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TARGET INITIATION POINT DELIVERY FOR TACTICAL WEAPONS

A. P. Bridges

[redacted] internal Sandia [redacted] of the [redacted] and [redacted] for [redacted] understanding [redacted] approval.

ABSTRACT

A tactical delivery method which uses the target as the initiation point is presented in this paper. This method is described and estimates are made of the accuracy of such a delivery when an inertial system is used.

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TABLE OF CONTENTS

I.	Introduction	4
II.	Delivery Method	4
III.	Bomb Director and Fuze	6
IV.	Error Analysis	7
V.	Summary	12
VI.	Bibliography	13

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I. INTRODUCTION

The prime considerations for the delivery of any weapon to any target are (1) hitting the target accurately, and (2) the safety of the delivery aircraft from enemy action. In other words, the accuracy of hitting the target is normally determined by the "price" you are willing to pay. In the tactical situation, the problem of hitting the target and escaping safely becomes, to a large degree, a problem of out-maneuvering the enemy. It is for this reason that the preparation of this paper is thought justified.

The present thinking concerning tactical bombing is that one must have available the capability for a completely flexible, maximum speed, "zero" altitude delivery. A method that has been proposed for tactical delivery of a weapon, which (to the author's knowledge) best meets the above conditions, is shown in this paper. This method uses an inertial system as bomb director and fuze and, in brief, consists of the following: (a) the pilot flies over or alongside the target, (b) he then maneuvers in the shortest possible time to the desired toss distance and onto a heading routing through the target, (c) the bomb is then tossed to the burst point and the proper escape maneuver is begun. An example of this method is discussed and estimates are made of the accuracy of such a delivery when an inertial system is used. It should be remembered, however, that the discussion in this paper is not complete and is certainly subject to revision as better and more accurate information becomes available.

II. DELIVERY METHOD

A target initiation point (TIP) delivery for tactical weapons may be defined simply as a method where the weapon delivery is begun when the aircraft is directly over or alongside the target and all subsequent aircraft maneuvers are designed to return the weapon to the target at a time when the aircraft is deemed to be a safe distance from an atomic burst. An inertial system which will furnish longitudinal and lateral distance of travel after the target initiation point is reached will be incorporated into the system both as a bomb director and bomb fuze.

An example of such a TIP delivery is shown in Figures 1 and 2. The follow-ing coordinate system has been assumed: (a) the X-axis lies along a line parallel to the longitudinal axis of the airplane as it passes over the target (X = 0 at the target), (b) the Y-axis lies along a line parallel to the lateral axis of the airplane as it passes over the target (Y = 0 at the target), and (c) the Z-axis (altitude) lies along a line parallel to the vertical axis of the airplane as it passes over the target (Z = altitude of airplane = 600 feet).

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Figure 1 is a side view of the vertical delivery plane (X, Z plane) and Figure 2 is a plane view of the horizontal plane (X, Y plane) of such a delivery. The maneuver consists of the pilot flying over the target and, at this time, starting his delivery maneuver and bomb director. His maneuver shall consist of appropriate turns to get his aircraft on a heading 180° from his initial heading and along the X-axis at a specified distance from the target in the shortest reasonable time. The toss maneuver is then begun and the weapon is tossed to the target and appropriate escape maneuvers are begun.

For convenience of discussion, a particular example of a TIP delivery system (see Figures 1 and 2) is assumed. Other examples, such as an offset method where Y ≠ 0 or where the heading of the final approach for toss ≠ 180° from the initial heading, can be assumed. The example of Figures 1 and 2 is in most cases the most conservative (longer time and more difficult maneuver) and is chosen for discussion on this basis. Figure 3 is a time plot of this maneuver. At time t = 0, the aircraft is over the target and initiation of the delivery method begins. He may then, by a suitable maneuver such as 1/2g turn clockwise and a 4g turn counterclockwise, return to a heading of 180° from his initial heading and along the X-axis. At this time, t = 70.4 sec. in Figure 3, an additional eight seconds is assumed for the pilot to determine from his bomb director that he is or is not on the proper course and realign himself. At the end of this time or more accurately, at a predetermined distance from the target as determined by his bomb director, he starts his pull-up maneuver to toss the bomb. In Figure 3, this is a 7g pull-up with a toss up at 45° to the horizontal with a tangential velocity of 1000 fps. The distance of the toss in this case is 26,000 feet with an elapsed time of approximately 40 seconds. A lower g turn or pull-up is permissible, this would extend the time necessary for such a maneuver and reduce the separation distance of weapon and aircraft at burst. It is realized that the velocity decreases for constant thrust in a constant g turn or in a constant g pull-up. We are, however, only interested in the availability of the tangential velocity at release by either prediction or instrumentation (depending on the type bomb release computer used). The change in velocity during a turn or pull-up affects only the distance travelled during a specific time and does not affect the horizontal fuze or delivery error. The 4g turn and 7g pull-up in this case have been assumed for maximum conditions of acceleration, and constant velocity has been assumed throughout for simplicity. It should be noted that as the aircraft velocity decreases, the time for the complete maneuver decreases. Therefore, it is believed that a time of 125 seconds, even for a maximum toss at less than 7g, may be considered the maximum for the above described maneuver.

