Feb. 11, 1969 G. TYE 3,427,437

KINEMATIC SIGHT

Filed Sept. 15, 1964 Sheet 1 of 5

FIG.1

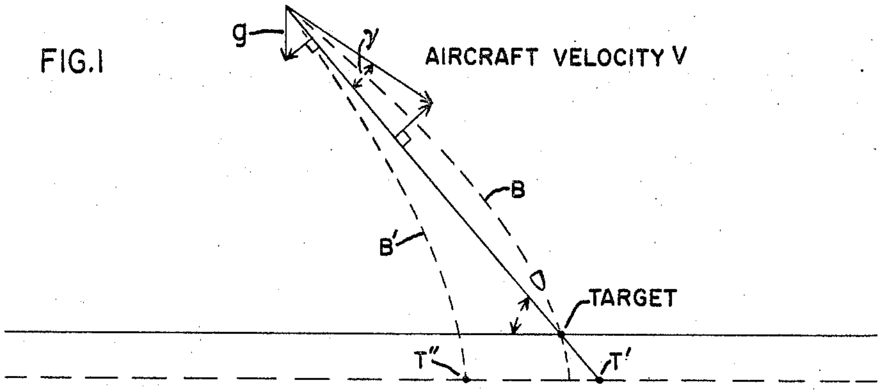
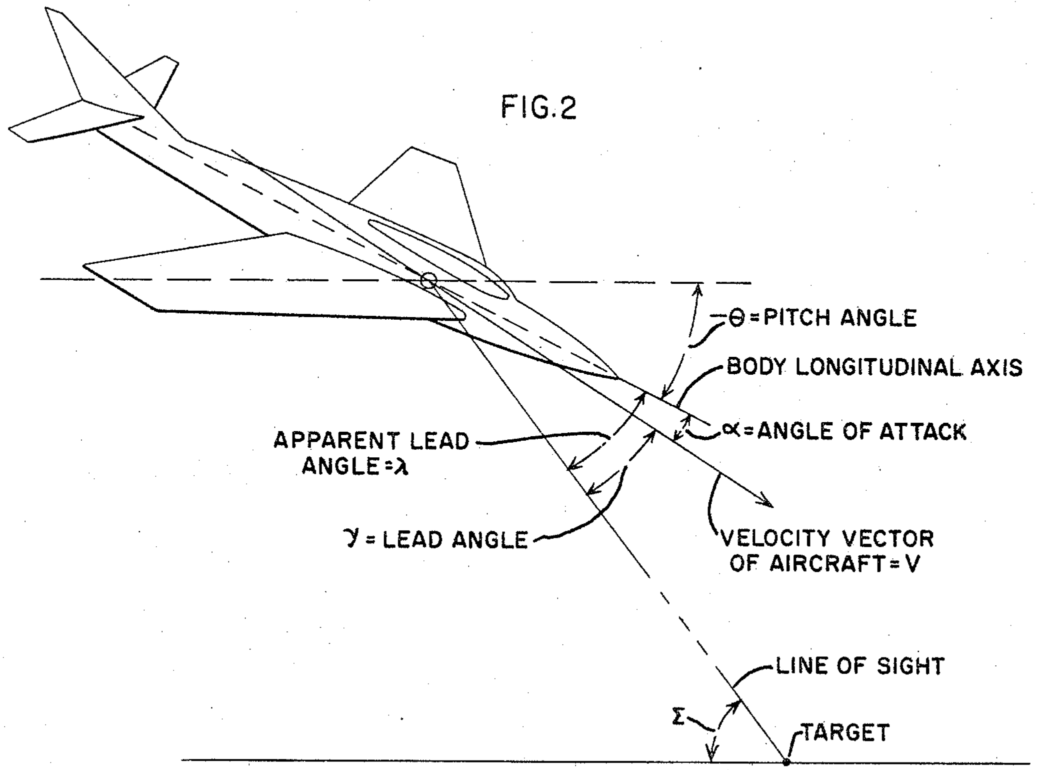


