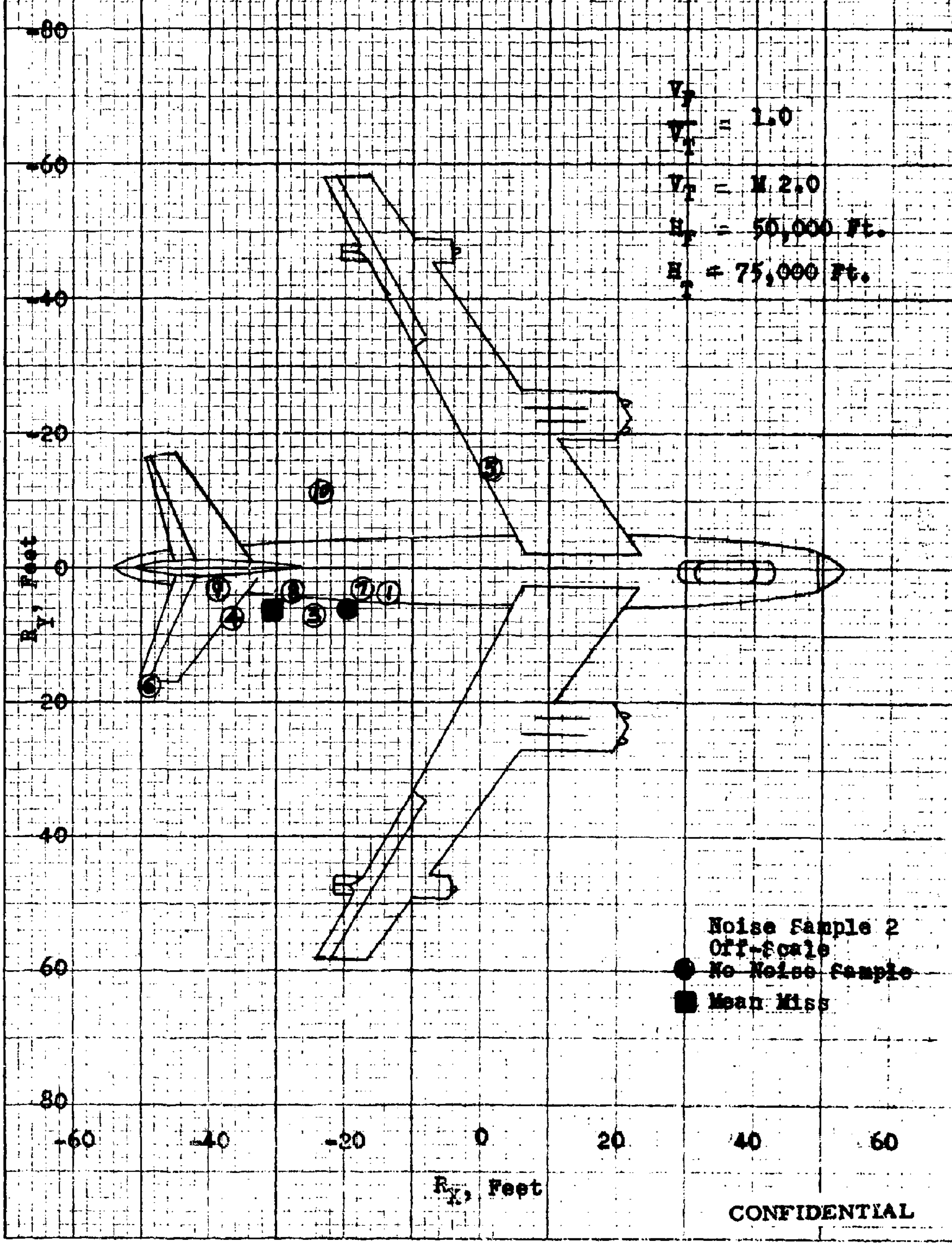

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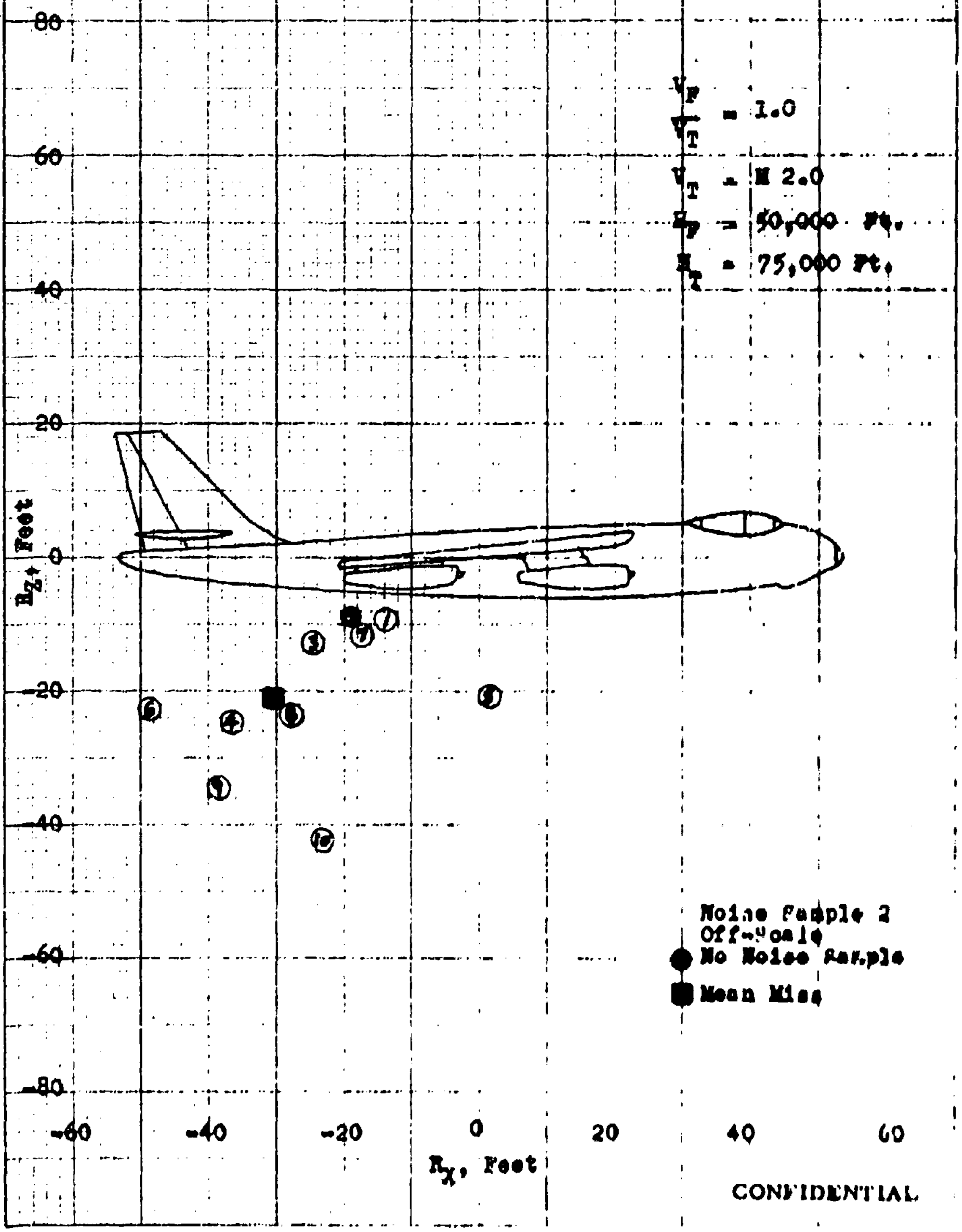
Fig. 75 - Sparrow III Miss