United States Patent [19]

Cox et al.

[11] **3,880,043**

[45] **Apr. 29, 1975**

[54] **PROJECTILE DELIVERY SYSTEM**

[75] Inventors: **William Ervin Cox**, Palos Verdes Estates; **Lloyd R. Ferry**, Rolling Hills Estates, both of Calif.

[73] Assignee: **Northrop Corporation**, Los Angeles, Calif.

[22] Filed: **Sept. 21, 1973**

[21] Appl. No.: **399,529**

[52] **U.S. Cl.**..... **89/1.5 E**; 235/61.5 D; 235/61.5 S

[51] **Int. Cl.**..... **B64d 1/04**

[58] **Field of Search** ... 235/61.5 D, 61.5 S, 61.5 DF, 235/61.5 R; 89/1.5 R, 1.5 E, 1.5 S, 1.814

[56] **References Cited**

UNITED STATES PATENTS

2,985,373	5/1961	Helgeson et al.	89/1.5 E
2,995,984	8/1961	Helgeson et al.	89/1.5 E
3,427,437	2/1969	Tye	89/1.5 E
3,499,363	3/1970	Lauro	89/1.5 R
3,779,129	12/1973	Lauro	89/1.814 X

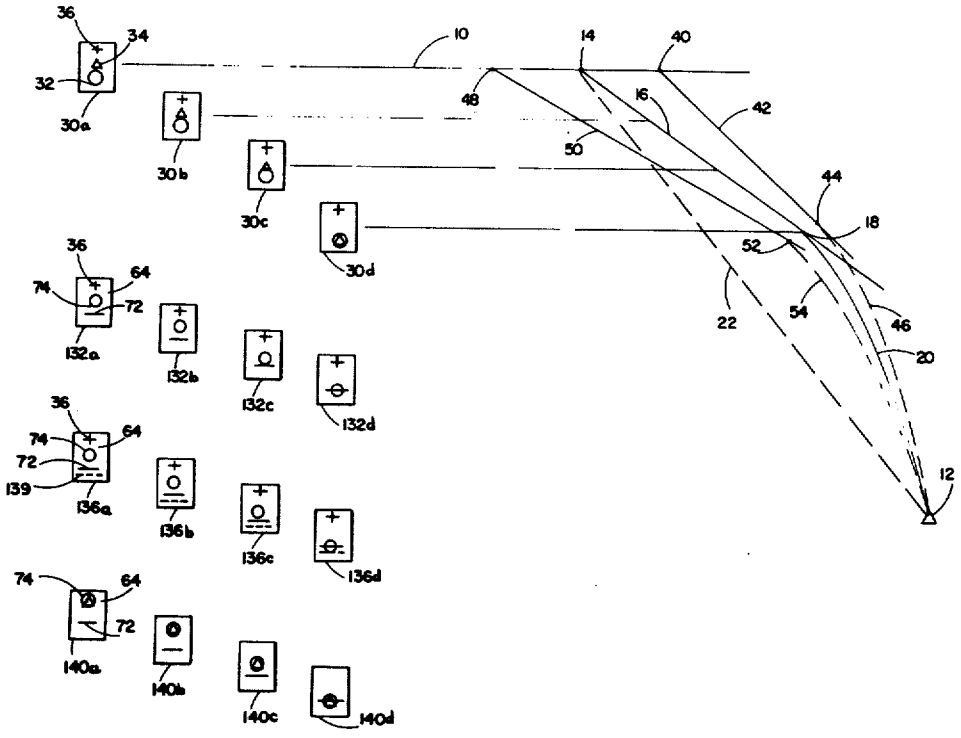
Primary Examiner—Samuel W. Engle

Attorney, Agent, or Firm—Edward A. Sokolski

[57] **ABSTRACT**

A projectile delivery system for delivery of projectiles such as bombs containing an explosive charge and the like from airborne equipment. The delivery system contains an optical glass permitting presentation of a target image representative of a remote target. The system also provides for the display of an aiming reticle on said optical plane and which is shiftable thereon in response to a change of altitude of the airborne equipment. A projectile release cue is also displayed on the optical plane and shiftable thereon in response to a change of attitude, airspeed or angle of attack of the airborne equipment. The pilot of the airborne equipment will follow a dive path which will align the target image and the aiming reticle. Thus, when the airborne equipment moves to a desired pre-established projectile release point, the coincident aiming reticle and target image will have shifted on the optical plane so that they will coincide with the projectile release cue, which represents the optimum projectile release point. A central processor which forms part of the projectile delivery system will receive external information concerning airspeed, angle of attack, altitude, the attitude of the aircraft, and the like, and this information will be computed along with manually introduced information such as target altitude and the like in order to obtain the optimum projectile release point.

28 Claims, 8 Drawing Figures



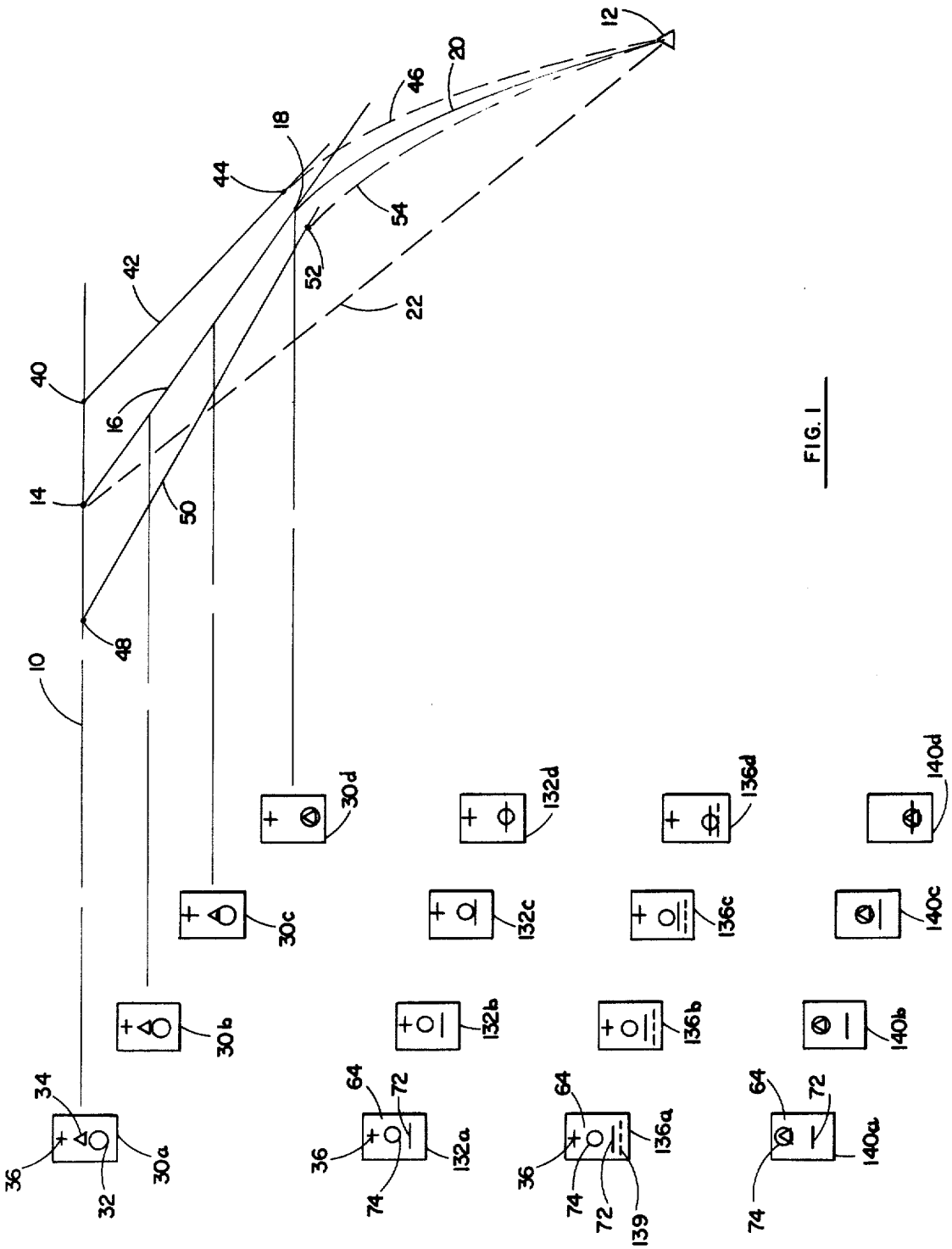

12
20
46
18
44
54
52
22
42
40
16
14
50
48
10
30d
30c
30b
30a
34
36
32
132d
132c
132b
132a
64
72
74
136d
136c
136b
136a
139
140d
140c
140b
140a