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III. BOMB DIRECTOR AND FUZE

An inertial system which will serve both as bomb director in the aircraft and as a fuze in the weapon will be incorporated into the TIP delivery system. The errors of the system which will be shown in the next section will then be the errors of the fuze. The inertial system will consist of a stable platform in the weapon having three complete axes of freedom with three mutually perpendicular accelerometers mounted upon the platform for measurement of longitudinal, lateral and vertical acceleration (X, Y, Z) together with associated integrators. The vertical accelerometer is included only for the capability of measuring vertical distance for other types of delivery.

At time of initiation (when the aircraft is directly over the target and the pilot "pickles" the system) the inertial system begins to measure the distance from the target along the X-axis and Y-axis of the weapon. The distance along the X-axis and Y-axis will be referred to hereafter as the X-distance and Y-distance. The weapon will be fuzed when the longitudinal (X) distance returns to zero at the end of the manouver. The lateral (Y) distance is necessary only to tell the pilot when he is in the vertical plane extending from the release point through the target.

The bomb director should consist of the following:

A. <u>Y-Displacement Indicator</u>:

A dial should be provided to indicate the Y-distance from this vertical plane containing the X, Z axes. A visual or audio signal may be provided to indicate to the pilot when he is in this vertical plane (and thus may begin his final delivery tactics).

B. <u>X-Displacement Indicator</u>:

A dial should be provided to indicate the X-distance of the plane (weapon) from the initiation point (target). A visual or audio signal may be provided to indicate a pre-set distance from the target. This signal would then be an indication to the pilot that he is within the toss distance of the target.

C. <u>Heading Indicator</u>:

An indicator should be provided which will give the heading of the aircraft. This does not necessarily mean the true heading and can thus be relative heading. Provisions should be made to mark the initial heading of the aircraft as it passes over the target initiation point. A heading of 180° from the initial heading is the desired heading for the final delivery tactics. A visual or audio signal may be provided to indicate when the initial heading plus 180° has been obtained.

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D. Bomb Release Computer:

One of two types of release computers may be employed (1) a manual pre-set fixed angle of release device which requires prescribed delivery conditions or (2) an automatic computer which takes a continuous input of distance, velocity, altitude, and g pull-up and computes the proper release angle to hit the target. For the error analysis of Section IV, we have assumed pre-set conditions of distance, velocity, altitude, g pull-up and release angle.

It is obvious from the above that when the following three conditions have been met: (1) the X-Displacement Indicator reads zero, (2) the X-Displacement Indicator reads less than the pre-set distance, and (3) the Heading Indicator reads 180° from the initiation point value, the final delivery tactics (the toss) may be carried out, the weapon tossed to the target, and escape maneuvers begun.

The bomb fuze will function on a measurement of X-distance from the initiation point (target), and will determine the burst point by its return to zero. A measurement of zero X-distance will thus be the only necessary fuzing signal.

The above example assumes that the target is visible for identification but is not visible at the maximum maneuver range. If we may assume that the target is visible at maximum range or if for a particular strike the target is visible at maximum maneuver range, the problem is simplified. We may thus simplify the bomb director by eliminating either the Y-Displacement Indicator or the Heading Indicator. It is shown later that using only the Heading Indicator reduces the Y-distance error appreciably. The use of only the Heading Indicator, however, may be more difficult than the use of only the Y-Displacement Indicator. The visual identification of the target at maximum range permits pickling for initiation with the aircraft to one side of the target. The possibility of using such an offset allows for greater versatility in the initial approach. No further discussion of such TIP delivery maneuvers will be made in this paper as such appears to be particular examples of the assumed general case.

IV. ERROR ANALYSIS

A brief description has been given in Sections II and III of the delivery method, bomb director and fuze. The purpose of this section will be to provide an estimate of the fuzing error of a TIP delivery system. The estimate of errors of such a delivery system is based upon the use of an inertial system as a fuze with information pick-offs for the bomb director. The estimates made in this section are, at best, based on an educated guess. They are, however, based on performance figures of other inertial systems.

The following parameters will contribute errors toward a total fuzing error:

1. Horizontal velocity error.
2. True vertical error.
3. Platform drift.
4. Accelerometer error.
5. Integrator error.
6. Target recognition error.
7. Ballistic reproducibility.
8. Final pull-up error.
9. Altitude error.
10. Azimuth error.
11. Other errors.

1. Horizontal Velocity Error:

The error in horizontal velocity may be due to several things such as (a) the air speed indicator, instrumental errors, (b) the air speed indicator, installation errors, (c) weather prediction accuracy, (temperature, pressure) and (d) wind prediction accuracy. The error in the longitudinal ground speed is approximately $\sigma = 1.0$ per cent for errors (a), (b) and (c) above plus an assumed value of approximately $\sigma = 5$ mph $\cong 7.3$ fps for error (d), wind prediction. This error in wind prediction is an assumed value based upon a verbal conversation with Lt. Col. J. A. Ryan. The evidence used by Lt. Col. Ryan to arrive at this value is unavailable at present. Until this value can be substantiated or determined, the above error of $\sigma = 5$ mph, shall be assumed to be a necessary criterion for proper performance of this system.