FIG.2



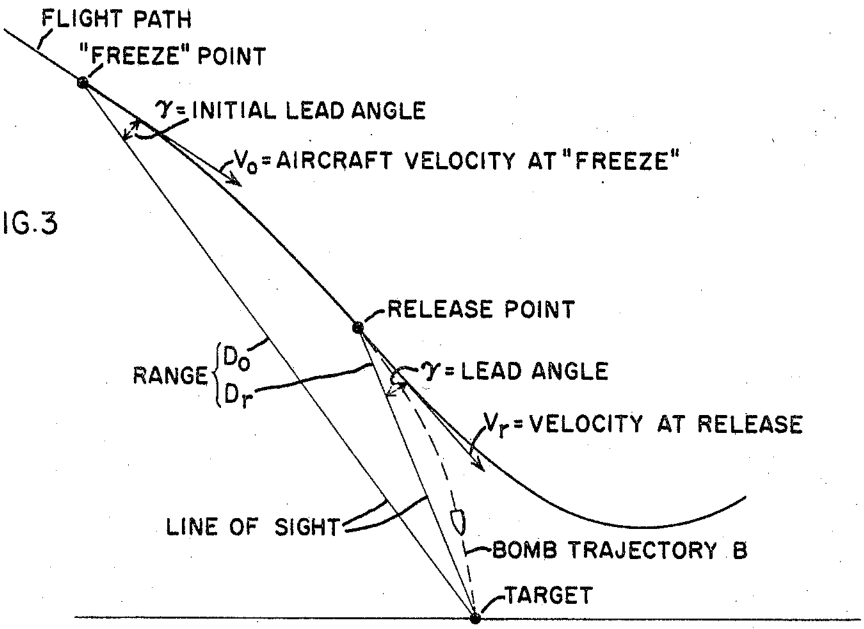


FIG. 3

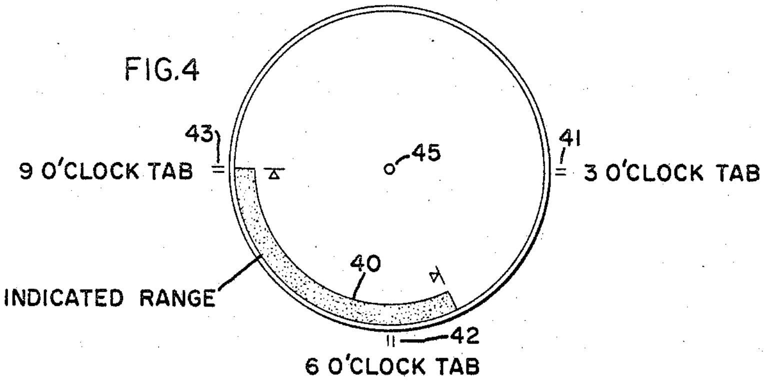


FIG. 4

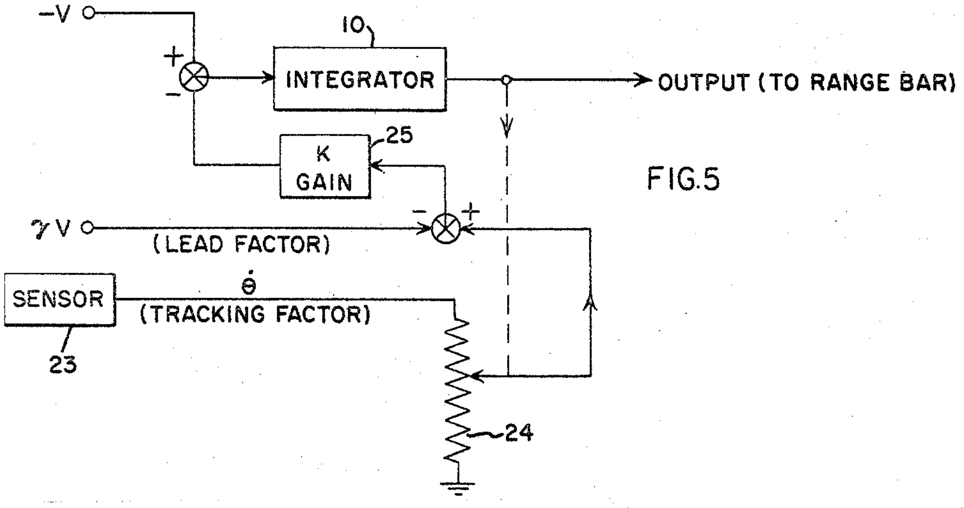


FIG. 5

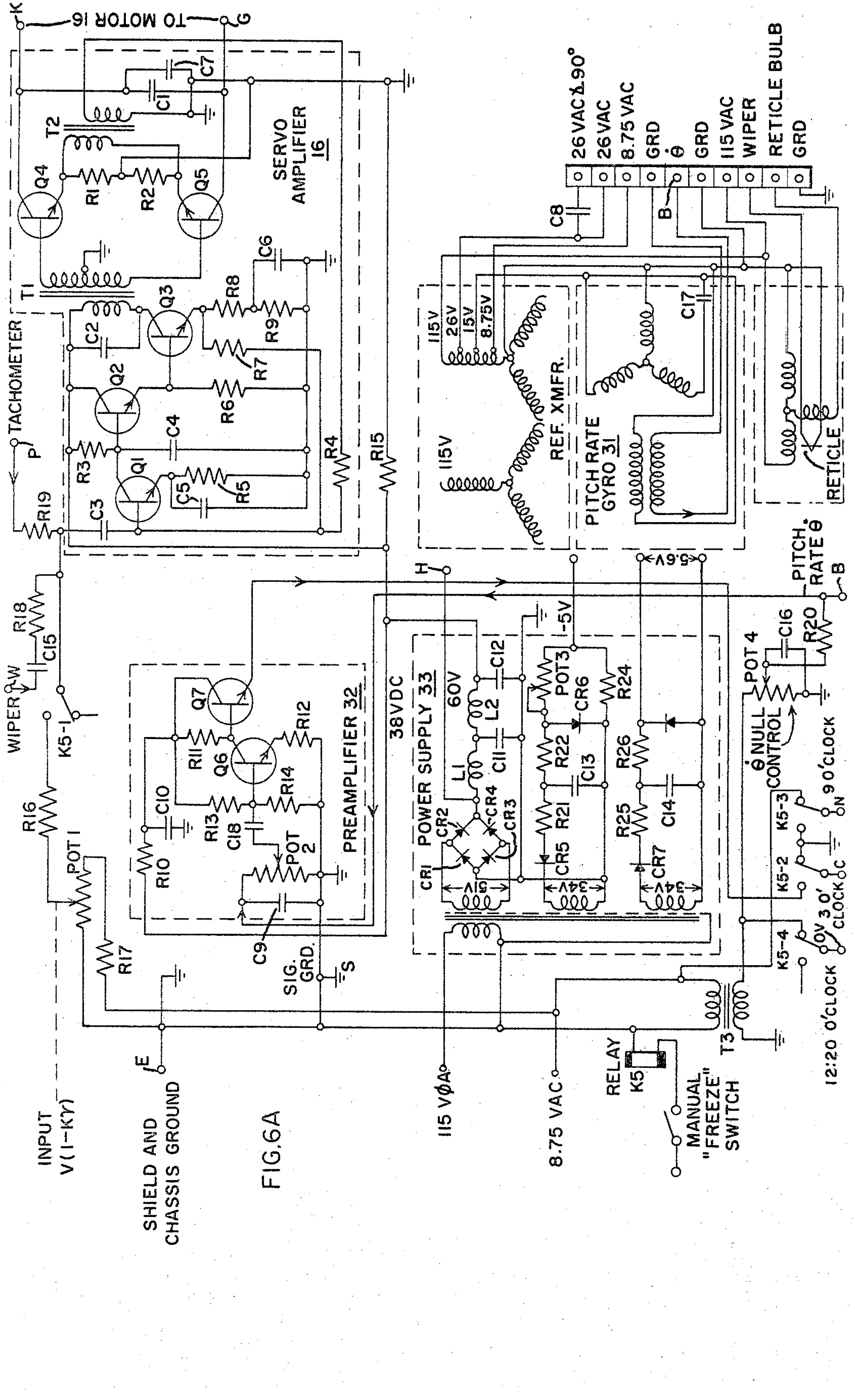

K
TO MOTOR 16
G
C7
C1
T2
SERVO AMPLIFIER 16
Q4
R1
R2
Q5
C6
T1
R8
Q3
C2
R9
TACHOMETER
Q2
R7
R6
P
C4
R3
R4
R15
Q1
C5
R5
R19
C3
R18
WIPER
W
C15
K5-1
R16
POT 1
R17
INPUT V(1-KY)
SHIELD AND CHASSIS GROUND
E
Q7
R12
R11
Q6
R14
C10
R13
C18
POT 2
R10
C9
SIG. GRD.
S
PREAMPLIFIER 32
38VDC
H
POWER SUPPLY 33
60V
C12
L2
L1
C11
CR2
CR4
CR3
CR1
51V
115 VϕA
8.75 VAC
-5V
POT3
CR6
R24
R22
C13
R21
CR5
34V
R26
R25
C14
CR7
5.6V
C8
26 VAC ∠90°
26 VAC
8.75 VAC
GRD
θ̇
GRD
115 VAC
WIPER
RETICLE BULB
GRD
B
115V
26V
15V
8.75V
REF. XMFR.
C17
PITCH RATE GYRO 31
RETICLE
PITCH RATE θ̇
C16
R20
POT 4
θ̇ NULL CONTROL
9 O'CLOCK
K5-3
K5-2
C
N
0V
3 O' CLOCK
K5-4
T3
12:20 O'CLOCK
RELAY K5
MANUAL "FREEZE" SWITCH