FIG. 1

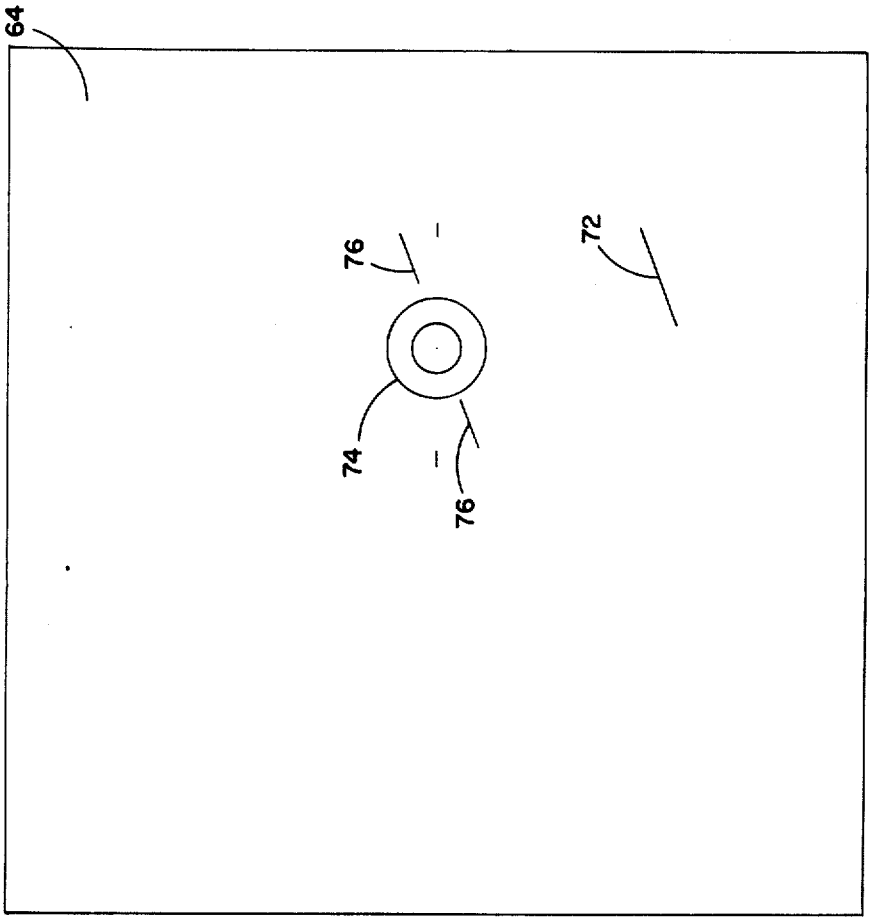

64
76
72
74
76

FIG. 4

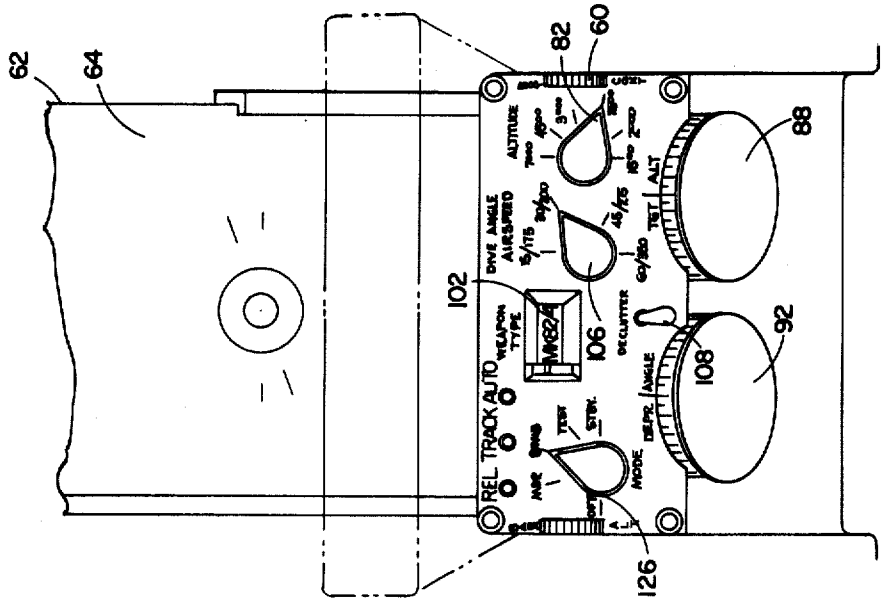

62
64
82
60
88
102
106
92
108
126
REL TRACK AUTO
WEAPON TYPE
HMR224
DIVE ANGLE
AIRSPEED
ALTITUDE
DECLUTTER
DEPR. ANGLE
MODE
TEST
STBY
ALT

FIG. 2

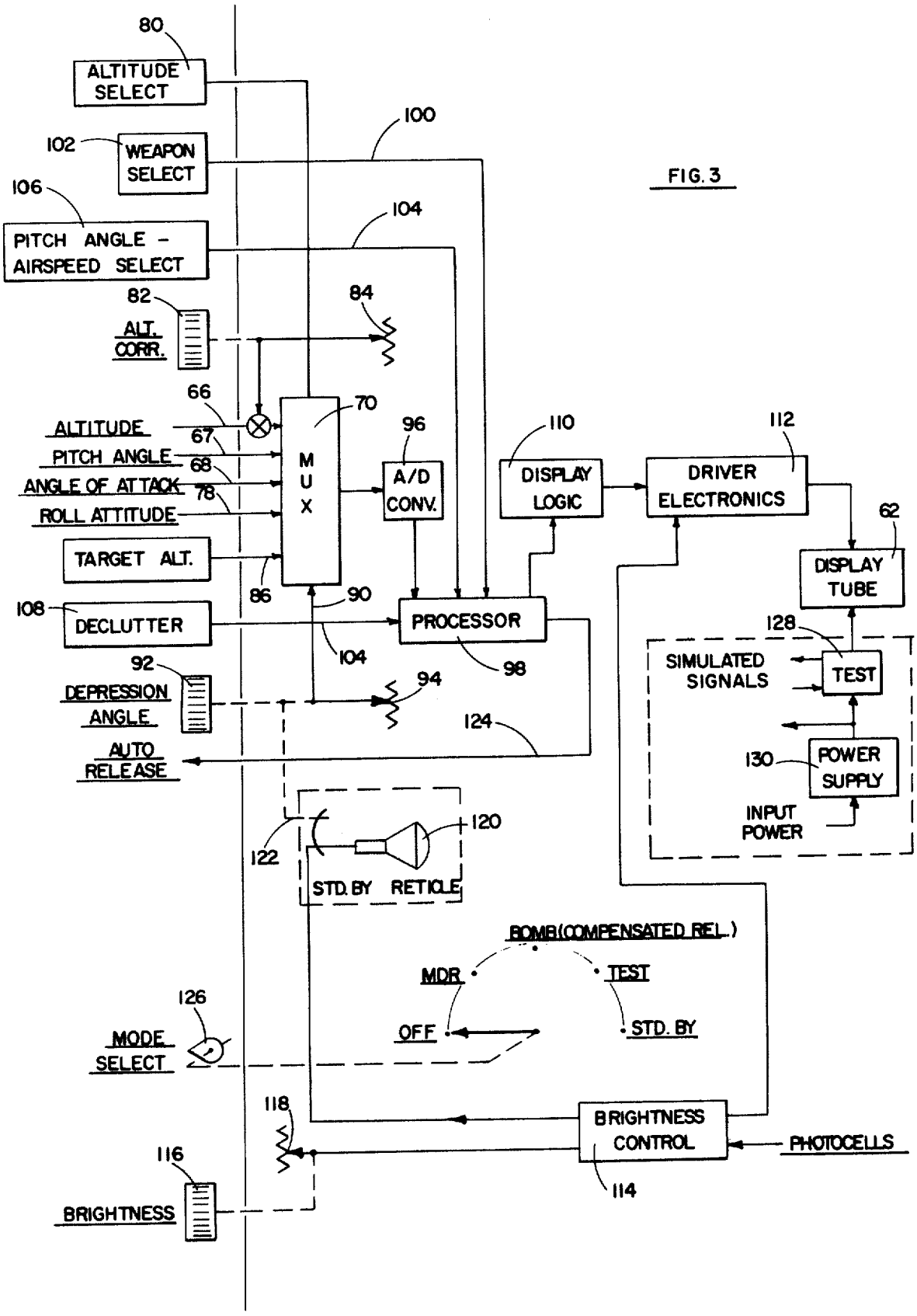

80
ALTITUDE SELECT
100
102
WEAPON SELECT
106
PITCH ANGLE - AIRSPEED SELECT
104
82
ALT. CORR.
84
66
ALTITUDE
67
PITCH ANGLE
68
ANGLE OF ATTACK
78
ROLL ATTITUDE
70
MUX
96
A/D CONV.
110
DISPLAY LOGIC
112
DRIVER ELECTRONICS
62
DISPLAY TUBE
TARGET ALT.
86
90
108
DECLUTTER
PROCESSOR
98
104
128
SIMULATED SIGNALS
TEST
92
DEPRESSION ANGLE
94
124
AUTO RELEASE
130
POWER SUPPLY
INPUT POWER
120
122
STD. BY RETICLE
BOMB(COMPENSATED REL.)
MDR
TEST
OFF
STD. BY
126
MODE SELECT
118
BRIGHTNESS CONTROL
PHOTOCELLS
116
BRIGHTNESS
114