It is not unreasonable to think that a tactical ground speed indicator that would indicate ground speed as accurately or more accurately than the above system can be developed.

2. True Vertical Error:

It is necessary to establish a vertical reference for our inertial system. This may be done in either of two ways: (i) the vertical may be determined at the home base and carried to the target or (ii), the vertical may be determined from the average dynamic vertical over a period of time. The first method above is impractical because of the size and weight desired for the inertial package. The second method appears to be feasible. We cannot use the dynamic vertical

because of rather large chance wing loading by gusts of wind. We can, however, use the average dynamic vertical over a period of time by making the precession rate of the gyros rather small (say 10°/min). The error between the true vertical and the average dynamic vertical will then be less than 0.1°. This error is usually spoken of as the maximum tolerance or 3σ value, therefore, it appears we may be conservative and say the most likely σ is $.033^{\circ}$ with the maximum sigma, (used in Figure 4) being 0.1°.

Provisions must be made for a calibration period of 60 seconds or longer just before the target initiation point. Obviously, the optimum time would be immediately preceeding initiation. This is not absolutely necessary, however, and a small time interval may occur between the calibration period and the target initiation point. For this discussion, it shall be assumed that this calibration run occurred immediately before the target initiation point. The pilot will be required to fly as straight and as level a flight as possible during the calibration run. This requirement is believed to be sufficient to establish the required platform vertical using the average dynamic vertical.

3. Platform Drift:

The platform will have a drift rate of approximately 1°/hr. in vertical and in azimuth.

4. Accelerometer Error:

An accelerometer error of 0.001g or $\sigma = .0322$ ft/sec.^{2} will be estimated as the accelerometer error. It is expected that the accuracy for the first part of the scale will be better than this with the error increasing due to non-linearity of the scale. However, as the majority of the accelerations experienced will be less than $\pm$ 1g, it is expected that a value of 0.001g is a very reasonable average.

5. Integrator Error:

An integrator error of 0.1 percent of the output will be assumed for the error of the first integrator (velocity) and also for the error of the second integrator (distance).

6. Target Recognition Error:

Two types of errors are obvious for target recognition: (i) gross error and (ii) error in judgment. Gross errors will not be considered in this computation of fuze accuracy. However, it should be noted that this system has an advantage over the LABS system in that it requires identification of only one point. This one point of necessary identification is the target. This point must be located in any case if the

mission is to be successful. An error in judgment of target location with respect to the airplane or airplane to target will be approximately 200 feet in ground (X or Y distance) distance. The reaction time for the pilot to "pickle" over the target is approximately 0.1 sec. These figures have been used by Lt. Col. J. A. Ryan as the maximum tolerance, however, we shall be conservative and use them as the standard deviation in this paper.

7. Ballistic Reproducibility:

Errors in free flight trajectory will occur due to lack of consistency and misalignment of the ballistic case. This error (probable error) has been estimated as approximately 3 mils for the TX-7 and TX-12. This gives a standard deviation of approximately 4.5 mils. This is, perhaps, meaningless when one considers a toss. Therefore, to be conservative we shall assume this applies to the total ballistic travel through the atmosphere.

8. Final Pull-up Errors:

The errors that occur in the final pull-up or in the release angle during pull-up are very dependent upon how well the bomb release computer is mechanized. The errors in general are: (i) error in constant g pull-up; this is approximately $\sigma = 1/5g$ for a pilot requirement of a constant 7g pull-up, (ii) error in maintaining a constant velocity throughout the delivery maneuver; this error is approximately $\sigma = 10$ mph or 15 fps, (iii) error in estimating the appropriate place to begin final pull-up; this error is estimated as approximately $\sigma = 500$ feet, (iv) errors will also occur due to the computation of the appropriate angle of release, error in the bomb release circuits and error in computing angles of attack; these errors are unknown but will probably be of the order of one to two degrees (two degrees used in calculation). It should be noted that all of the above errors will vary according to the bomb release computer used. The figures given are for a type of bomb release computer where the computation of release angle is done at the home base and specific velocity, constant altitude, and constant distance and constant g pull-up are required of the pilot.

The errors of the above paragraph will not affect the X or Y distance error for a sufficiently high air burst. It will, however, induce an error in the altitude of burst. For a 45° release angle, this error becomes significant but for low angle releases (flat trajectories) this error is small. In fact, the error in burst height for a 20-30 degree release angle is approximately one-half the impact error.

9. Altitude Error:

Any error made by the pilot concerning altitude will be reflected directly into the burst height. It is expected that a pilot can hold a specified low altitude such as 600 feet to a standard deviation of approximately 200 feet.

10. Azimuth Errors

Errors in azimuth will be reflected as errors both in the X distance and the Y distance. A standard deviation of approximately one degree in azimuth is estimated to be reasonable. The azimuth error contributes to the longitudinal distance error as $(1-\cos\theta)$, where θ is the azimuth error and contributes to the lateral error as $\sin\theta$. For small angles, the errors in the X and Y distances are small but they increase rapidly as the angle increases. If, as stated previously, the target can be viewed visually at maximum range, the Y distance error can be reduced appreciably.