Distance (Improved Missile)
Pull-up Attacks
X-Z Miss Distance at the Target
$\tau_o = 45°$, R_{max} Launch, Fighter Course - D-1



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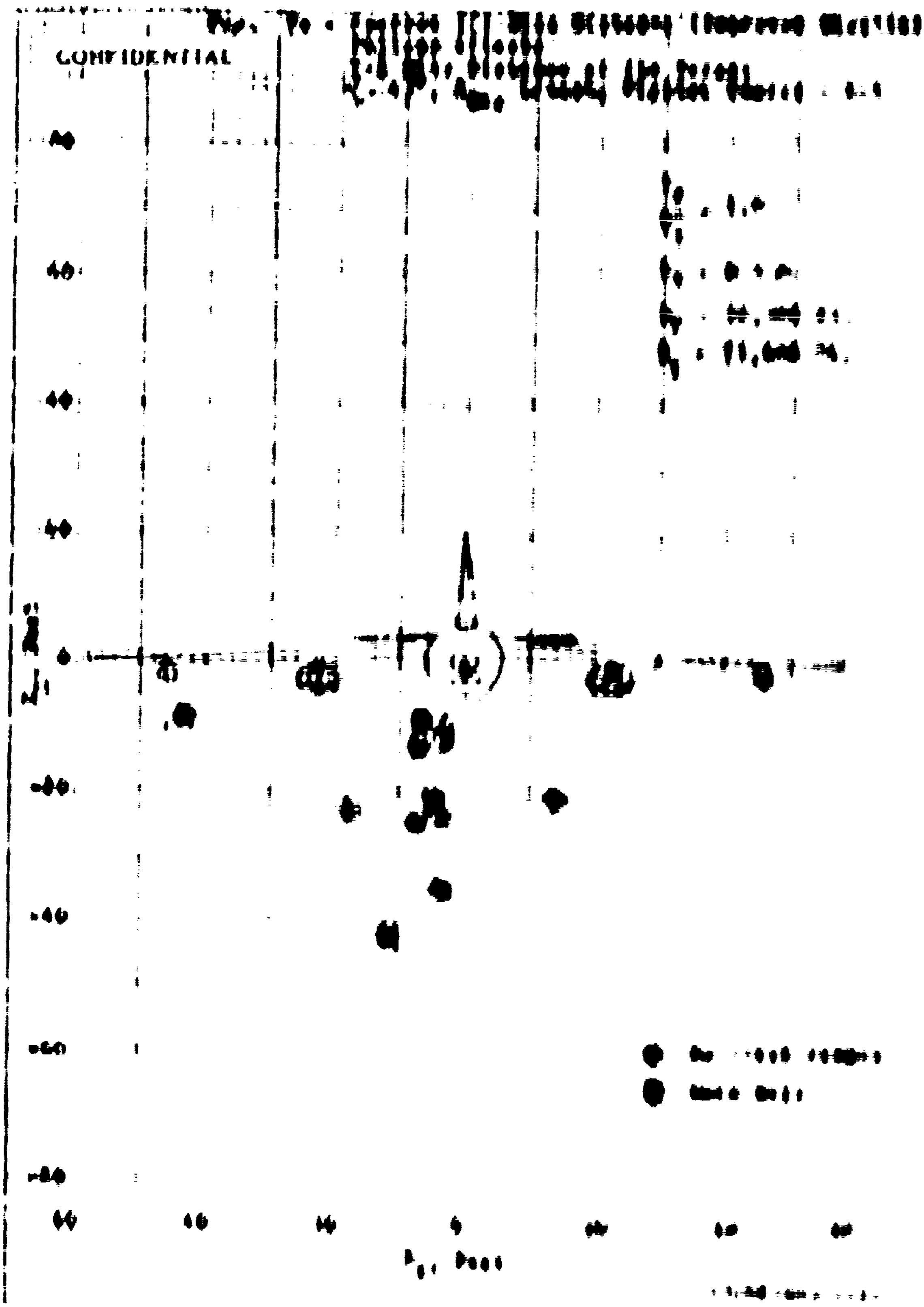

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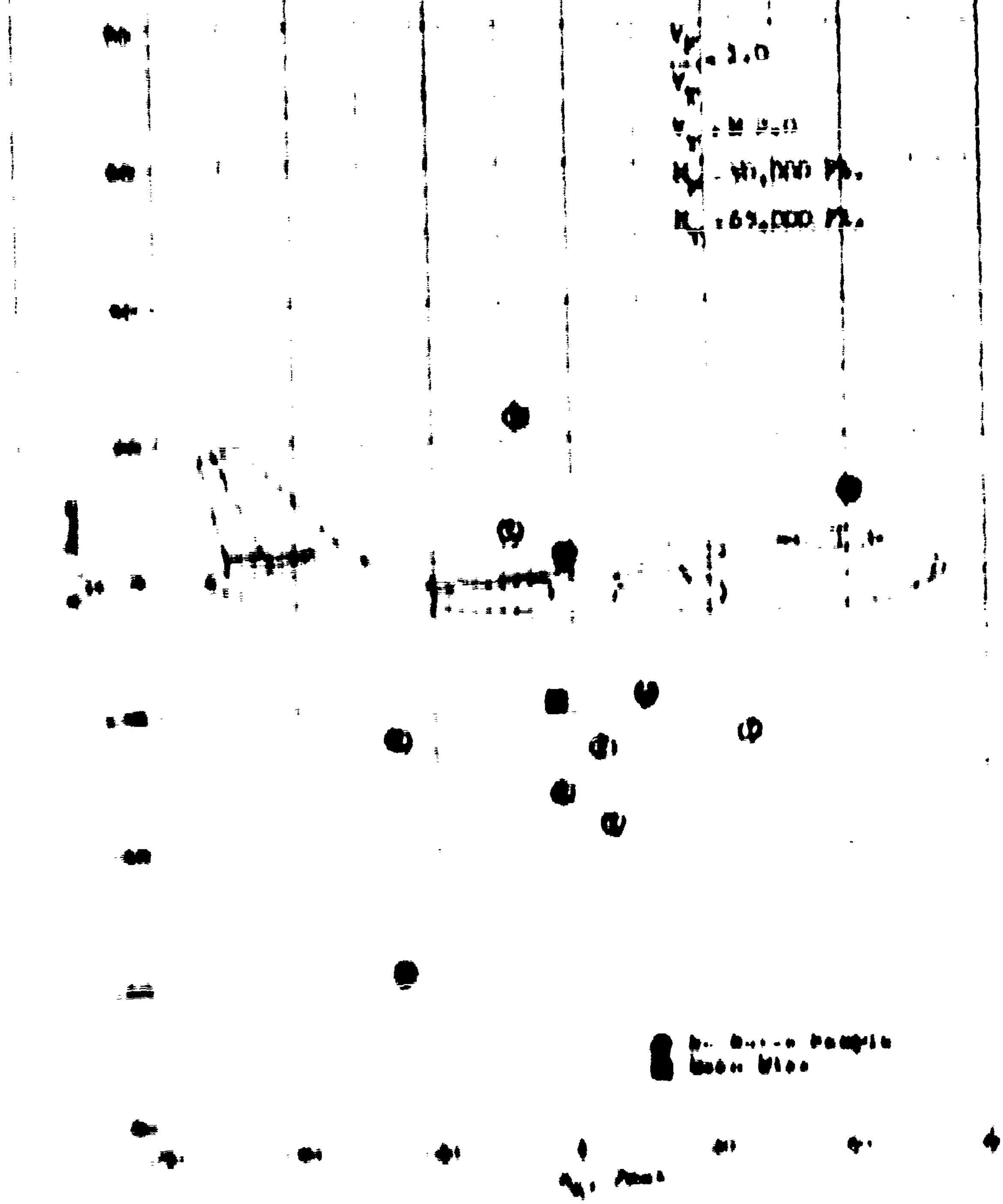