FIG. 3

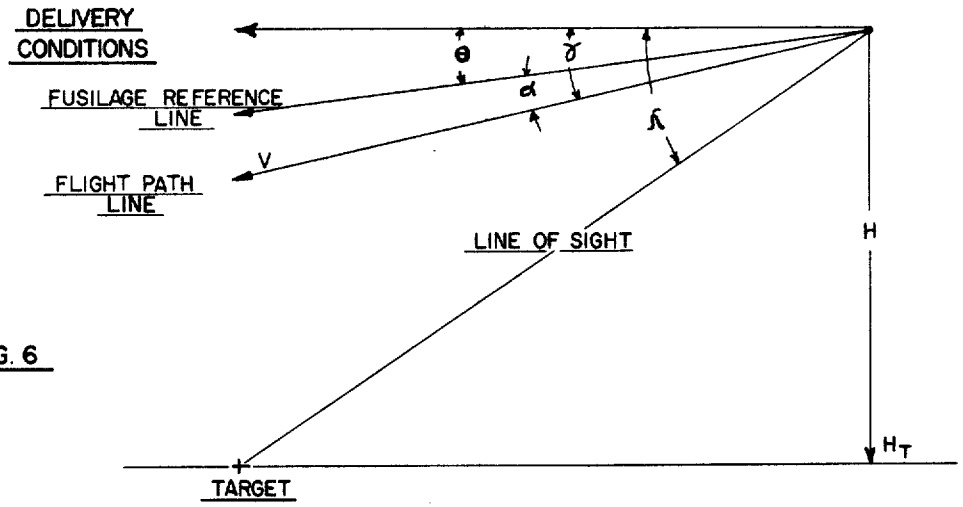


FIG. 6

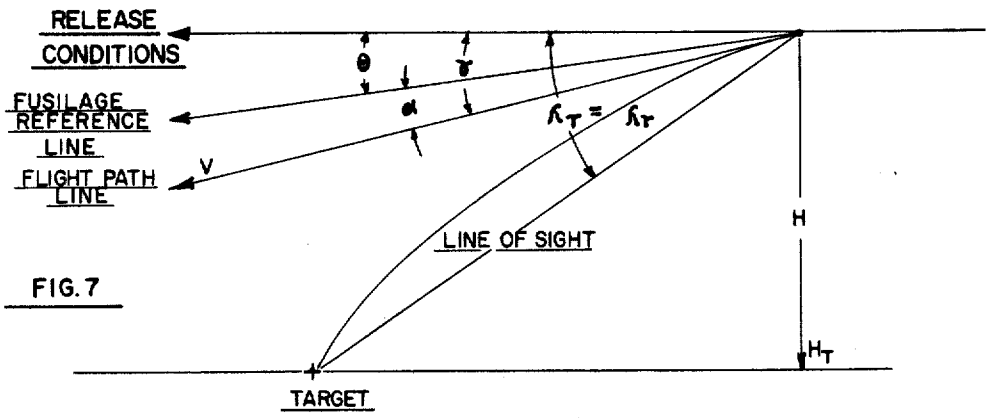


FIG. 7

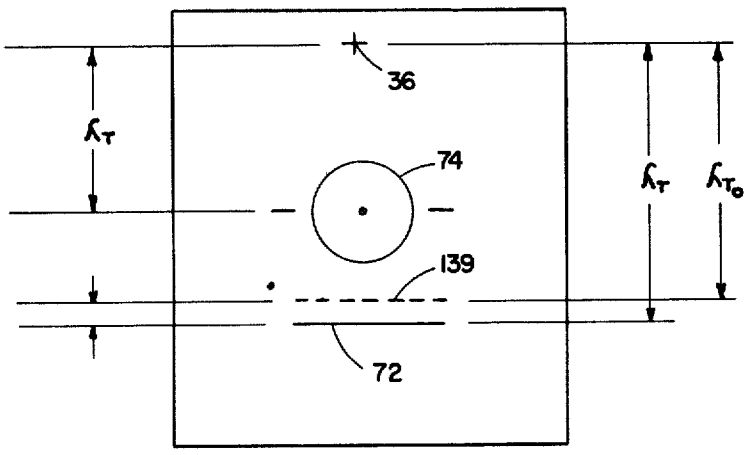


FIG. 5

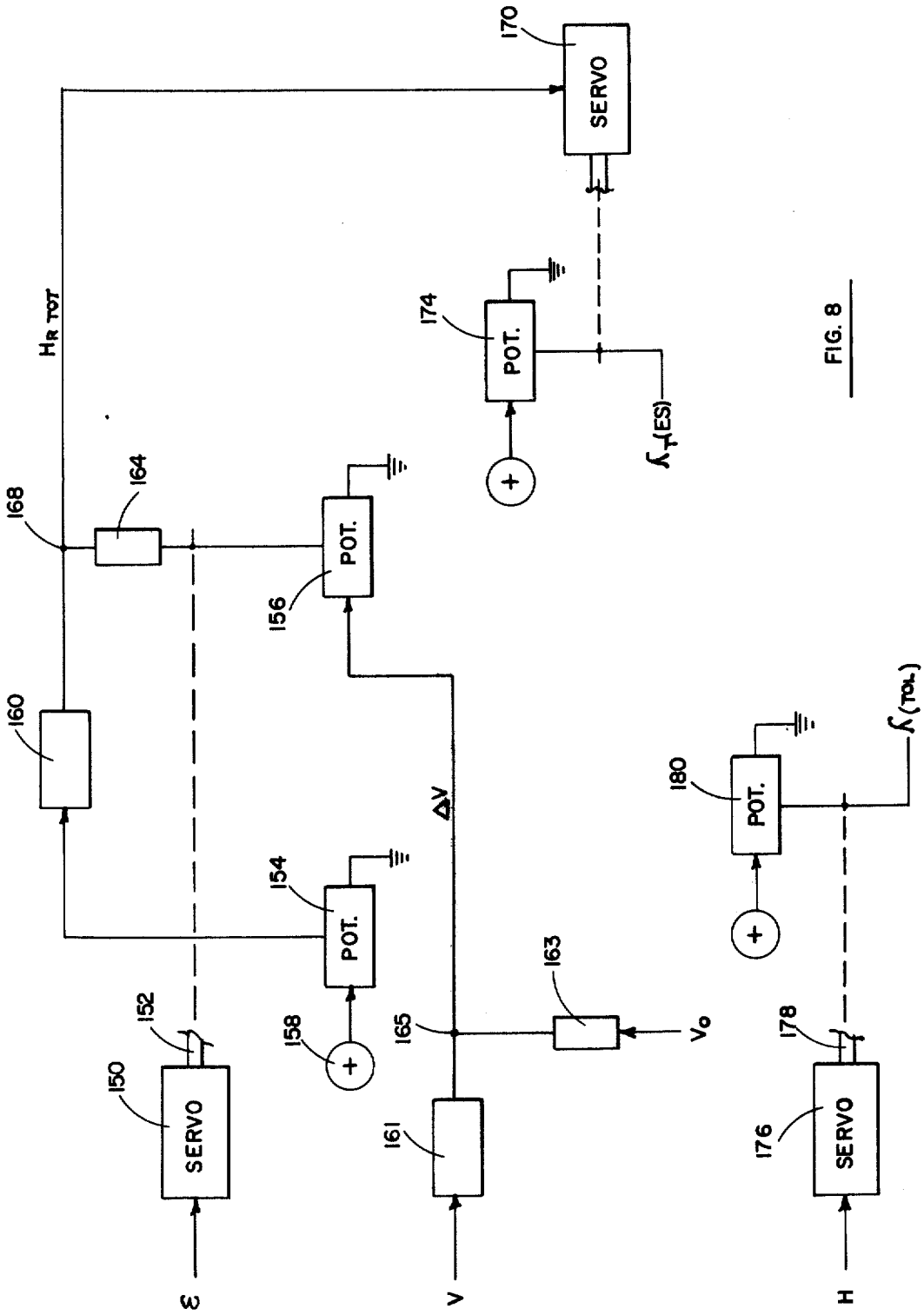

170
SERVO
174
POT.
$f_{T(ES)}$
$H_{R\ TOT}$
164
168
POT.
156
160
154
POT.
152
150
SERVO
158
165
163
V_o
161
ΔV
180
POT.
$f_{(TOT.)}$
178
176
SERVO
ε
V
H

FIG. 8

PROJECTILE DELIVERY SYSTEM

BACKGROUND OF THE INVENTION

This invention relates in general to certain new and useful improvements in projectile delivery systems, and more particularly, to projectile delivery systems used with airborne equipment and which enable the pilot of the airborne equipment to obtain optimum release conditions for delivery of a projectile toward a remote target.

Systems for the delivery of projectiles from airborne equipment have been used since the time that aircraft were employed in armed conflicts. These systems are designed to aid the pilot or other personnel in the effective delivery of projectiles, such as bombs containing an explosive charge, (often referred to as "weapons") to a remote target. Such weapon delivery systems are primarily designed to provide the pilot of the airborne equipment with information which assists him in arriving at the correct bomb release position.

These weapon delivery systems have been the subject matter of a substantial amount of research and development in order to improve the effectiveness and the accuracy for precise weapon delivery. The presently available weapon delivery systems will vary in complexity from standard air data instruments with a fixed depressed reticle sight used in the so-called "canned delivery bombing", which largely relies upon pilot judgement and experience, to much more sophisticated systems with continuous automatic tracking and projectile release features.

The continuous automatic tracking and release systems have been found to be highly effective in many forms of airborne equipment used for weapon delivery. However, these systems require a substantial amount of monitoring by the pilot or other personnel in the airborne equipment in order to lend to effective operation. In addition, these automatic tracking and release systems are quite costly, both in terms of the cost to manufacture and cost of installation, and in addition, the cost of maintenance. Furthermore, these complex systems must be continually altered or otherwise adjusted in order to compensate for different types of weapons.

The presently available projectile delivery systems which permit operation with a canned delivery bombing technique usually employ a fixed depressed reticle as a bomb-sight in the aircraft. The canned delivery bombing systems are more widely used than the continuous automatic tracking and release system due primarily to the cost factors. In addition these sophisticated systems are more prone to breakdown requiring substantial repair and maintenance.

In the canned delivery bombing techniques, the pilot attempts to release the bomb or other weapon at a preplanned set of values corresponding to the dive angle of the aircraft, airspeed, target depression angle, and the altitude that has been pre-calculated to result in a target hit, while permitting the aircraft to recover from a dive with a specified ground clearance. The pilot will generally maneuver the aircraft to enter the dive, correct his aiming point during the dive, and release the bomb or other projectile as he passes through the planned release altitude.

The pilot of the aircraft cannot consistently judge his dive entry to match the pre-established dive angle and airspeed and at the same time obtain coincidence of the target reticle and the target at the preplanned release altitude. While the pilot can attempt to correct for recognized deviations from planned dive angle and airspeed values by revising his release altitude or his aiming point, these attempts to compensate for the deviations are often ineffective. This revising of the release altitude and aim point can only be accomplished by approximate estimation, resulting in compensation errors which are a major contributing factor to bombing inaccuracy. Furthermore, during the delivery of these weapons in hostile environments, the pilot has little time to compensate for any miscalculations or undesirable attitude conditions of the aircraft.

The present invention relates to improvements in the canned projectile delivery system, that is a system which utilizes a target release cue to identify a correct projectile release point together with an aiming reticle for target alignment in order to achieve the correct projectile release point. With this system of the present invention, the pilot will cause the aircraft to drive toward the remote target when he determines that the aircraft has reached a correct or optimum dive initiation point. Even if the optimum dive initiation point is overshot or undershot so that the required dive angle is steeper or shallower than the optimum dive angle, the projectile delivery system of the present invention will still permit a dive path containing a projectile release point which enables a target hit. The system of the present invention will also enable the achievement of a dive path with the correct projectile release point even though the airspeed may vary from the preplanned airspeed. If the aircraft overshoots the correct dive initiation point, the subject projectile delivery system will operate to present a projectile release point which will be at a greater height and lesser ground range than the design preplanned release point, but which will nevertheless be as effective as if the projectile was released at the preplanned release conditions. The converse is also true, in that the subject projectile delivery system will compensate for a dive initiation prior to the preplanned dive initiation point. An earlier dive initiation will result in a shallower dive and the bomb release point will thereupon exist at a lower height and greater ground range than the preplanned bomb release angle, but which is equally as effective as if the projectile was released at the preplanned release conditions. The characteristics of the subject system are such that with either late dive initiation or early dive initiation, the preplanned ground clearance with respect to the aircraft will be achieved.

It is, therefore, the primary object of the present invention to provide a projectile delivery system for use with airborne equipment which is relatively simple in its construction, and which is relatively simple for operation by the pilot of the airborne equipment.

It is another object of the present invention to provide a projectile delivery system of the type stated which can be manufactured at a relatively low unit cost and requires little, if any, periodic maintenance.

It is a further object of the present invention to provide a projectile delivery system of the type stated which is highly reliable and enables precise projectile delivery to a remote target.

It is also an object of the present invention to provide a projectile delivery system of the type stated which does not compromise ground clearance requirements in dive recoveries.