For the most simple system the axes of the X and Y accelerometers should be aligned with the longitudinal and lateral axes of the airplane at the moment of initiation. This may be done by precessing the stable platform until the accelerometer axes are aligned with the airplane axes. However, if very abrupt maneuvers occur immediately before initiation of the TIP delivery system, small errors will be introduced into the system because of the finite precession rate of the platform. For turn rates of less than one degree per second, the azimuth error is expected to be a fraction of a degree. A value of $\sigma = 0.1°$ shall be assumed for lack of more complete information concerning the details of the inertial system.

11. Other Errors:

Other errors will be present in an inertial system. These errors occur because of earth anomalies, centripetal acceleration, coriolis acceleration, change in altitude, latitude, horizontal velocity and horizontal direction. These errors contribute in varying degrees depending upon whether horizontal or vertical accelerations are measured. The magnitude of these errors for such a maneuver as described is small and will not affect the total standard deviation.

Figure 4 gives a summary of the errors (standard deviations) of the parameters of a TIP delivery system such as that shown in Figures 1, 2 and 3. Included in this figure for comparison are estimates of the error for delivery maneuvers requiring less time than the maximum case of Figures 1, 2 and 3.

For a maximum time of 125 seconds, the standard deviation for the fuze error (includes delivery error) is approximately 1650 feet for the X distance, approximately 890 feet for the Y distance with visible target (Heading Indicator only) and approximately 1800 feet for the Y distance using a Y displacement indicator. Errors in altitude will be discussed below.

Errors in altitude will be due principally to errors made during the final delivery and errors made during the pull-up phase, i.e. error in velocity, error in release angle, error in constant g pull-up and distance error at the beginning of the pull-up phase. The estimated contribution of these parameters to an error in altitude is shown in Figure 5. Included in this

[redacted]

figure for comparison are other release conditions. For a maximum time of 125 seconds and a 45° toss, the error (standard deviation) in altitude is estimated to be 830 feet. This assumes a zero error in X and Y distance.

V. SUMMARY

A low level delivery system capable of delivering atomic weapons has been described. This system, target initiation point delivery, has been described in detail and estimates of the standard deviations for the various parameters have been made. The estimates made have been conservative throughout this paper. These estimates are subject to revision (downward for all with the possible exception of wind prediction) when further information or data becomes available.

It should be emphasized that the delivery system described in this paper is only one of several target initiation point delivery systems. For the method proposed (which gives the maximum sigma) the accuracy of delivery is presently estimated to be 1650 feet in range, 1800 feet in deflection and 830 feet in altitude. These errors may be reduced by means described within the body of this paper.