FIG. 6A

FIG. 6B

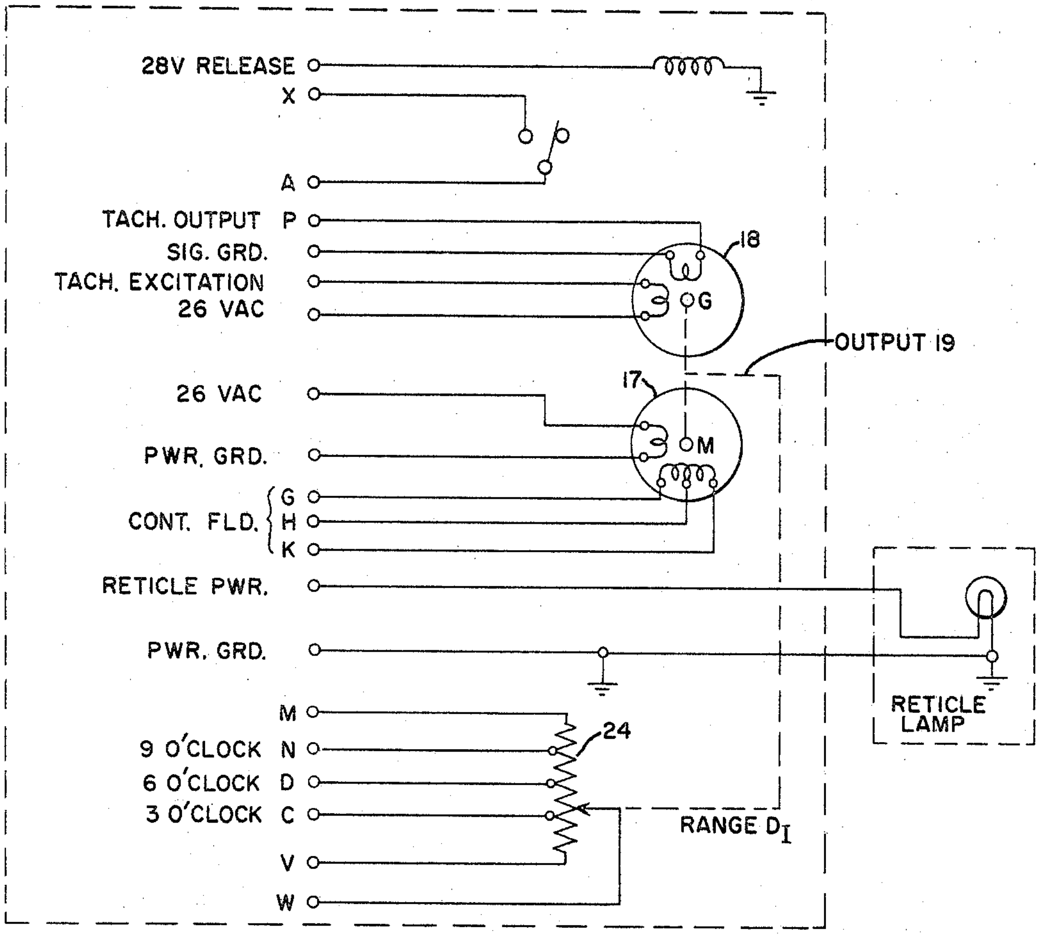
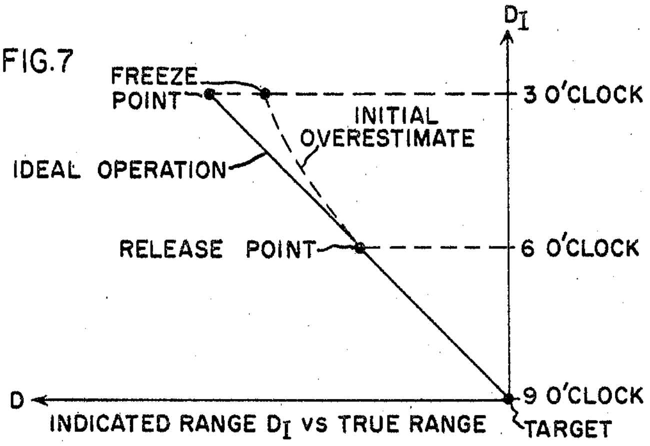

28V RELEASE
X
A
TACH. OUTPUT P
SIG. GRD.
TACH. EXCITATION
26 VAC
18
G
OUTPUT 19
17
26 VAC
PWR. GRD.
M
CONT. FLD.
G
H
K
RETICLE PWR.
PWR. GRD.
RETICLE LAMP
M
9 O'CLOCK N
6 O'CLOCK D
3 O'CLOCK C
24
RANGE D_I
V
W