It is an additional object of the present invention to provide a projectile delivery system of the type stated which is rugged in its construction and capable of withstanding substantial vibrations, wide temperature variations and substantial acceleration forces.

It is another salient object of the present invention to provide a method for sighting a remote target and altering the attitude of airborne equipment to deliver a projectile from the airborne equipment to the remote target.

With the above and other objects in view, our invention resides in the novel features of form, construction, arrangement, and combination of parts presently described and pointed out in the claims.

GENERAL DESCRIPTION

In general terms, the present invention relates to a projectile delivery system for use with airborne equipment. This system comprises an optical plane which is capable of presenting a target image representative of a remote target on the optical plane. The system also includes display generating means for presenting an aiming reticle on the optical plane and which is shiftable thereon in response to a change in altitude of the airborne equipment. The display generating means also produces a projectile release cue on the optical plane representative of a function of the location of the remote target with respect to the airborne equipment. In addition, processing means is included within the projectile delivery system and is operatively connected to the display generating means for adjustably positioning the target image and the aiming reticle on the optical plane in response to a change of altitude of the airborne equipment. This processing means also provides for adjustably positioning the projectile release cue on the optical plane in response to a change in the attitude of the airborne equipment.

The projectile delivery system of the present invention can be characterized in further detail in that means is provided for introducing signals into the processing means which is representative of the altitude, the pitch angle and the angle of attack of the airborne equipment to enable the adjustable positioning of the projectile release cue. In addition, roll stabilizing means is operatively associated with the processing means to stabilize the aiming reticle projectile release cue against roll of the airborne equipment. In addition, adjustable depression means is operatively associated with the processing means to continuously adjustably depress the aiming reticle on the optical plane so that the dive angle of the airborne equipment remains constant when the target image and aiming reticle are aligned.

In a preferred aspect of the present invention, the airborne equipment is the aircraft of the type which is capable of delivering bombs containing a high explosive charge and a projectile capable of being delivered by the subject delivery system is a bomb which contains a high explosive charge. In this respect, the target image is a view of a remote target which is capable of being visually seen through the optical plane. The projectile release cue mentioned above is adjustably positioned in response, not only to a change in attitude, but also to a change of velocity and a change in the angle of attack of the airborne equipment.

The display generating means, mentioned above, will generally include a display tube or similar display device which is capable of optically depicting information, such as the aiming reticle and the projectile release cue, thereon. As indicated, the target image is actually that image which can be seen through the optical plane. The display generating means would normally include display logic and driver electronics. The processing means is a processor to be hereinafter described and actually controls the display generating means for shifting the sighting reticle, and the projectile release cue on the optical plane. The means for introducing the signals into the processing means which are representative of altitude, pitch angle and angle of attack will generally include a multiplexer which receives signals from the airborne equipment.

The projectile delivery system of the present invention can also be described in general terms as a system which comprises display means permitting the viewing of a target image representative of a remote target. The system also includes the display generating means for presenting the projectile release cue on the display means. The processing means mentioned above will receive signals representative of the altitude, the pitch angle and the angle of attack of the airborne equipment. In addition, the system will include means for introducing signals under manual control representative of the altitude and dive angle of the airborne equipment, and these signals will be combined in a multiplexer and in turn, introduced into the processing means. In this way, the processing means will automatically adjustably position the target image and the sighting reticle with respect to the projectile release cue, in response to a change of the altitude of the airborne equipment.

In addition, in a preferred aspect of the present invention, the projectile delivery system will include means for introducing a signal into the multiplexing means under manual control and which signal is representative of the target altitude. Furthermore, means will also be provided for introducing a signal under manual control into the multiplexing means which is representative of a depression angle of the reticle.

Also, in the preferred aspect of the present invention, a projectile type selector is provided for selecting one of a plurality of projectile types. This selector mechanism is operatively connected to the precessing means for adjusting the processing means to enable compensation for the selected projectile type. The system will include mode control means permitting manual selection between various modes of operation. In one aspect of the present invention, it is possible to automatically release the projectile when the target image and the aiming reticle become aligned with the projectile release cue. The mode control means mentioned above, will permit an off condition, and a standby condition in which an auxiliary display means, such as a standby reticle is utilized.

The method of the present invention can be described in general terms as a method for sighting a remote target and altering the attitude of airborne equipment to deliver a projectile from the airborne equipment to the remote target. This method will comprise the presenting of the target image representative of a remote target on an optical plane in the airborne equipment. In addition, an aiming reticle and a projectile release cue are generated on the optical plane. Again, the projectile release cue is representative of a function of the location of the remote target with respect to the airborne equipment. The method will include the auto-

matically adjustably positioning the aiming reticle on the optical plane in response to a change of altitude of the airborne equipment, and adjustably positioning the projectile release cue on the optical plane in response to a function of the attitude, the velocity and the angle of attack of the airborne equipment.

In addition, the method will automatically continuously depress the aiming reticle on the optical plane so that the dive angle of the airborne equipment remains constant when the target image and the aiming reticle are aligned. the method will also permit the selecting of one of a plurality of projectile types as mentioned above, and further, the method, in one aspect of the present invention, can be adapted to automatically release the projectile when the target image becomes aligned with the projectile release cue.

In essence, the projectile delivery system of the present invention is based on the principle of guiding the airborne equipment along a delivery drive path such that the angle existing between the dive path (which is the sum of the pitch attitude and the aerodynamic angle of attack) and the sightline to the target is a function of the height of the airborne equipment above the target. The guide of this airborne equipment along the delivery dive path is also achieved by calculating the release height as a function of the drive path angle from the horizontal and the velocity.

This delivery system will contain the refractive and and/or reflective optical elements to permit the presentation of an aiming reticle, release cues and other possible visible displays collimated at infinity. The optical system is designed to simultaneously permit direct viewing of a real target in juxtaposition to the collimated displays of the aiming reticle, release cue and other possible presentations. Furthermore, the target image may be artificially presented and the location of this target image is then derived by means other than direct viewing.

The pilot of the aircraft will normally determine a set of conditions which are designed to lead to a perfect projectile release point. Thus, if this set of conditions which account for altitude, airspeed, dive angle and the like are correct or true, then a projectile released at the perfect projectile release point will result in a perfect target strike. These perfect conditions are often referred to as the "optimum" conditions inasmuch as the system of the present invention at optimum operation will result in perfect conditions and hence a perfect target hit. Furthermore, since the pilot would normally determine these conditions which are designed to lead to a perfect release point, these conditions are often referred to as "predetermined" or "preplanned" conditions. In addition, if the preplanned or predetermined conditions coincide with those optimum conditions which lead to a perfect target hit, the predetermined or preplanned conditions will be equivalent to the optimum or perfect conditions.

DEFINITIONS

The recent advances in the field of airborne equipment and aerospace technology has created a condition of multiple uses of terms which has led to some confusion. In view of the fact, that in some cases there is no precise or accurate standarization of terms, the following definitions are set forth for purposes of clarity and for understanding their use in this instant application. It should therefore be recognized that these definitions are only exemplary and therefore non-limiting. In addition, reference may be made to FIGS. **4** through **6** of the drawings in order to more fully appreciate the significance of the terms as used in this application.

As used herein:

The term "dive angle", which is represented by the symbol γ herein, refers to the angle at which an aircraft is flying relative to a horizontal plane, generally at ground level. Thus if an aircraft was diving toward ground level, the dive angle would be the angle existing between a horizontal plane and the approach line or dive path of the aircraft toward ground level, or in other words, the angle at which aircraft is approaching the ground level.

The term "pitch angle", which is represented by the symbol θ herein, refers to the angle which the axial centerline of the aircraft fuselage generates with respect to the horizontal plane. Thus the nose of the aircraft may be pointed at an angle relative to the ground which may be less than or greater than the dive angle of the aircraft.

the term "angle of attack", which is represented by the symbol α herein, refers to the angle existing between the dive angle and the pitch angle of the aircraft.

The term "target altitude", which is represented by the symbol H_T herein, refers to the altitude of a target relative to sea level.

The term "airspeed", which is represented by the symbol V herein, refers to the velocity of the aircraft relative to the surrounding air environment.

The term "aircraft altitude", which is represented by the symbol H herein, refers to the height or altitude of the aircraft relative to sea level.

The term "sight line", refers to the line of sight from an aircraft to a remote target.

The term "reticle depression angle", which is represented by the symbol λ_T herein, refers to the distance existing between a data reference point representing a fuselage reference line on an optical sight and the centerpoint of a sighting reticle on the optical sight, and which is equivalent to the angle viewable by the aircraft pilot subtended by these two points.

The term "release cue" refers to the designation or indicia appearing on a sight glass to indicate the optimum projectile release point; and with particular reference to FIG. **6**, the release cue depression angle is represented by the symbol λ_r, which refers to the distance between a data reference point and a release cue on an optical sight; and which is equivalent to the angle subtended by the data reference point on the optical sight glass and an apparent optimum projectile release point, as represented by the release cue on the sight glass as viewable by the aircraft pilot.

The term "nominal release cue" refers to a projectile release point which is the preplanned optimum projectile release point and which deviates from the release cue on a sight glass, representative of the apparent optimum projectile release point by an amount to compensate for incorrect attitude of the aircraft; and with particular reference to FIG. **6** the nominal release cue is represented by the symbol λ_{r_θ} which refers to the distance existing between a data reference point and the undisplayed nominal release cue on a sight glass; and which is equivalent to the angle which exists between the data reference point on the optical sight glass and a true optimum projectile release point as represented by the nominal release cue.

The term "roll attitude" (often referred to as "roll angle") refers to the angle existing between the normal vertical centerline of an aircraft fuselage when in a truly upright position, and the vertical plane assumed by the aircraft when it has shifted the vertical plane about its horizontal axis. Thus, for example, when the wings of an aircraft tilt so that one is higher than the other, the angle defined by a plane passing through the wings and a true horizontal would represent the roll angle or roll attitude of the aircraft.

FIGURES

Having thus generally described the invention, reference will now be made to the accompanying drawings in which:

FIG. **1** is a schematic view illustrating conventional projectile delivery sights and compensated release sights forming part of the system of the present invention with respect to a diagram showing aircraft trajectory and projectile trajectory;

FIG. **2** is a front elevational view of the projectile delivery system of the present invention and showing the operator's control panel and the optical display sight forming a part thereof;

FIG. **3** is a schematic view of the electrical circuitry which forms part of the projectile delivery system of the present invention;

FIG. **4** is a typical front plan view of an optical display forming part of the system of the present invention;

FIG. **5** is a schamatic front elevational view of an optical display showing the relationship of various components in the display;

FIG. **6** is a diagrammatic view, related to FIG. **5**, illustrating projectile delivery conditions which are achieved with airborne equipment when using the projectile delivery system of the present invention;

FIG. **7** is a diagrammatic view, similar to FIG. **5** illustrating projectile release conditions which are achieved with airborne equipment using the projectile delivery system of the present invention; and

FIG. **8** is a schematic view of the electrical circuitry included within the processor forming part of the projectile delivery system of the present invention.