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FIGURE

TYPICAL TARGET INITIAT
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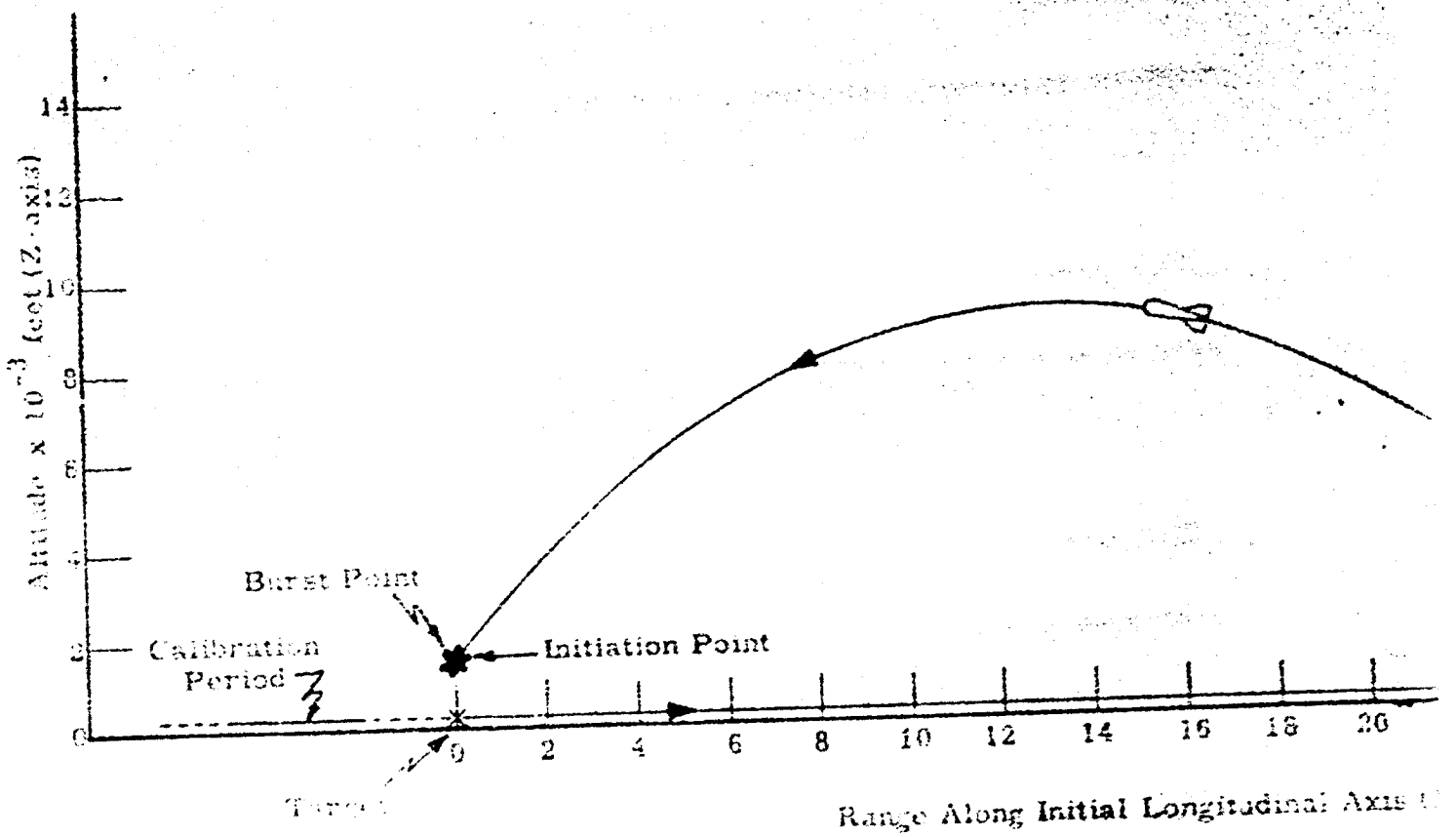
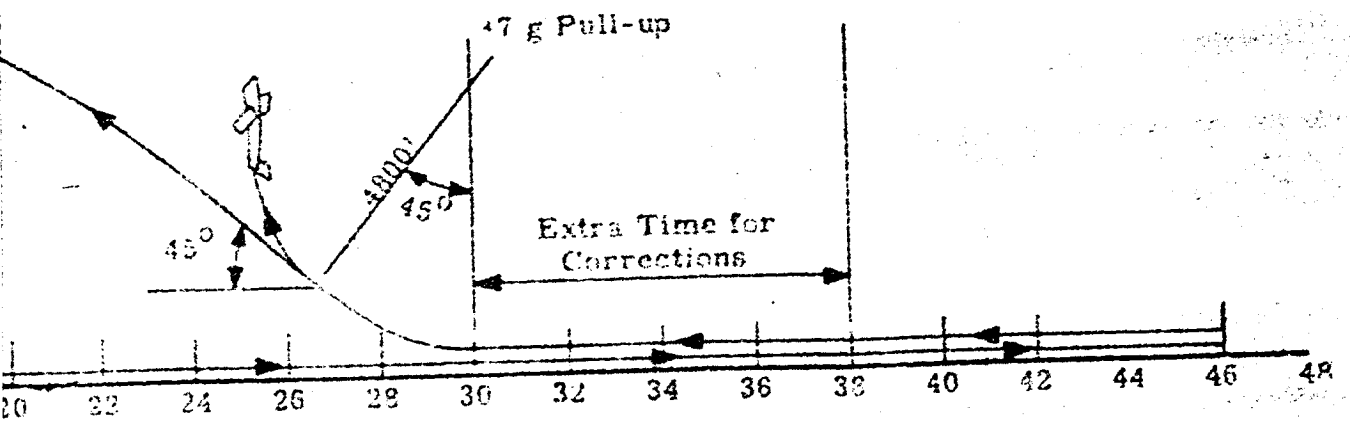


URE 1

IATION POINT DELIVERY
e View)

ASSUMPTIONS:

TX-7 or TX-12 Weapon
Airplane Speed Constant during Entire Maneuver
Airplane Speed = 1000 fps ≈ 0.9 Mach Number
Constant Altitude for Plane Maneuver until Pull-up
(Deck Level, i.e. 1000 fps or Less)
Constant (Average) Air Density for Maneuver
Constant (Average) Drag Coefficient for Maneuver
Maximum Range Toss, i.e. Release Angle of 45°