FIG. 7



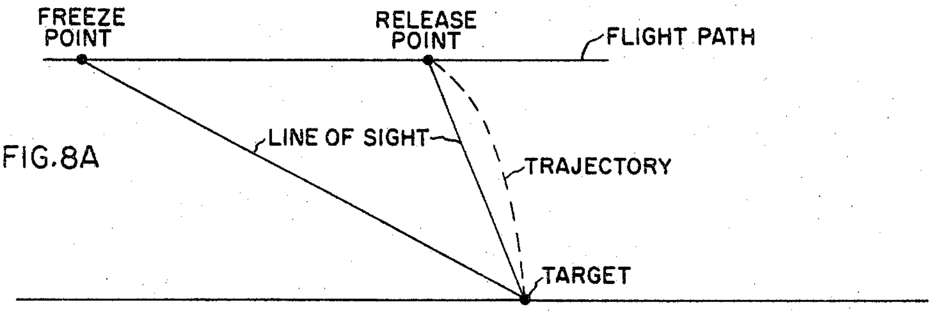
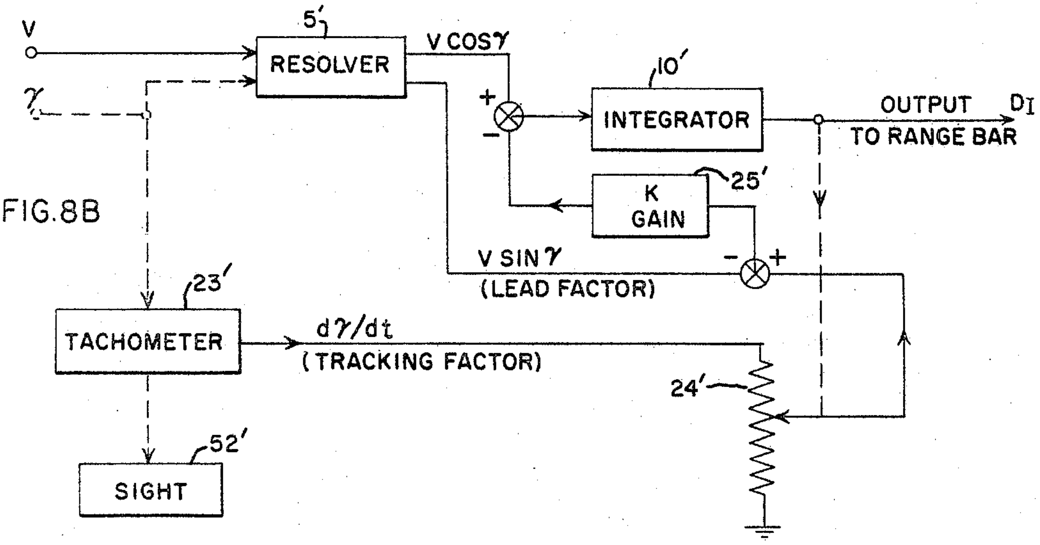


FIG. 8A

FIG. 8B



3,427,437

KINEMATIC SIGHT

Gene Tye, Endwell, N.Y., assignor to General Electric Company, a corporation of New York

Filed Sept. 15, 1964, Ser. No. 396,688
U.S. Cl. 235—61.5 4 Claims
Int. Cl. G06f *15/58;* G06g *7/80*

ABSTRACT OF THE DISCLOSURE

A dive bombing sight which passively derives slant range to target from the kinematic perimeters of the problem. A minimum complexity system requiring only a pitch rate gyro as a sensor input. Range is computed in a closed loop manner by integrating air speed (nominally constant) plus a signal proportional to range error obtained as the difference between the component of air speed across the line of sight and the product of pitch rate and presently indicated range. The range computation is initiated when the pilot estimates that range is equal to the value preset as an initial range of the integrator by maintaining the sight tipper on the target from the time that the range computation is initiated until a preselect release range is reached. The error in the initial range estimate, and consequently the present range measurement, is reduced to a small value. Indicated range is displayed as an integral part of the sight reticle so that the pilot can correlate errors in indicated range with observed tracking errors, and thus make the necessary delay or advance correction in bomb release.

This invention relates to sighting mechanisms and the like, more particularly to sighting mechanisms for directing a projectile or missile to a target. For example, it is useful in the control of guns, bombing apparatus, parachute drops, etc., and has for its object the provision of an improved mechanism of this character. This invention has special application to dive bombing sighting mechanisms for controlling the release of bombs from airplanes or other airborne vehicles so as to follow a course towards the target for which the bomb will hit the target.

With the present state of the art, it is possible to make fire control sights of almost any desired accuracy. The detailed empirical and theoretical knowledge of ballistic characteristics enables accurate prediction of projectile trajectories. Instrumentation such as with radar or laser range finders and precision inertial sensors enables accurate measurement of relative position and vehicle motion. However, the cost and maintenance requirements of sophisticated equipment seriously limit their range of applications. The function of a bomb sight computer is to indicate a point at which a released bomb will intercept a target. The mathematical relationships can be conveniently considered from the FIGURE 1 diagram.

The simplest method of dive bombing is to rely on simple pilot estimates. That is, the procedure can be to fly the aircraft at a predetermined dive angle to a predetermined range from the target where free fall ballistic requirements are known to be satisfied. The success of this method then depends on pilot estimates. The pilot must esimate the range to the target and, to a lesser extent, the alignment of the target with a sighting reference, of the aircraft. The type of aiming skill involved is analogous to that required for manual aiming of ground based weapons. If the range estimate is incorrect, the projectile overshoots or undershoots as indicated in FIGURE 1 for a target T', for which the range was underestimated. Similarly, if the aircraft is improperly aimed, the projectile will follow an incorrect trajectory as illustrated in FIGURE 1 by path B'. In addition to the obvious difficulties involved in estimating range from the air and in performing any fire control process at aircraft speeds, etc., there is the unusual problem of determining the direction of the aircraft velocity. There is no inexpensive source of accurate information on the instantaneous flight path direction. While the attitude of the aircraft can be determined, there is frequently an uncertainty of several degrees in the angle of attack α and therefore the lead angle γ (see FIGURE 2) provided by the velocity vector. For reasons such as these, conventional bombing by aiming on the basis of estimations has not been satisfactory for accurate bombing.

To overcome these problems, attempts have been made to automatically control bomb release by relying on sensors such as accelerometers to determine the proper release point. For example, if an aircraft is flown so as to maintain a reticle with a fixed depression angle during a bombing run, a curved path is followed as illustrated in FIGURE 3. As the aircraft approaches the target, the flight path curvature increases. This increasing curvature requires an increasing acceleration, normal to the aircraft velocity vector. It is evident that a correlation between this acceleration and the desired release range can be readily derived for a particular bombing problem. However, a release based upon a direct measurement of acceleration does not work well in practice because the aircraft does not follow the theoretical curve and the desired curvature is relatively small. That is, the normal spurious deviations of an aircraft from an ideal run, due to air turbulence, pilot corrections, etc., are generally of the same order of magnitude as the desired curvature, sometimes larger. As a result, the spurious motion of the aircraft creates "noise" which frequently obscures the fire control sensor signals.

Accordingly, it is an object of the invention to provide a computing sight which produces accurate operation in spite of substantial errors in estimations and in the presence of substantial turbulence creating noise in sensor signals.