DETAILED DESCRIPTIONS

Referring now in more detail and by reference characters to the drawings, FIG. **1** presents a schematic diagram in the right-hand portion thereof, which illustrates aircraft trajectory and a projectile trajectory with respect to a remote target. FIG. **1**, in the left-hand portion thereof, illustrates a fixed depressed reticle sight mechanism as well as compensated release sights which form part of the system of the present invention. These various sight mechanisms, including the fixed depressed sight and compensated release sights, are correlated positionally to the aircraft trajectory and the projectile trajectory.

More specifically, in FIG. **1**, **10** designates an aircraft trajectory in a horizontal plane and **12** designates a remote target, generally at ground level. If the aircraft was to release a projectile, such as a bomb, a missile, or the like, which may contain an explosive charge, the aircraft would follow the trajectory **10** until it reached an optimum dive initiation point **14**. When the aircraft reached the preplanned dive initiation point **14**, it would dive at a selected preplanned dive angle to follow a preplanned dive path **16** at an optimum dive speed. As the aircraft follows the dive path **16**, it would normally release the projectile at a preplanned projectile release point **18**.

These preplanned conditions, mentioned above, are equivalent to the optimum conditions since these conditions will theoretically define the most exact conditions which in combination would lead to a target hit by the projectile. These preplanned and hence optimum conditions would normally take into consideration such factors as the altitude of the aircraft relative to the target, the dive angle, and the airspeed. When these optimum or perfect conditions are achieved, a projectile released from the aircraft at the projectile release point **18** will follow a projectile trajectory **20** directly to the remote target **12**. The pilot of the aircraft will initially have a target sightline **22** when he reaches the optimum dive initiation point **14**.

The term "projectile" as used herein will normally refer to any form of device for air to ground delivery from airborne equipment to a remote target. More specifically, the projectile which is used in aircraft of this type will normally be a bomb containing a high explosive charge. However, it should be recognized that the projectile could adopt the form of bullets or other projectiles discharged from cannons or other guns, or the projectile could adopt the form of rockets or missiles which contain explosive charges, or the like. The projectile delivery system of the present invention was specifically designed for use in the delivery of bombs from aircraft, although the system is highly effective with other forms of projectiles. In the case of bomb delivery, the system of the present invention is most effective with that form of bombing known as dive bombing, as opposed to the so-called "high level bombing" in which bombs are dropped from a plane following a relatively straight horizontal path.

In the so-called canned delivery bombing, the pilot will normally attempt to determine, in advance of the dive point **14**, a set of pre-determined conditions which include the desired dive point, such as the dive point **14**, the desired dive angle so that the plane follows a dive path **16**, and the desired projectile release point such as the release point **18**. Even with the conventional fixed depressed reticle sight, if the pilot accurately determined these optimum conditions and then followed a precise aircraft trajectory which complied with these optimum conditions and which would also include the optimum conditions, then the bomb or other projectile would follow the true projectile trajectory path **20** for a direct hit on the target **12**.

These pre-determined plans or planned conditions, as stated above, also include a consideration of the altitude of the plane along the horizontal path **10** prior to a dive, the correct dive angle, and the airspeed of the aircraft during the dive along the dive path **14**. Each of these factors must be very accurately judged in order for the pilot to achieve the preplanned dive entry point **14**, follow the prelanned dive path **16**, and release just at the preplanned projectile release point **18** when the aircraft pilot is flying the aircraft at the preplanned velocity. Consequently, these preplanned conditions when using a fixed depressed reticle sight are seldom achieved with exactness, and even with considerable experience and constant practice are only approximately achieved. Thus in principle, the flight path during a bombing dive is dictated by an endeavor to keep

the angle between the sight line-to-target and the airplane velocity vector the same for each given altitude as would exist with a dive initiated from a perfect preplanned dive point.

Reference numeral **30***a* designates a fixed depressed reticle sight which includes a fixed reticle **32** and an image of the target **34** appearing through the sight glass with respect to a data reference point **36** which is often referred to as an "armament datum reference". This latter reference point **36** may or may not be visually presented on the actual sight glass in a fixed reticle sight. The aircraft is initially flying along the horizontal flight path **10** and at the point when the pilot initially reaches the optimum dive initiation point **14**, the pilot will pitch the aircraft over into the dive path. It can be observed that immediately after the dive has been initiated the target image **34** would appear somewhat centrally in the sight glass with respect to the depressed reticle **32** and the reference point **36.** When the aircraft is in the dive path **16**, the target image **34** will shift downwardly toward the fixed reticle **32** as indicated by the sight glass **30***b*. As the aircraft continues its descent in the dive path **16**, the target image **34** will even more closely approach the fixed reticle **32** as indicated in the sight glass **30***c*. Finally, when the aircraft has reached the projectile release point **18** on the dive path **16**, the target image **34** will be superimposed and aligned with the fixed depressed reticle **32** as indicated on the sight glass **30***d*. It should be recognized that the sight glasses referred to as 30*a* through **30***d* are essentially the same sight glass showing different locations of an aircraft with respect to the remote target **12.**

If the pilot of the aircraft passes beyond or "overshoots" the preplanned dive initiation point **14**, the pilot may attempt to correct the over-shooting by initiating the dive at a later dive initiation point **40.** In this case, the dive angle resulting from the pilot maintaining the preplanned downward movement of the target image is steeper, so that the pilot would follow the dive path **42.** If the projectile was released at the preplanned altitude with the target image superimposed with the fixed reticle, the projectile would overshoot the target. This overshoot could be avoided by releasing of the projectile at an adjusted release point **44** so that the projectile would follow the trajectory **46.** In this case, it can be observed that the correct or optimum release point exists at a greater height than the preplanned release point and the target image at this release point would be located at some point above the fixed reticle **32.**

In like manner, if the dive initiation occurs prior to the preplanned dive initiation point **14**, so that dive initiation occurs at the point **48**, the aircraft will follow a dive path **50**, which is shallower than the preplanned dive path **16.** If the pilot of the aircraft should release the projectile at the preplanned altitude in this case with the target image superimposed over the fixed reticle **32**, the projectile would undershoot the target. This undershoot of the projectile could be avoided by releasing the projectile at an adjusted projectile release point **52** so that the projectile follows a trajectory **54** to the target. In this case, it can be observed that the earlier dive initiation will result in a shallower dive and the correct projectile release point **52** will exist at a lower height than the preplanned projectile release point **18.** In the case of the overshooting the target image **34** at the release point will appear below the fixed depressed reticle **32.**

The projectile delivery system of the present invention can be more fully understood by reference to FIGS. **2, 3** and **4** of the drawings. The delivery system includes at least a control housing **60** and a display tube **62**, the latter being mounted on the upper end of the housing **60.** The housing **60** would normally be provided with brackets or other fastening means (not shown), for attachment to the aircraft in a location which is convenient for operation by the pilot. Normally, the control housing **60** would be mounted directly in front of the pilot so that the display tube **62** is positioned for convenient viewing of a target. In this respect, it should be observed that the housing **60** and the display tube **62** could be separated so that the control housing **60** could be mounted in some other location in the cockpit or other portion of the aircraft.

The display tube **62** will utilize a conventional combining glass **64** which serves as an optical plane. This combining glass **64** would normally operate in conjuction with and receive display images from a collimating lens, and which display images are ultimately generated and derived from some form of cathode ray tube or similar display generating mechanism. The image which is generated by this display generating mechanism would normally pass through a beam splitter for direction to a folding mirror then ultimate introduction through the collimating lens into the combining glass **64.** In this way, the display generating mechanism could generate a display for presentation on the combining glass **64,** and in addition, the pilot would be able to simultaneously observe the target through the combining glass **64.** In this respect, the pilot will observe an image of the target, which is referred to as the "target image" inasmuch as the observation of the remote target occurs through the combining glass **64.** While this so-called target image actually constitutes a visual viewing of the target through the combining glass **64,** much as in the same manner as if the pilot viewed the target through any other form of transparent medium, it should be recognized that the target image could be generated by means of the display generating mechanism mentioned above.

In one embodiment of the present invention, the display tube **62** will utilize a combining glass **64** in combination with a display generating mechanism in the form of a digitally addressed dot matrix electron beam display. Thus, one form of electron beam display system which may be used in combination with the combining glass and the optical system aforementioned is that type of system more fully illustrated and described in U.S. Pat. No. 3,646,382, dated Feb. 29, 1972. This form of display generating device utilizes an area electron source in combination with a series of thin apertured dynode plates which act collectively to generate a scanning electron beam. The position of the beam is determined by digital addressing signals applied to patterned electrodes on the dynode plates. With this system, it is possible to generate the desired form of display for presentation through the combining glass **64.**

By further reference to FIG. **4**, it can be observed that the display generating means, mentioned above, will present the display of a projectile release cue **72** in the form of a roll stablized line symbol, and an aiming reticle **74.** In addition, the display generating means may also be designed to permit generation of a roll bar

indicator **76** located with respect to the sighting reticle **74** for easy observation by the pilot of aircraft roll. The presentation of the roll bar indicator is, however, optional and not always used. In addition to the foregoing, the display generating means could be designed, if desired, to present an airspeed indicator display, a digitally presented, multi-digit pitch angle readout along with the sign of the angle of attack. For example, the sign could be positive e.g. (+) when the aircraft is climbing and negative e.g. (−) when the aircraft is descending. In addition, the display generating means could also be designed to permit generation of an altitude indicator readout in combination with a position indicator. This latter group of optional displays are not illustrated in FIG. **4** since they would only be used in special occasions, although they are available for display on the combining glass **64.**

The actual control system which provides for compensated projectile release and delivery is more fully illustrated in FIG. **3** of the drawings, and includes a multiplexer **70** which receives an altitude input signal **66,** a pitch angle signal **67,** an angle of attack signal **68,** and a roll attitude signal **78.** These various signals are generated at sensors which are normally installed in the aircraft and upon installation of the subject projectile display delivery system, the multiplexer **70** would be connected to these various sensors. In addition, the multiplexer **70** also receives a selected or preset aircraft altitude signal from an altitude select switch **80** which is mounted on the control housing **60.** An altitude correction setting switch **82,** which operates a potentiometer **84** may also be provided to generate an input into the multiplexer **70,** in the manner as illustrated in FIG. **3.** In addition, the multiplexer **70** receives a target altitude input signal **86** which is introduced through a manually operable target altitude dial **88** located on the control housing **60.** Finally, a depression angle signal **90** is also introduced into the multiplexer **70** by means of a manually operable depression angle dial **92** located on the control housing **66** and which operates a potentiometer **94.**

Each of the signals introduced into the multiplexer **70** are then combined and introduced into an analog-digital converter **96** for subsequent introduction into a processor **98** to be hereinafter described in more detail.