Fig. [illegible] Pull-up Attacks [illegible] Fighter Course [illegible]



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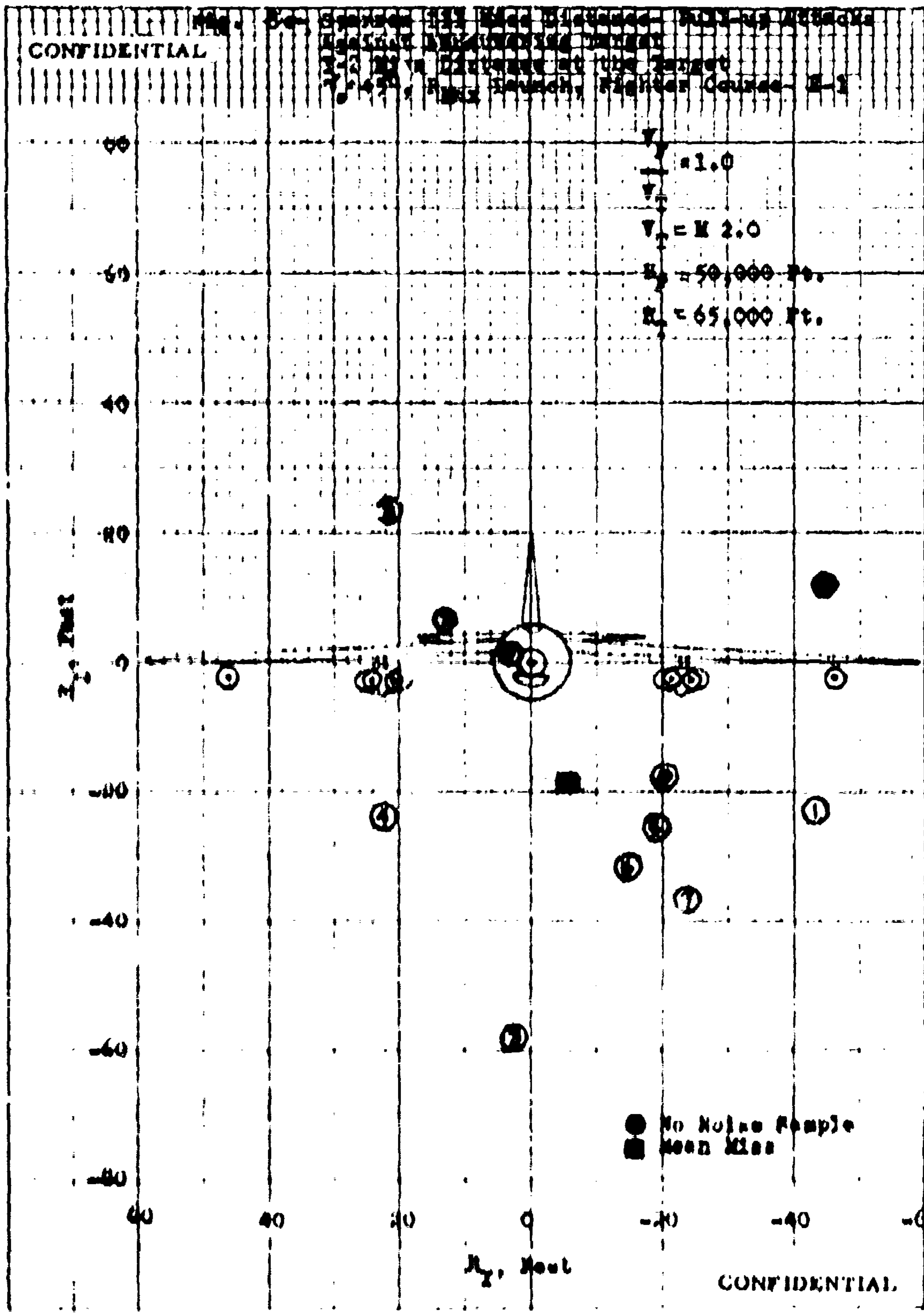
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= 50,000 Ft.
= 65,000 Ft.
No Noise Sample
Mean Miss
, Feet
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