It is a further object of the invention to provide a computing sight mechanism which accurately corrects for range information errors by effectively extracting the range information buried in the noise of the aircraft sight tracking data.

It is a further object of the invention to provide a bomb sight which inherently corrects for errors due to sources such as down-range wind, angle of attack variation, and air speed data deficiencies.

It is a further object of the invention to provide a bomb sight which, in addition to providing range estimate corrections, is adapted to take advantage of pilot skill in smooth and precise operation of an aircraft along a predetermined path to improve overall accuracy.

Briefly stated, in accordance with certain aspects of the invention, a computing sight is provided which is particularly useful for dive bombing. It is characterized by the integrated use of both estimate information and sensor information. The latter is effectively smoothed to reduce the effect of noise and is used to correct the estimate errors. The sight therefore makes the most of both estimate and sensor data.

Conveniently, the sight generates a normalized range indicia band for informing the operator of the correct range point for releasing the bomb so as to hit the target. The range band initially presents a length corresponding to a fixed range preselected as the range at which target tracking should commence. The pilot, by estimations, maneuvers the aircraft to the selected range point with a selected dive angle and air speed. The bomb sight computer is then engaged at this "freeze" point and the aircraft is maneuvered so as to maintain the sight reticle in alignment with the target. The reticle has a fixed displacement from the position corresponding to a straight line path along the flight plane of the aircraft so as to produce the proper aircraft position and velocity for a bomb hit by release of the bomb at a predetermined release point which is a predetermined fraction of the estimated "freeze" range. A servo loop is provided which drives the range indicia band at a rate which is equal to air speed plus a correction corresponding to the error in indicated range. The error in range is computed by comparing the known component of air speed across the line of sight to target with the product of indicated range and the pitch rate generated as a consequence of tracking the target with the sight tipper. The correction corresponding to range error is added to the known range rate (air speed) with a magnitude and sense so as to reduce the difference between indicated range and true range to a small value prior to reaching the preselected release range. Accordingly, perturbations in pitch rate resulting from tracking errors have a significantly reduced effect upon bomb release error compared to the result which would be obtained if the output of a gyro (or accelerometer) were used directly to effect a bomb release.

The invention, together with further objects and advantages thereof, may best be understood by referring to the following description taken in conjunction with the appended drawings in which like numerals indicate like parts and in which:

FIGURE 1 is a diagram illustrating a conventional approach to the dive bombing problem.

FIGURE 2 is a diagram illustrating various geometric quantities involved in dive bombing in respect to the bombing aircraft.

FIGURE 3 is a diagram illustrating a dive bombing flight path trajectory of the type in which a constant lead angle is maintained up to the release point.

FIGURE 4 illustrates a preferred reticle and range bar optical display for a bombing sight.

FIGURE 5 is a block diagram illustrating the operation of the invention.

FIGURES 6A and 6B comprise a schematic diagram of a dive bomb computer for the FIGURE 5 block diagram which is preferred for low cost, high reliability applications.

FIGURE 7 is a graph illustrating the requirements for proper bomb release in the FIGURE 5 computer.

FIGURES 8A and 8B are respectively ballistic and block diagrams of a second embodiment of the invention.

As used in the drawings and specifications, the following symbols have the meanings as indicated:

D=True slant range to ground target.
D_o=Range at which system is estimated (by the pilot) to be initiated.
D_I=Indicated (computed) slant range to target.
$\dot{D}_I$=Time rate of change of indicated range.
D_r=Slant range at which bomb is to be released.
Σ=Line of sight angle as measured relative to a horizontal line which lies in that vertical plane containing the line of sight to target.
$\dot{\Sigma}$=Time rate of change of line of sight angle.
θ=Pitch angle of the aircraft as measured relative to the same reference as Σ.
$\dot{\theta}$=Time rate of change of aircraft pitch angle.
γ=Lead angle; angle between aircraft velocity vector and line of sight to target as measured in the vertical plane defined by line of sight to target.
α=Angle of attack; angle between aircraft pitch attitude and the velocity vector.
V=Instantaneous air speed of aircraft.
V_o=Aircraft air speed at "freeze."
V_r=Aircraft air speed at release.
G=Gravitational acceleration.
K=System gain constant.
t_f=Bomb time of fall.

Referring now to the drawings, FIGURE 5 is a block diagram of a form of the invention in which the output

signal D_I is used to drive the range bar **40** of the FIGURE 4 sight display. The semicircular range bar **40** initially extends from the 9 o'clock tab **43**, representing the target point, past the 6 o'clock tab **42**, representing the bomb release point, to the 3 o'clock tab **41**, representing the "freeze" point. With the aircraft having been maneuvered by estimate to the initial point in space which is the predetermined position represented by the FIGURE 3 "freeze" point, and having the proper dive angle θ, initial target range D_o and predetermined air speed, the aircraft is flown to follow the FIGURE 3 flight path by continuously maneuvering the aircraft to maintain alignment of the pip **45** with the target. Maintenance of alignment pip **45** with the target accomplishes the desired dive angle θ since the pip **45** is placed, relative to the aircraft flight axis and to the normal pilot eye position, to cause the line of flight of the aircraft to deviate from the pilot's line of sight to the target by an angle γ. The particular angle γ is predetermined for each application according to the flight characteristics of the aircraft model and tactical requirements. It is this deviation γ that causes the aircraft to "overfly" requiring a constantly increasing dive angle which is attained by turning the aircraft about its pitch axis creating the measurable time rate of change $\dot{\theta}$ of pitch angle used by the computer as hereinafter described. When range bar **40** has drawn back to the 6 o'clock tab **42** position indicating that the aircraft has reached the proper release point, the bomb is released.