xis (X-axis) of plane x 10^{-3} feet

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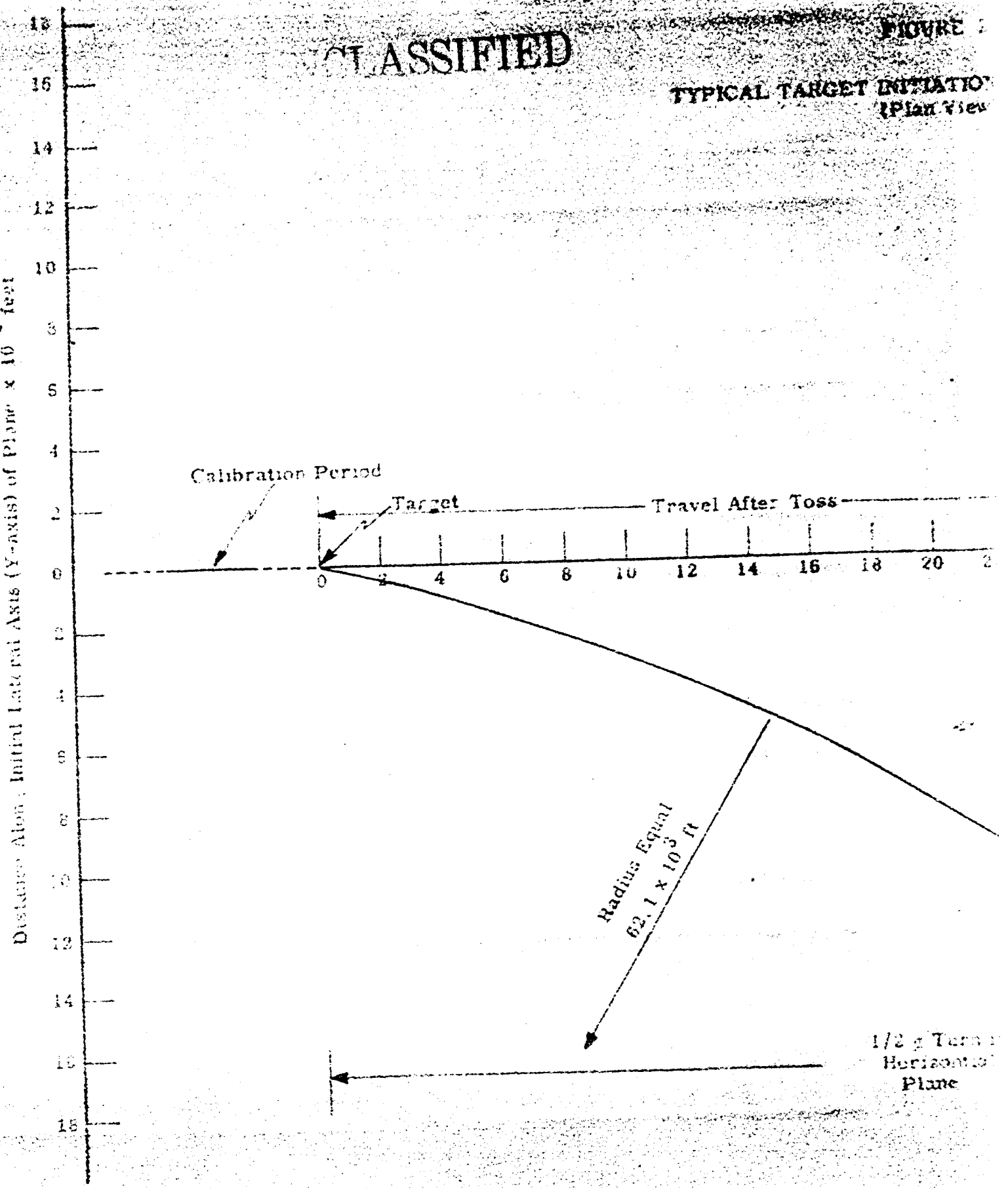
FIGURE

TYPICAL TARGET INITIATION
(Plan View



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Range Along Initial Longitudinal Axis

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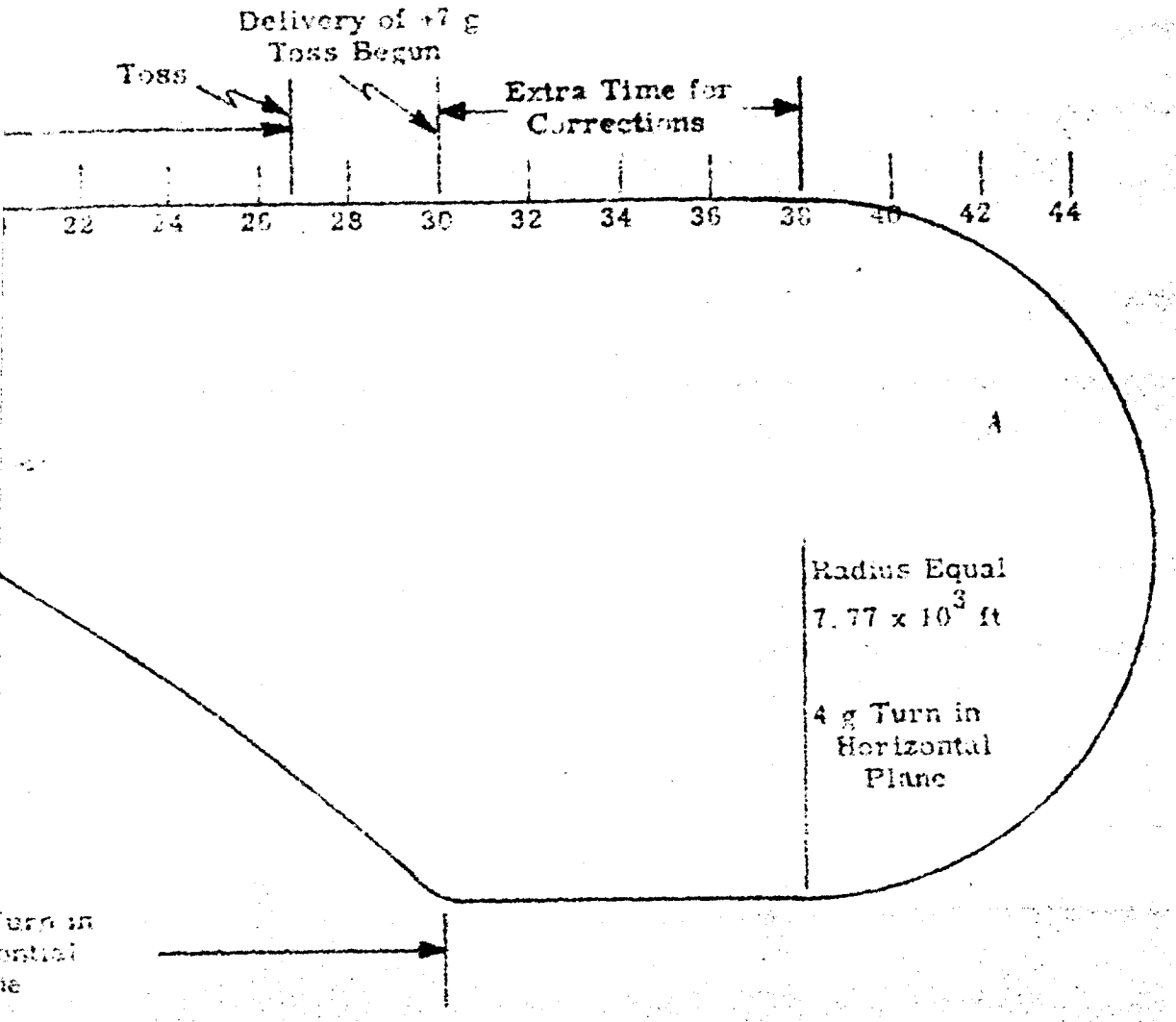
TION POINT DELIVERY
View)