The processor **98** also receives a weapon select signal **100** which is introduced by means of a weapon select switch **102** mounted on the control housing **60.** In addition, the processor **98** will receive a pitch angle and a selected airspeed combined signal **104,** which is introduced into the processor by means of a multi-position selector switch **106** also mounted on the control housing **60.** Finally, the processor **98** will receive a declutter signal **104** which is introduced by means of a declutter switch **106** mounted on the control housing **60** and operating a conventional declutter circuit **108.** This declutter signal **104** will operate to effectively remove any electrical noise generated in or introduced into the system.

After the processor **98** has processed the various input signals, it will generate an output in a manner to be hereinafter described, to a display generating mechanism which may comprise display logic **110.** The output of the display logic **110** will operate driver electronics **112** which, in turn, operates the display tube **62.** This display generating mechanism may adopt various forms in the present invention and will be hereinafter described in more detail.

As indicated previously, the pilot of the aircraft will observe the target image directly through the combining glass **64.** The display generating mechanism in combination with the processor **98** will permit the generation of the release cue **72** and the aiming reticle **74** and optionally the roll bar indicator **76.** The processor **98** ultimately receives the altitude input signal **66** and the inputs of the aircraft altitude select switch **80,** and the altitude correction switch **82** to generate the proper altitude.

The processor **98** operating in conjunction with the display generating means will cause the display of the aiming reticle **74.** The aiming reticle **74,** which is essentially a function of the altitude of the aircraft, will automatically shift on the combining glass **64** in response to the change of altitude of the aircraft. The various input signals to the processor **98** permits a shifting movement of the aiming reticle **74** in response to the change of altitude of the aircraft.

The roll bar indicator is compensated, as aforesaid, and will shift in response to a roll of the aircraft. Thus, the processor **98** in combination with the display generating means can generate a roll bar indicator line **76** which maintains a truly horizontal reference. Thus, if the aircraft rolled 20° for example, the roll bar indicator **76** would appear to be located at a 20° angle with the respect to a horizontal centerline on the combining glass **64;** although in actuality, the combining glass would be rotated 20° with the aircraft while the roll bar indicator **76** would maintain a truly horizontal reference. The projectile release cue **72** is generated by the processor **98** in combination with the display logic **110** in a manner to be hereinafter described in more detail.

The aiming reticle **74** and the release cue **72** are actually stabilized around the velocity vector of the aircraft. Consequently, if the pilot of the aircraft introduces the aircraft into a bank, an imaginary line extending between the straight line direction axis of the aircraft and the aiming reticle **74** and release cue **72** will remain vertically in inertial coordinates. The extension of this imaginary line points toward the earths centroid. This function is accomplished by the processor receiving data from a gyroscope (not shown) on the aircraft. This form of gyroscope is normally found on aircraft of the type which would utilize the projectile delivery system of the present invention.

The angular position of the velocity vector around which the rotation of the aircraft may be caused by roll is a function of the aerodynamic angle of attack of the aircraft. The angular position of the velocity vector is also a function of the angle of the velocity vector to the aiming reticle and the angle of the velocity vector to the release cue. The angular position of this velocity vector is then derived by the processor **98** from these functions mentioned above.

The display logic **110** and hence the driver electronics **112** will vary depending upon the type of display tube **62** which is utilized. The display logic **110** and the driver electronics **112** will preferably adopt the form of display means set forth in the aforementioned U.S. Pat. No. 3,646,382 in the event that the digitally addressed electronic beam display is utilized. However, it should be observed that the driver electronics **112** and hence the display logic **110** would be altered if a cathode ray

tube or other raster pattern display generating device is utilized in combination therewith.

The driver electronics **112** will receive a brightness control signal from a brightness control circuit **114**, and which is operated by a manually rotatable brightness control switch **116**, the latter of which is present on the control housing **60**. The brightness control switch **116** will effectively operate a potentiometer **118**, which controls the brightness control circuit **114**. In addition, this control circuit **114** will receive inputs from various photo-cells (not shown), and which are normally located within the cockpit of the aircraft.

In some cases, it may be desired to utilize a standby reticle **120** as opposed to the compensated aiming reticle in the projectile delivery system of the present invention. Therefore an optional standby reticle **120**, which may be a fixed depressed reticle, may also be provided and used in conjunction with the present invention, if desired. The standby reticle **120**, in this case, would receive a depression angle input signal **122** which can be generated by the pilot through adjustment of the depression angle control knob **92**.

From the above, it can be observed that the processor **98** in combination with the display logic **110**, the driver electronics **112**, and the display tube **62**, or other form of display generating means will generate an aiming reticle **74** and target release cue **72** on the combining glass **64**, in addition to the other aircraft information. The pilot will observe the target image in the sighting glass and during the course of flight, and particularly along the dive path, the pilot will align the aiming reticle **74** with the target image. When the aircraft reaches the optimum projectile release point, the target image which coincides with the optical reticle **74** will become aligned with the release cue **72**. At this point, an optimum projectile release condition has been achieved and the pilot can manually release the projectile. On the other hand, it should be observed that the projectile could be automatically released, and for this purpose, the processor may be provided with an automatic release output **124**. The automatic release output would be introduced into an automatic release mechanism (not shown) which is capable of automatically releasing a particular projectile. The automatic release mechanism is conventional in its construction and is, therefore, neither illustrated nor described in any further detail herein.

The projectile release system of the present invention is also provided with a mode control switch **126** or so-called "mode selector" switch, which is mounted on the exterior of the control housing **60** in the manner as illustrated in FIG. **2**. The mode control switch **126** is in a form of a multi-position switch having an "off" position, a manually depressed reticle position, designated as "MDR", a "compensating release" position, a "test" position, and a "standby" position. The off position on the mode selector switch will de-energize the projectile delivery system.

By shifting the mode selector switch **126** to the manually depressed reticle condition, the system will permit use of a manually depressible aiming reticle. When the mode selector switch **126** is shifted to the manually depressible reticle, the manually depressible aiming reticle will be energized permitting the display of aircraft flight path angle, altitude, calibrating airspeed and roll attitude on the combining glass as aforesaid. However, the aiming reticle **74** will not be compensated in accordance with the present invention, and depression of the aiming reticle **74** will be accomplished by manual adjustment of the dial **92**.

When the selector switch **126** is shifted to the compensated release position, the system of the present invention will operate to generate the display on the combining glass **64** as indicated and will display and provide for compensated movement of the optical reticle in accordance with the present invention. In this case the manually depressed reticle condition is similar to the compensated release position with respect to the information displayed on the combining glass **64**, except that the optical reticle will not move toward a compensated release level.

When the mode selector switch **126** is shifted to the test position, a test of the entire system by simulated signals will be initiated, in a manner to be hereinafter described in more detail. Finally, when the mode selector switch **126** is shifted to the standby position, the manually depressible backup or stand-by mechanical reticle **120** would be used. This manually depressible stand-by reticle would normally be illuminated by a quartz lamp.

It should be observed that the connection of the mode selector switch **126** to the components in this system is essentially conventional, and the circuitry thereof has not been illustrated in FIG. **3** in order to maintain brevity and clarity. However, for example, it should be obvious that it is simple to connect the test position to a test circuit (hereinafter described), the standby position of the switch **126** to the standby reticle **120**, and the manually depressed reticle position to the processor **98** to permit display of the various information on the combining glass **64**, but without compensating the aiming reticle **74**.

The system of the present invention is also provided with a test circuit **128** which will generate the simulated test signals delivered to various components of the system, such as the multiplexer **70** and the processor **98**. In addition, the test circuit **128** will receive a response signal from these various components. By comparing the simulated test signal and the response signal, and thereafter displaying this information on the display tube **62**, it is possible to verify the integrity of the system. In addition, a power supply **130** is also provided and is operatively connected to the test circuit **128** and the other components in the system which require a source of power. The power supply **130** could receive a power input, if desired, from the power source of the aircraft.

The operation of the compensated release sight portion of the system can be more fully understood by again referring to FIG. **1** of the drawings. Reference numerals **132***a*, **132***b*, **132***c*, and **132***d*, all schematically represent sight glasses or so-called "reticle sights" which sequentially show a depression of an aiming reticle **74** with respect to a projectile release cue **72** on a combining glass **64**. The four sight glasses **132***a*–**132***d* are essentially the same sight glass showing different locations of the aiming reticle **74** with respect to the projectile release cue **72**. In this connection, it should be observed that the sight glasses **132***a*–**132***d* would effectively be located in the same horizontal plane as the sight glasses **30***a* through **30***d* respectively, and with respect to the aircraft trajectory as illustrated in FIG. **1**. Further, the aiming reticles **74** on the sight glasses **132***a*–**132***d* provide an indication of the target image

location during a dive progression with respect to the aircraft trajectory illustrated in FIG. 1.

Thus, if an aircraft were flying along the horizontal plane 10 and a dive was initiated at the preplanned entry point 14, the aiming reticle 74 would assume the position as illustrated in the sighting glass 132*a*. As the aircraft was following the dive path 16, the aiming reticle 74 would further downwardly toward the release cue 72. As the aircraft still durther descended along the dive path 16, the aiming reticle 74 would assume the position with respect to the release cue 72 on the sight glass 132*c*. Finally, when the aircraft has reached the optimum projectile release point 18, the aiming reticle 74 will become aligned with the release cue 72 as illustrated on the sight glass 132*d*.

It can be observed that the target image of the remote target 12 has been deleted from the sighting glasses 132*a*–132*d* for purposes of clarity. It should also be observed that the data reference point 36 was added to the sight glasses for purposes of reference, although again, this data reference point 36 would not normally be generated by the display generating mechanism and would not appear on the combining glass 64.