In FIGURE 5, the computing servomechanism apparatus integrates the target range $\dot{\theta}$, using pitch rate $\dot{\theta}$ sensed by a rate gyro, in accordance with the following relationship:

$$-\dot{D}_I=V-K(V\gamma-D_I\dot{\theta})$$

where K is a selected computer constant and the remaining terms (V=airspeed) as defined above and in FIGURES 1–3. The indicated range rate $\dot{D}_I$ determined from integration of the D_I output is accordingly determined by the aircraft velocity and the difference between the predetermined lead angle factor $V\gamma$ and the measured factor $D_I\dot{\theta}$, as described more fully hereinafter. An integrator **10**, such as a servoamplifier and servomotor, receives aircraft velocity from a conventional airspeed computer or, more simply, by a handset potentiometer set to the airspeed to be maintained by the aircraft in the dive. This results in range bar **40** being driven from the 3 o'clock position down towards the 6 o'clock position by the mechanical displacement generated by the servomotor of integrator **10**. Because the initial position or displacement of the servomechanism corresponds to the predetermined range at which the "freeze" or commencement of the bombing run has been selected, the energization of the servomechanism is equivalent to estimating range. In addition to the usual rate feedback loop (not shown), a second loop is provided for correcting any original error on the basis of the bombing run dynamics. In accordance with the predetermined lead angle γ, a second rate quantity, corresponding to the aircraft velocity component normal to the line of sight $V \sin \gamma$ is introduced at terminal 13, preferably handset as γV. (For small angles, $\sin \gamma \simeq \gamma$.) Provided the freeze range estimate and the aircraft aiming have been perfect, the second quantity (γV) is substantially balanced at terminal 14 by a third quantity $\dot{\theta}\, D_I$ which also has the dimensions of the component of aircraft velocity normal to the line of sight. The pitch rate $\dot{\theta}$ is measured by a rate gyro **23**, conveniently the gyro in the pitch channel of the flight control system. The computer range output D_I is derived as a feedback quantity by a wiper on potentiometer **24** which is driven by the servomotor of integrator **10** in parallel with the range bar **40**. The difference between the second and third quantities as existing at **14** is multiplied by a predetermined gain factor K using a conventional preset servo gain multiplier device **25** degeneratively connected at **15** to the input of the servo integrator **10**. As a result, the rate at which range bar **40** is driven is adjusted so that at the 6 o'clock position the aircraft has the predetermined range and lead angle necessary for a bomb hit. As illustrated graphically in FIGURE 7, if the pilot originally overestimates the freeze range and initiates operation of the bombing computer late, the pitch rate signal is high. That is, for the same lead angle, the pitch rate is inversely proportional to the target range so that the lead angle quantity $K\gamma V$ is not neutralized by the normal velocity quantity $K\dot{\theta}D_I$ and the range bar **40** speed is thereby increased so that the range bar position D_I has been corrected at the 6 o'clock position.

Considering more carefully the relationships involved for the computer illustrated in FIGURE 5, its operation is primarily based on the fact that certain aircraft motion relative to the target can be used to measure the target range D. That is, the rate

$$\left(\frac{d\Sigma}{d\tau}=\dot{\Sigma}\right)$$

at which the line of sight rotates can be expressed as a function of range D. Specifically, at any instant, the component of the aircraft velocity V normal to the line of sight ($V \sin \gamma \simeq V\gamma$) is equal to the product of the length of the line of sight D and its angular rate $\dot{\Sigma}$ about the target. The algebraic equation (for perfect tracking) is:

$$V \sin \gamma = D\dot{\Sigma} \tag{2}$$

Theoretically, the range D ($D=D_0-V_t$) can be generated because airspeed can be measured, Σ is essentially equal to θ which can be measured by pitch rate resulting from tracking, and the lead angle γ can be predetermined. Therefore:

$$\dot{\theta}=\frac{V \sin \gamma}{D} \tag{3}$$

By substituting Equation 3 for the pitch rate term $\dot{\theta}$ in Equation 1, the validity of Equation 1 can be seen by inspection of FIGURES 1–3. (The usual approximations for small γ, $V \cos \gamma = V$ and $\sin \gamma = \gamma$, are made.) The relationship is:

$$-\dot{D}_I = V - K\left(V\gamma - D_I\frac{V\gamma}{D}\right) = V - KV\gamma\left(1-\frac{D_I}{D}\right) \tag{4}$$

It can be seen from this relationship that the fire control sight has the following characteristics:

First, the sight utilizes and combines both estimate information (D_o) and measurement (D_I, V, γ) information. Initially, the computer relies entirely on the operator's estimate of range (D_o). This initial condition continues to dominate the computer operation to the extent that the original estimate of range was correct. If the estimate was perfect, the computer will generate the range output signal as if this were the sole consideration. However, considered in respect to Equation 4, the measured range information introduced by the last term by means of measured pitch rate, will modify the integrator operation.

Second, the measured range information, in the case of FIGURE 5 by a pitch rate $\dot{\theta}$, is smoothed by the integrator. Because of this feature, very substantial useful information can be derived even where the instantaneous values include a large noise factor which may even be greater than the instantaneous information factor.

Third, the sight utilizes operator skill. Insofar as the operator can correctly estimate range and operate the vehicle in such a manner that the desired trajectory is followed, the computer operation will be enhanced. The closer the estimated freeze range is to the correct freeze range, the lesser will be the reliance on tracking correction. The smoother the pilot flies, keeping the reticle on target, the smoother will be the integrated correction factor.

Fourth, analysis of the problem reveals that the computer obtains compensation for factors such as: down-range wind, errors estimating the angle between line of sight and the velocity vector and down-range target speed, If the target is moving towards the aircraft, or if there is a down-range wind towards the target, or if lead angle is too large (because of reticle alignment error, for example), or if the airspeed data is on the low side, it can be seen that the time of bomb release should be advanced. For each of these conditions, the curvature sensor signal will be greater and the indicated release range will be reached earlier.

Some other characteristics of the computer include the relative simplicity of the required computer apparatus and the simplicity of the required sensors. Furthermore, it will be noted that the set up enables the operator to make compensations. For example, if an aircraft makes a sudden pitch movement just before the release point is reached, the pilot can delay or anticipate manual bomb release to compensate for the computer operation. (On the other hand, it is obvious that the bomb release operation can be made automatic by sensing the computer output at the 6 o'clock position.)

The necessary relationship among range (D_r), lead angle (γ), velocity (V) and sight angle Σ to achieve a bombing hit for a low drag bomb is readily determined to be:

$$D_r=\frac{2V^2 \sin \gamma \cos (\Sigma-\gamma)}{g \cos^2 \Sigma} \tag{5}$$

As can be seen from this relationship, the critical factors are lead angle and velocity. This emphasizes the difficulties of accurate bombing on the basis of estimates. If bomb release is based on measuring the aircraft pitch rate or acceleration, the relationship can be considered by substituting $\dot{\Sigma}$ into Equation 5 on the basis of Equation 2 and rearranging as follows:

$$\frac{D_r}{D}=\frac{2V_0\dot{\Sigma} \cos (\Sigma-\gamma)}{g \cos^2 \Sigma}=1 \text{ (for a hit)} \tag{6}$$

It can be seen that reliance on sensors makes accuracy essentially independent of pitch angle and makes the velocity factor substantially less critical, if $\dot{\Sigma}$ could be measured accurately. With the FIGURE 5 computer, both methods are used and combined. The combination allows a relative weighting which is determined by the selection of K. Values in the range of 10–20 are preferred. Larger values tend to reduce the range error but this is opposed by difficulty in tracking a target in the presence of wind gusts or other noise disturbances.