ASSUMPTIONS:

TX-7 or TX-12 Weapon
Airplane Speed Constant during Entire Maneuver
Airplane Speed = 1000 fps ≈ 0.9 Mach Number
Constant Altitude for Plane Maneuver until Pull-up
(Deck Level, i.e. 1000 fps or Less)
Constant (Average) Air Density for Maneuver
Constant (Average) Drag Coefficient for Maneuver
Maximum Range Toss, i.e. Release Angle of 45°



Axis (X-axis) of Plane x 10^-3 feet

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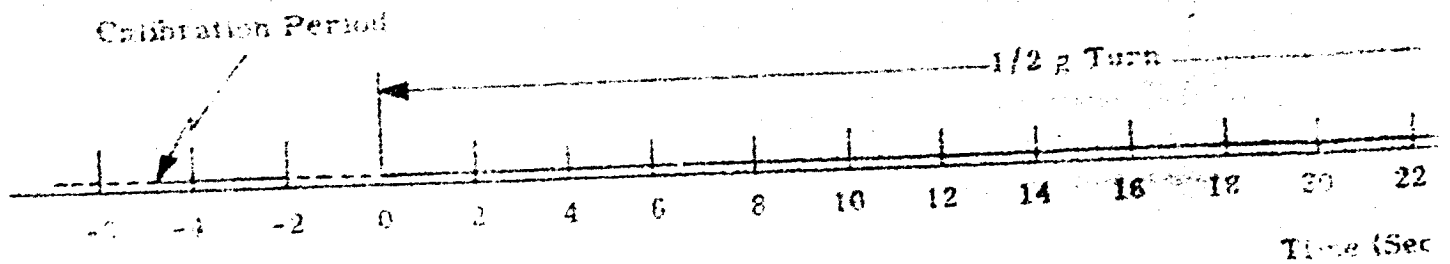
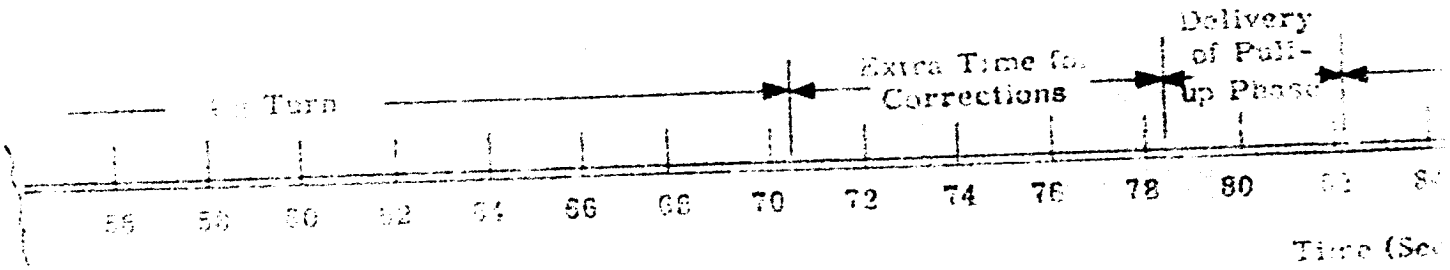
FIGURE 3