In the event that the aircraft using the compensated release sight of the present invention did not initiate the dive at the preplanned dive initiation point 14, the aiming reticle 74 would still shift downwardly, to the point where the aiming reticle 74 was aligned with the release cue 72 at the optimum projectile release point 18. Further, the aiming reticle 74 would shift downwardly on the sight glass with a decrease of altitude and with respect to the data reference point 36, at the same rate as if the dive were initiated at the preplanned dive entry point 14.

Sighting glasses 136*a*, 136*b*, 136*c* and 136*d* illustrate this same relationship of the sighting reticle 74 to the reference point 36 when the dive is entered at point 40 closer in to the target than planned. These sighting glasses 136*a*–136*d* are similar to the sighting glasses 132*a*–132*d* respectively, and would be located in the same horizontal planes as the respective sight glasses 30*a*–30*d* for reference to the aircraft trajectory in FIG. 1. In this case, the pilot would follow the steeper dive path 42 associated with keeping the target image in the aiming reticle 74. The release cue 72 which would normally appear at its nominal release cue position designated by reference numeral 139, would be driven to a corrected position relative to the data reference point 36. The variation of the corrected release cue 72 from its preplanned or nominal position 139 is shown by the distance between the nominal position 139 to the displayed release cue 72 in the sight glasses 136*a*–136*d*. The correct position of the release cue 72 with respect to reference point 36 indicates the depression angle of the target image at the release altitude 44 where projectile release should be made in order to compensate for the steeper than planned dive angle. As the pilot followed the dive path 42, the aiming reticle would shift downwardly toward the displayed release cue 72 as illustrated on the sight glases 136*b* and 136*c*. Again, when the aiming reticle 74 became aligned with the projectile release cue 72, the aircraft would have reached the correct projectile release point 44 and the projectile would follow the trajectory 46 to impact with the remote target 12.

A similar situation would exist if the pilot were to initiate the dive prior to the preplanned entry point 14. The aiming reticle 74 would be driven relative to the reference point 36 exactly as shown in sighting glasses 132*a*–132*d* and 136*a*–136*d*, but, in this case, the corrected release cue would be driven below its preplanned position to cue release at a lower altitude to compensate for the shallower dive angle.

In sighting glass illustrations 132*a*–132*d* and 136*a*–136*d* only the positions of the aiming reticle 74 and the release cue 72 on the sighting glass have been shown; for purposes of clarity the target image has not been shown. Sighting glasses 140*a*–140*d* show how the sight and target image, represented by the triangle, would appear to the pilot during the dive. The pilot maintains the target image coincident with the aiming reticle throughout the dive, and the projectile is released, either manually or automatically when the aiming reticle reaches the release cue.

These sighting glasses designated as 140*a*, 140*b*, 140*c* and 140*d*, correspond respectively to the sighting glasses 132*a* through 132*d*, and would also be located on the same horizontal planes as the sighting glasses 30*a* through 30*d* respectively, with respect to the aircraft trajectory illustrated in FIG. 1. The sighting glasses 140*a* through 140*d* all show the position of the optical reticle 74 with the target image coinciding with the optical reticle for various descending altitudes of the aircraft along a dive path. Again, it should be observed as the aircraft descends along a dive path, such as the dive path 16, the pilot will maintain the target image within the aiming reticle 74, which will depress along the combining glass 64 until it becomes aligned with the projectile release cue 72. At this point, the aircraft has reached the optimum projectile release point.

In this connection, it should be observed that the compensated sighting release system of the present invention enables the formation of a locus of optimum projectile release points, such as the projectile release points 44, 18 and 52. It can be observed that the nominal projectile release cue 139 which does not appear and which represents the preplanned release point will only be displayed when the aircraft follows the preplanned dive path 16 with preplanned airspeed. Otherwise, when the aircraft follows something other than the preplanned dive path with preplanned air speed, the apparent projectile release cue 72 will be displayed in order to compensate for deviation from the preplanned delivery. This technique permits the pilot to always achieve the optimum projectile release point to thereby ensure a target hit.

A characteristic of the present invention of considerable practical importance is that the ground clearance of the aircraft in recovery from the dive is essentially independent of variation from preplanned dive angle and airspeed. If the dive is steeper or faster than planned, greater altitude is lost in recovery than planned but this is compensated for by release having been made at a greater altitude than planned. Similarly, if the dive is shallower or slower than planned, release is made at a lower altitude than planned but this is compensated for by less altitude being lost in recovery than planned.

The processor 98 essentially performs certain mathematical functions by means of corresponding electrical circuitry. In order to more fully understand the mathematical relationships which are resolved in the processor 98, reference is made to FIGS. 5 through 7 of the drawings. FIG. 5 more specifically illustrates in sche-

matic form a sighting glass which is compensated in accordance with the present invention. This sighting glass **64** is likewise provided with the aiming reticle **74**, and a release cue **72**. In addition, a preplanned release cue **139**, illustrated in dotted lines, and a data reference point **138** are shown for reference on the sighting glass.

In accordance with the schematic illustration of FIG. **5**, it can be observed that as an aircraft is descending along a dive path, the aiming reticle **74** will depress downward away from the data reference point **138** toward the preplanned release cue **140**. In this case, the aiming reticle **74** will shift downwardly or will be depressed with respect to the data reference point **138** by a distance or equivalent angle of λ_T. The preplanned release cue **139** will be depressed relative to the data reference point **36** by a distance of equivalent angle of λ_{r_θ}. The release cue **72**, compensative for dive angle and airspeed variation from preplanned values, will be depressed relative to the data reference point **138** by a distance or equivalent angle of λ_r.

FIGS. **6** and **7** illustrate the various parameters which are achieved in projectile delivery conditions and those parameters which are achieved in projectile release conditions. Thus, the projectile delivery conditions, as illustrated in FIG. **6**, would be presented while the aircraft is following a dive path, such as the preplanned dive path. Those conditions illustrated in FIG. **7** would exist when the aircraft has just reached the projectile release point.

As indicated previously, the processor operates in conjunction with the display logic **110** and the driver electronics **112** to display certain information which is derived from the multiplexer and other sensing units on the aircraft. In this respect, the processor performs that function of processing information for display purposes. The information which will normally be displayed is the aiming reticle **74** and the release cue **72** and in the correct positions relative to the data reference point **36**. Furthermore, both the aiming reticle **74** and release cue **72** are roll compensated as indicated previously.

In order to shift the aiming reticle **74** and to determine the desired position of the release cue **72**, the processor **98** solves the two following equations:

$$\lambda_r = \lambda_{r_\theta} + K_3(\theta - \theta_o) + K_4(V - V_o) + K_5(\alpha - \alpha_o)$$

$$\lambda_T = \alpha_o + \cot^{-1}[K_1(H - H_T) - K_2]$$

where:

θ = Pitch Angle
θ_o = Preplanned Pitch Angle
α = Angle of Attack
α_o = Preplanned Angle of Attack
V = Airspeed
V_o = Preplanned Airspeed
H_T = Target Altitude Above Sea Level
H = Aircraft Altitude Height Above Sea Level
λ_r = Release Cue Depression Angle
λ_{r_θ} = Preplanned Release Cue Depression Angle
λ_T = Reticle Depression Angle
$K_1 \rightarrow K_5$ = Precomputed Ballistic Constants as a function of Preplanned Release Parameters

$$V_o, \theta_o, \alpha_o, \lambda_{r_\theta}$$

It can be observed that the solution to the two equations will generate λ_r and λ_T which are the only parameters necessary to establish the compensating release cue **72** and the aiming reticle **74**. The equations are relatively straightforward and mathematical solutions thereof can easily be obtained by any of a number of electrical circuits. One such electrical circuit which forms the processor **98** to resolve these equations is more fully illustrated in FIG. **8** of the drawings.

FIG. **8** represents one form of analog computer circuitry which mechanizes the logic necessary to enable a solution of the equations resolved by the processor **98**. The analog computer circuitry includes a servo-motor **150** which is driven by a signal representative of the analog of the drive angle γ. The servo-motor **150** is provided with an output shaft **152**, and the angularity of which is directly proportional to the dive angle γ. This output shaft **152** drives two function wound potentiometers **154** and **156**. The opposite terminals of the potentiometers **154** and **156** are grounded as illustrated in FIG. **8**.

The first of these potentiometers **154** is wound to an empirical function, described hereinafter, and is excited by a voltage designated by reference numeral **158**, which is an analog of the selected nominal velocity V_o. The empirical function mentioned above is derived by repetitive solutions of the necessary equations resolved by the processor **98** and is such that the voltage sensed at the slider of the potentiometer **154** (to the extent rotated by the shaft **152**) is an exact analog of the correct projectile release height for the nominal velocity, V_o, and the exact measured dive angle γ.

In this respect, it can be observed that the voltage which is sensed at the slider is a combination of the measured altitude, the dive angle, and the nominal velocity designed as $H\gamma V_o$. This output of the potentiometer **154** is then introduced into a summing network **160**.

Signals representative of the measured velocity V and the nominal velocity V_o are introduced into summing networks **160** and **162** and are summed at a summing node **164**. The summation of these two velocities is equivalent to the velocity differential designated as ΔV and this velocity differential signal is used to excite the potentiometer **156**. This potentiometer **156** is also wound to an empirical function which is again derived by repetitive solutions of the equations resolved by the processor **98** as described above.

The potentiometer **156** generates an output voltage designated as $\Delta H \Delta W \gamma$ which is representative of the product of the change of height multiplied by the change in velocity and the dive angle. This signal is actually the analog of the change of release height resulting from velocity deviations. The output voltage $\Delta H \Delta V \gamma$ of the potentiometer **156** which is sensed at the slider thereof, is then introduced into a summing network **166** and then summed with the signal from the potentiometer **154** at a summing node **168**. The combination of these two output signals $H\gamma V_o$ and $\Delta H \Delta V \gamma$ results in a total computed release height signal, designated as H_{RTOT}.

The output signal representing the total computed release height is then introduced into a servo-motor **170** which is also provided with an output shaft **172** operating the slider of a potentiometer **174**. The potentiometer **174** is wound to an empirical function in the same manner as the potentiometer **154** and **156**. The potentiometer **174** also receives a predetermined reticle depression signal designated as $\lambda_r(E_s)$ which can be generated by the pilot of the aircraft at the contact housing **60**. The voltage sensed by the slider of the po-

tentiometer **174** is therefore the analog of λ_r and is employed to directly control the position of the projectile release cue.