The mechanization of the invention in the form indicated by FIGURE 5 uses a fixed freeze range and a fixed release range primarily because it enables simple automatic setting up of initial conditions. Variations such as manual setting of the indicated range to correspond to an estimated freeze range are apparent to those skilled in the art.

FIGURES 6A and 6B comprise a schematic diagram of an embodiment for implementing the system set out functionally in FIGURE 5. In this embodiment, the output, a mechanical shaft rotation **19** (see dotted line on right of FIGURE 6B) representing indicated range D_I, is generated by a conventional servomotor **17**. This is the same as the shaft position indicated by **19** in FIGURE 5 and servoamplifier **16** with motor **17** and a tachometer all as indicated in FIGURES 6A and 6B by **10A** and **10B** which make up the integrator **10** of FIGURE 5. The inputs of V and $KV\gamma$ shown at **12** and **13** in FIGURE 5 as modified by the constant K at **25** are, in the mechanization of FIGURE 6, fed in by POT 1 which is connected through switch K5–1 to integrator **10**. This results in an A-C signal to which the measured pitch rate signal, multiplied by indicated range, from the range potentiometer **24** is added through the wiper W terminal. The output $\dot{\theta}$ of a pitch rate gyro **31** is amplified by preamplifier **32** and is connected to the 3 o'clock tap of the range potentiometer **24** and the wiper W thereof is driven by the output **19** of motor **17**. Computer operation is initiated by the operator closing relay K5 when he estimates the range to the target as the correct freeze range. Operation of relay K5 closes the switch K5–1 connecting the signal from POT 1 to servo amplifier **16**. Initially, the standard servo amplifier **16** produces a signal for motor **17** such that the feedback signal from a tachometer generator **18**, through resistor R19, balances the input signals thereby controlling the speed of motor **17** in a conventional servo loop fashion. Relay K5 also closes a switch K5–2 connecting the output of a conventional linear transistor preamplifier **32** to the 3 o'clock terminal on the range potentiometer. The input to the preamplifier **32** is obtained from a conventional pitch rate gyro **31** through terminal B. By adjusting the gain of the preamplifier **32** by means of potentiometer POT **2**, and selecting the correct value for resistor R18, the input $KD_I\theta$ to servo amplifier **16**, including the gain term K, is obtained. The reference voltages required for operation of the computer are supplied by a conventional power supply **33**. Before relay K5 is operated initiating computer operation, the switches K5–2, K5–3, and K5–4 are in the unenergized positions illustrated in the drawing. With this condition, the 3 o'clock tap on range potentiometer **24** is grounded so that the wiper will be driven to this predetermined freeze range position. A positive voltage is thereby applied to terminal V and a negative voltage is applied to terminal N so that the input from the range wiper applied to servoamplifier **16** controls motor **17** so as to drive the wiper to the 3 o'clock position.

Representative values for the components illustrated in FIGURES 6A and 6B are as follows:

Transistor:		
Q1		2N335
Q2		2N335
Q3		2N335
Q4		2N1048
Q5		2N1048
Q6		2N336A
Q7		2N336A
Resistor:		
R1		5Ω
R2		5Ω
R3		24KΩ
R4		100KΩ
R5		5.6KΩ
R6		12KΩ
R7		100KΩ
R8		66.5Ω
R9		5.6KΩ
R10		510Ω
R11		20KΩ
R12		1.3KΩ
R13		360KΩ
R14		20KΩ
R15		2.0KΩ
R16		277.5KΩ$_p$
R17		200Ω
R18		81.775KΩ
R19		86.6KΩ
R20		200KΩ
R21		392Ω
R22		178Ω
R24		1000Ω
R25		392Ω
R26		178Ω
Transformer:		
T1		2.5:1
T2		1:1
T3		1:1
Capacitor:		
C1	μf	0.27
C2	μf	0.033
C3	μf	22
C4	μf	0.0015
C5	μf	22
C6	μf	47
C7	μf	0.0015
C8	μf	1.5
C9	μf	0.056
C10	μf	22
C11	μf	12
C12	μf	12
C13	μf	100
C14	μf	100
C15	μf	22
C16	μf	0.005
C17	μf	10
C18	μf	22
Diode:		
CR1		IN645
CR2		IN645
CR3		IN645
CR4		IN645
CR5		IN645
CR6		IN752A
CR7		IN645
CR8		IN752A
Inductor:		
L1	h	0.15
L2	h	0.15
Potentiometer:		
POT 1		200Ω
POT 2		20KΩ
POT 3		200Ω
POT 4		100KΩ

FIGURE 8A illustrates the ballistic problem for a level flight path and FIGURE 8B is a block diagram of a suitable sight computer system. The relationships are basically equivalent to those of the FIGURE 5 computer so that the corresponding components bear the same reference characters with primes. The primary difference is that for a level flight path the vehicle maintains a constant pitch rate of zero. However, the lead angle γ between the flight path and the line of sight changes at a rate directly corresponding to the pitch rate term in the FIGURE 5 computer. Accordingly, by tracking the target with a sight **32** and utilizing a techometer to generate the tracking factor $\dot{\gamma}$, the same tracking correction operation is maintained. In order to provide smoother operation, a motor drive under manual speed control is preferred for the sight tracking. The only other required modification of the system results from the lead angle having values which are in general not small. The approximations, $V \cos \gamma = V$ and $V \sin \gamma = V\gamma$, can no longer be made so that a resolver **51** is utilized to generate the range rate signal and the lead factor signal respectively.

As presented above, the invention relies on geometrical relationships for generating range corrections. In both the FIGURE 5 and FIGURE 8 system there is sight motion because of the aircraft having a relative velocity component transverse to the line of sight to the target. In sighting applications which do not involve an airbrone vehicle, this is not generally the case. Nevertheless, the invention can be employed in some instances even where the relative velocity of the sight and target is entirely along the line of sight. For example, if a target is tracked with an optical range finder of a type in which the range finder adjustment rate is inversely proportional to range, as is usually the case, the invention can be employed directly. The range rate signal is introduced to the integrator in the same manner as previously. Similarly, the tracking factor is introduced by a tachometer on the range finder adjustment mechanism, corresponding to tachometer **23′** in FIGURE 8B. Instead of a lead factor, a range rate signal is introduced to balance the tracking signal. Conveniently, this is achieved by adding the appropriate factor to the first range rate input, in a manner equivalent to the adjustment of input potentiometer POT 1 in FIGURE 6A.