TIME FOR THE TYPICAL TARGET INITIATION PO





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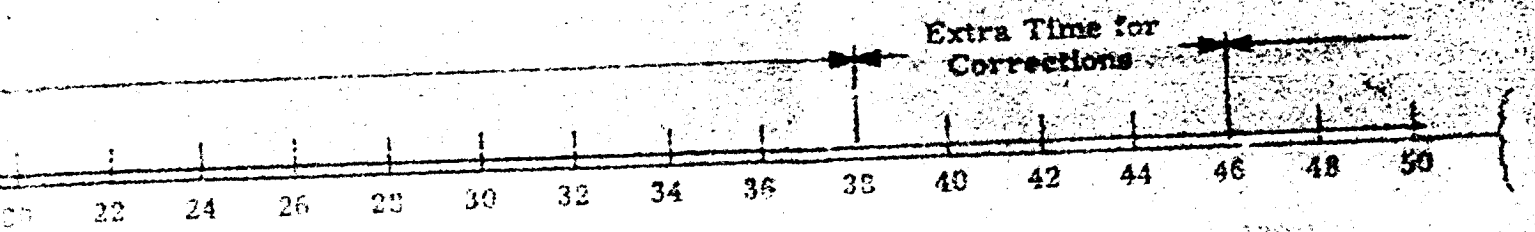
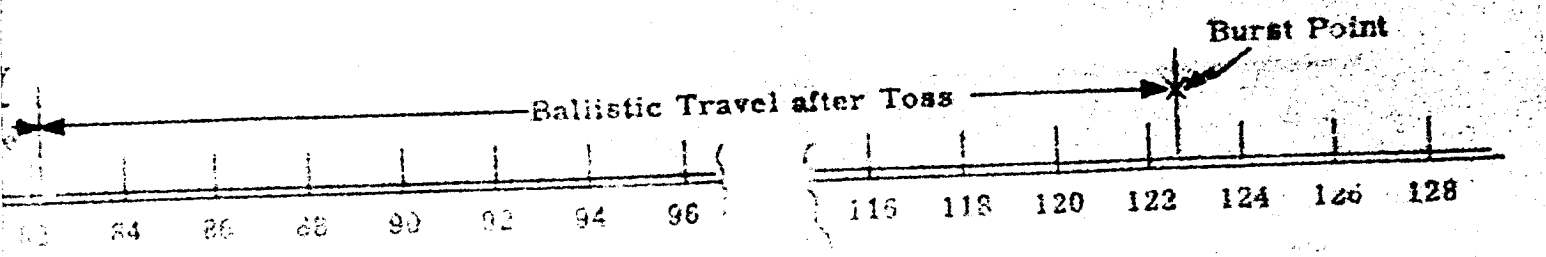
URE 3

ION POINT MANEUVER OF FIGURES 1 AND 2



ne (Sec)



Time (Sec)

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FIGURE 4

HORIZONTAL ERRORS OF A TARGET INITIATI

Standard Deviation (feet) / Parameters Based on Figures 1, 2 & 3	X Distance 75 Sec*	X Distance 100 Sec*	X Distance 125 Sec	Visi (Heading 75 Sec*
Velocity				
a) Air Speed	750	1000	1250	-
b) Wind Prediction	550	730	910	120
True Vertical	155	280	440	-
Platform Drift	10	25	50	-
Accelerometer	90	160	250	-
Integrator				
a) First	75	100	125	-
b) Second	50*	70*	85	-
Target Recognition	200	200	200	-
Ballistic Reproducibility	50*	60*	80	50*
Pull-up	-	-	-	-
Altitude	-	-	-	-
Azimuth	7*	10*	15	320*
Other	-	-	-	-
Total	1000*	1300*	1650	400*

* depends on trajectory average, value assumed for comparis

\- indicates that the errors due to these parameters are smal

FIGURE 5

ALTITUDE ERRORS* OF A TARGET INITIATIO

Standard Deviation / Parameters Based on Figures 1, 2 & 3	Altitude Error (Release Velocity = 1000 fps, Release Angle = 45°, See Figures 1, 2 and 3)	Altitude Error (Release Velocity = 1000 fp Release Angle = 25°, Release Altitude - desired burst altitude)
Altitude	200 feet	200 feet
Velocity	520 feet	170 feet
Release Angle	300 feet	150 feet
Constant g pull-up	200 feet	100 feet
Release Location Error	500 feet	250 feet
Total	830 feet	405 feet

* these errors have been computed assuming 26 [illegible] and 1.2

FIGURE 4

A TARGET INITIATION POINT DELIVERY SYSTEM

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Y Distance					
Visible Target (Heading Indicator Only)			With X Indicator		
75 Sec*	100 Sec*	125 Sec	75 Sec*	100 Sec*	125 Sec
-	-	-	-	-	-
180	240	300	550	730	910
-	-	-	155	280	440
-	-	-	10	25	50
-	-	-	90	160	250
-	-	-	75*	100*	125
-	-	-	20*	20*	20
-	-	-	200	200	200
50*	60*	80	50*	60*	80
-	-	-	-	-	-
-	-	-	-	-	-
320*	440*	525	870	1200	1465
-	-	-	-	-	-
400*	500*	600	1100*	1450*	1800

assumed for comparison
e parameters are small or are not applicable

FIGURE 5

A TARGET INITIATION POINT DELIVERY SYSTEM

tude Error ease Velocity 1000 fps, ease Angle = 45°, ease Altitude desired st altitude)	Altitude Error (Release Velocity = 730 fps, Release Angle = 45°, Release Altitude = desired burst altitude)	Altitude Error (Release Velocity = 765 fps, Release Angle = 30°, Release Altitude = desired burst altitude)
200 feet	200 feet	200 feet
170 feet	400 feet	235 feet
150 feet	300 feet	150 feet
160 feet	200 feet	100 feet
250 feet	500 feet	250 feet
405 feet	750 feet	450 feet

euming zero X and Y distance errors

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