The measured height above the target H, namely the altitude of the aircraft, exists in voltage analog form and is employed as an input to a servo-motor **176.** This servo-motor **176** includes an output shaft **178** which actuates the slider of a potentiometer **180.** The potentiometer **180** is would to the same function that the potentiometer **174** is wound and in this case, is an expression relating the depression angle to the measured height above the target. The voltage sensed by the slider of the potentiometer **180** is the analog of the depression angle λ and is determined only by the measured height above the target H.

The circuit illustrated in FIG. **8** essentially functions as a type of simple analog computer. It should also be recognized that it could be possible to substitute a more complex analog computer performing other computing functions in place of the processor **98.** In addition, it should be recognized that the function performed by the processor **98** could also be effectively performed by a suitably programmed digital computer. Nevertheless, with the compensating release sight of the present invention, it has been found that the processor **98** which performs these basic mathematical functions through the described electrical circuitry is highly efficient for this purpose.

Thus there has been illustrated and described a novel projectile delivery system which fulfills all of the objects and advantages sought therefor. Many changes, modifications, alterations and other uses and applications of the projectile delivery system will, however, become apparent to those skilled in the art after considering this specification and the accompanying drawings which form a part thereof. All such changes, modifications, alterations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention which is limited only by the following claims.

Having thus described our invention, what we desire to claim and secure by letters patent is:

1. A projectile delivery system for use with airborne equipment, said delivery system comprising an optical plane, means operatively forming part of said optical plane capable of presenting a target image representative of a remote target on said optical plane, display generating means for presenting a sighting reticle on said optical plane and which is shiftable thereon in response to a change in altitude of said airborne equipment, said display generating means also producing a projectile release cue spaced downwardly from said sighting reticle on said optical plane representative of a function of the location of said remote target with respect to the airborne equipment, said target image shifting downwardly on said optical plane as said airborne equipment enters and follows along a dive path toward a ground level, processing means operatively connected to said display generating means for adjustably shifting the sighting reticle downwardly on the optical plane toward said projectile release cue in response to a reduction of altitude of the airborne equipment as the airborne equipment follows the dive path, and means also operatively associated with said processing means for adjustably positioning the projectile release cue on the optical plane either toward or away from the shifting sighting reticle in response to a change in the attitude of the airborne equipment as the airborne equipment follows said dive path, said last named means shifting said projectile release cue to a desired position on said optical plane so that a projectile released from the airborne equipment when the target image and sighting reticle are substantially aligned with said projectile release cue is designed to follow a trajectory to the remote target.

2. The projectile system of claim **1** further characterized in that means is provided for introducing signals into said processing means representative of the altitude, pitch angle and angle of attack of said airborne equipment to enable the adjustable positioning of the projectile release cue.

3. The projectile delivery system of claim **1** further characterized in that roll stabilizing means is operatively associated with said processing means to stabilize the projectile release cue against roll of the airborne equipment.

4. The projectile delivery system of claim **1** further characterized in that adjustable depression means is operatively associated with said processing means to continuously adjustably depress the sighting reticle on the optical plane so that the dive angle of the airborne equipment remains constant when the target image and sighting reticle are aligned.

5. The projectile delivery system of claim **1** further characterized in that the airborne equipment is aircraft of the type capable of delivering bombs containing a high explosive charge and that the projectile capable of being delivered by the projectile delivery system is a bomb containing a high explosive charge.

6. The projectile delivery system of claim **1** further characterized in that the target image is a view of the remote target which is capable of being visually seen through the optical plane.

7. The projectile delivery system of claim **1** further characterized in that the projectile release cue is adjustably positioned in response to a change in attitude and velocity and angle of attack of said airborne equipment.

8. A projectile delivery system for use with airborne equipment, said delivery system comprising display means permitting viewing of a target image representative of a remote target, display generating means for presenting a projectile release cue on said display means, multiplexing means for operatively receiving signals representative of altitude and pitch angle and angle of attack of the airborne equipment, conversion means operatively connected to said multiplexing means for converting such signals to digital format, processing means operatively connected to said conversion means to receive the digital representations of such signals, means for introducing signals under manual control representative of altitude and dive angle of said airborne equipment into said processing means, computing means forming part of said processing means for automatically adjustably positioning the target image with respect to the projectile release cue in response to a change of the attitude of said airborne equipment, and means for operatively connecting an output of said processing means to said display generating means to enable said display means to visually display the target image and the automatically adjustably positioned projectile release cue.

9. The projectile delivery system of claim **8** further characterized in that the multiplexing means receives

the signals representative of altitude, pitch angle and angle of attack from remote sensors in the airborne equipment independent of operator control.

10. The projectile delivery system of claim **9** further characterized in that means is provided for introducing a signal under manual control representative of the target altitude into said multiplexing means.

11. The projectile delivery system of claim **8** further characterized in that said display generating means is also capable of permitting a visual display of a sighting reticle on said display means and that the target image and the sighting reticle are capable of being aligned and adjustably positioned with respect to the projectile release cue in response to changes in the altitude of the airborne equipment.

12. The projectile delivery system of cliam **8** further characterized in that said display generating means is also capable of permitting a visual display of a sighting reticle on said display means and that the target image and the sighting reticle are capable of being aligned and adjustably positioned with respect to the projectile release cue in response to changes in the altitude of the airborne equipment, and that means is provided for introducing a signal under manual control into said multiplexing means, and which signal is representative of a depression angle of the reticle.

13. The projectile delivery system of claim **8** further characterized in that means for selecting one of a plurality of projectile types is operatively connected to said processing means for adjusting the processing means to enable the processing means to compensate for the selected projectile type.

14. The projectile delivery system of claim **8** further characterized in that means is operatively connected to said processing means to permit automatic release of the projectile when the target image becomes aligned with the projectile release cue.

15. The projectile delivery system of claim **8** further characterized in that mode select means is operatively connected to said processing means to operatively select between an off condition which deenergizes said system, a depressed reticle condition which permits shiftable movement of the reticle in response to change of altitude of the airborne equipment, and a stand-by condition in which an auxiliary display means is utilized.

16. A method for sighting a remote target and altering the attitude of airborne equipment to deliver a projectile from the airborne equipment to the remote target, said method comprising presenting a target image representative of the remote target on an optical plane in the airborne equipment, generating a sighting reticle on the optical plane representative of a function of the location of said remote target with respect to the airborne equipment, automatically shifting the target image downwardly on the optical plane with respect to a datum reference point as airborne equipment enters and follows along a dive path toward a ground level, automatically adjustably shifting the sighting reticle downwardly on the optical plane away from the datum reference point in response to a reduction of altitude of the airborne equipment as the airborne equipment follows the dive path, generating a projectile release cue on the optical plane, determining an optimum position for the projectile release cue so that a projectile released from said airborne equipment is designed to follow a trajectory toward the remote target when the target image and sighting reticle are substantially aligned with the projectile release cue, and adjustably shifting the projectile release cue on the optical plane either toward or away from the shifting sighting reticle and to the determined optimum position in response to a change in the attitude of the airborne equipment as said airborne equipment follows said dive path.

17. The method of claim **16** further characterized in that the projectile release cue is adjustably positioned in response to a function of the attitude, velocity and angle of attack of the airborne equipment.

18. The method of claim **16** further characterized in that the method includes stabilizing the release cue against roll of the airborne equipment.

19. The method of claim **16** further characterized in that the method comprises continuously automatically depressing the sighting reticle on the optical plane so that the dive angle of the airborne equipment remains constant when the target image and sighting reticle are aligned.

20. The method of claim **16** further characterized in that the target image is a view of the remote target which is capable of being visually seen through the optical plane.

21. The method of claim **16** further characterized in that the method includes selecting one of a plurality of projectile types so that the adjustable positioning of the target image and reticle compensates for the selected projectile type.

22. The method of claim **16** further characterized in that the method comprises automatically releasing the projectile when the target image becomes aligned with the projectile release cue.

23. The method of claim **16** further characterized in that the method comprises operatively selecting between an off condition which de-energizes the automatically adjustable positioning, a depressed reticle condition which permits shiftable movement of the reticle in response to change of altitude of the airborne equipment, and a standby condition in which an auxiliary display means is utilized.

24. A projectile delivery system for use with airborne equipment, said delivery system comprising an optical plane capable of presenting a target image representative of a remote target on said optical plane, display generating means for presenting a sighting reticle on said optical plane and which is shiftable thereon in response to a change in altitude of said airborne equipment, said display generating means also producing a projectile release cue on said optical plane representative of a function of the location of said remote target with respect to the airborne equipment, said target image shifting downwardly on said optical plane away from a datum reference point as said airborne equipment enters and follows along a dive path represented by a dive angle γ, processing means operatively connected to said display generating means for adjustably depressing the sighting reticle on the optical plane by an equivalent angle of γ_T with respect to the datum reference point in response to a change of altitude of the airborne equipment as the airborne equipment follows along the dive path, and a release cue controlling means also operatively associated with said processing means for adjustably positioning the projectile release cue on the optical plane by an equivalent angle of λ_{r_0} with respect to the datum reference point in response to a change in the attitude of the airborne equipment

when said airborne equipment follows the dive angle γ, said processing means operating in conjunction with said release cue controlling means for shifting the projectile release cue on the optical plane from a preplanned release cue point througn an equivalent angle λ_{r_0} so that a projectile released from the airborne equipment is designed to follow a trajectory to the remote target when the target image and sighting reticle are aligned with the release cue on the optical plane, said processing means computing the desired equivalent angle λ_T as a function of the dive angle γ and the desired equivalent angle λ_r with respect to the equivalent angle λ_{r_0} as a function of at least the dive angle γ.

25. The projectile system of claim **24** further characterized in that means is provided for introducing signals into said processing means representative of the altitude, pitch angle and angle of attack of said airborne equipment to enable the adjustable positioning of the projectile release cue.

26. The projectile delivery system of claim **24** further characterized in that roll stabilizing means is operatively associated with said processing means to stabilize the projectile release cue against roll of the airborne equipment.

27. The projectile delivery system of claim **24** further characterized in that adjustable depression means is operatively associated with said processing means to continuously adjustably depress the sighting reticle on the optical plane so that the dive angle of the airborne equipment remains constant when the target image and sighting reticle are aligned.

28. The projectile delivery system of claim **24** further characterized in that the projectile release cue is also adjustably positioned in response to a change in attitude and velocity γ and angle of attack of said airborne equipment, and said processing means computes the desired release cue position also as a function of the velocity and angle of attack.

* * * * *