While particular embodiments of the invention have been shown and described herein, it is not intended that the invention be limited to such disclosure, but that changes and modifications can be made and incorporated within the scope of the claims.

What is claimed is:

1. A bomb sight computer comprising:
   (a) a bomb sight, having a reticle, for permitting tracking of a target with a predetermined angle γ of deviation and having means for displaying indicia representing the range D_I from said sight to the target;
   (b) means for measuring the rate $\dot{\theta}$ at which the vehicle borne sight rotates and for generating a signal representing said $\dot{\theta}$;
   (c) means for measuring vehicle velocity V and for generating a signal representing said velocity V; and
   (d) computing means responsive to said means for measuring the rate $\dot{\theta}$ and said means for measuring vehicle velocity V for driving said indicia representing range, said computing means determining D_I according to the relationship:

$$-\dot{D}_I = V - K(V\gamma - D_I\dot{\theta})$$

wherein K is a system constant and $\dot{D}_I$ is the time derivative of the range D_I.

2. In an air-to-ground bombing system based on the concept that for each combination of approach velocity, release range and constant angle of deviation between line of sight and path of flight in the bomb run, there is a peculiar rate of change of pitch which indicates a release point from which a low drag bomb can be released to follow a free fall course to a ground target, the combination of:
   (a) display means including a moveable range bar for indicating the distance to said target from an aircraft flying at a constant velocity and approaching that target and including a reticle for visually aligning said aircraft on a path of positive deviation from a line of sight course by said constant angle;
   (b) means for generating a signal representing said constant velocity;
   (c) pilot activated driving means for driving said range bar responsive to the passage of time and responsive to a signal representing said constant velocity to cause said range bar to recede from a preset predetermined distance value from the target at which distance said driving means is activated whereby said range bar indicates distance remaining to the target;
   (d) means for sensing the rate of change of pitch of said aircraft and for creating a signal representing said rate of change of pitch; and
   (e) summing means responsive to said signals representing said constant velocity and said rate of change of pitch and to a signal proportional to said constant angle for adjusting said driving means and also responsive to position of said range bar for accelerating or decelerating said driving means by an amount proportional to a calculated error in position of said range bar whereby continual correction of said range bar position will more accurately indicate when the said aircraft has arrived at said release point.

3. An air-to-ground sight comprising:
   (a) Visual sighting means for guiding an aircraft toward a ground target from a point in space at a predetermined distance D_o from said ground target with a constant predetermined sight deflection angle of overflight between the straight line from said aircraft to said target and the line of actual flight of said aircraft to cause said aircraft to approach a bomb release distance D_r from the target with an increasing change $\dot{\theta}$ of pitch angle θ;
   (b) means for generating signals representing aircraft velocity V, the product V sin γ of the sine of the sight deflection angle γ and said velocity V the rate of change $\dot{\theta}$ of the aircraft pitch angle θ and the said distance D_o;
   (c) visual target range indicating means for indicating distance from a target in terms of D_o and D_r to a pilot; and
   (d) computing means for driving said range indicating means including:
      (1) means for integrating said signal representing aircraft velocity V to produce a signal representing a distance traveled and for subtracting that signal from the said signal representing D_o to produce a signal representing the computed range D_I to the target;
      (2) multiplying means responsive to said means for generating signals for generating a signal which represents the product $D_I\dot{\theta}$;
      (3) comparator means responsive to said multiplying means for generating a signal representing $K(D_I\dot{\theta} - V \sin \gamma)$ wherein K is a constant;
      (4) summing means for algebraically adding

$$K(D_I\dot{\theta} - V \sin \gamma)$$

to V in the integration process so as to cause the D_I produced thereby to
      (5) drive means responsive to said means for integrating for driving said visual target range indicating means to display D_I; and
      (6) means for activating said computing means whereby the pilot of the aircraft can start the sight ranging and approach process when at distance D_o from the target.

4. Airborne air-to-ground bombing sight for bombing a target from a release point at a predetermined distance D_r from said target comprising:
   (a) visual aiming means for maintaining an aircraft on a course at a predetermined angle γ of deviation from the line of sight to said target;
   (b) means for generating a signal representative of the velocity V of said aircraft;
   (c) means for generating a signal representative of V sin γ, the velocity of said aircraft multipled by the sine of said predetermined angle;
   (d) means for generating a signal representative of the rate of change $\dot{\theta}$ of the pitch angle of said aircraft as it pursues said course at said predetermined angle;
   (e) integrator means for integrating said signal representative of the velocity V over a period of time to produce a signal representative of the distance traveled;
   (f) display means for indicating an initial distance D_o from said target at which distance the sight should be activated and a bomb run started;
   (g) drive means responsive to said integrator means for generating a signal representative of the distance D_I to the target which distance is said initial distance D_o minus said distance traveled, said display means being driven by said drive means to indicate said distance D_I;
   (h) means for multiplying said signal representative of said rate of change $\dot{\theta}$ by said signal representative of distance D_I to produce a signal representing $D_I\dot{\theta}$;
   (i) means for comparing said signal representing $D_I\dot{\theta}$ with said signal representative of V sin γ and for generating a signal representative of the difference $(V \sin \gamma - D_I\dot{\theta})$ between those signals;
   (j) means for summing said signal representative of the velocity V with signal proportional to said signal representative of the difference $(D_I\dot{\theta} - V \sin \gamma)$ over a period of time to decrease any error in said distance D_I to the target caused by activation of the sight at a range other than the distance D_o; and
   (k) means for activating said sight, whereby activation of said sight at other than the correct initial distance D_o from the target and flying a course as determined by said angle γ will cause the said distance D_I as

indicated to be corrected so that when D_I as indicated is equal to the distance D_r, the aircraft will be at said release point.

References Cited

UNITED STATES PATENTS

3,264,451	8/1966	Faxen et al.	235—61.5
3,091,993	6/1963	Brink et al.	235—61.5X
2,995,985	8/1961	Helgeson et al.	235—61.5X
2,995,984	8/1961	Helgeson et al.	235—61.5X

MARTIN P. HARTMAN, *Primary Examiner.*

ROBERT W. WEIG, *Assistant Examiner.*

U.S. Cl. X.R.

89—1.5