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TOSS-BOMBING AID FOR AIRCRAFT

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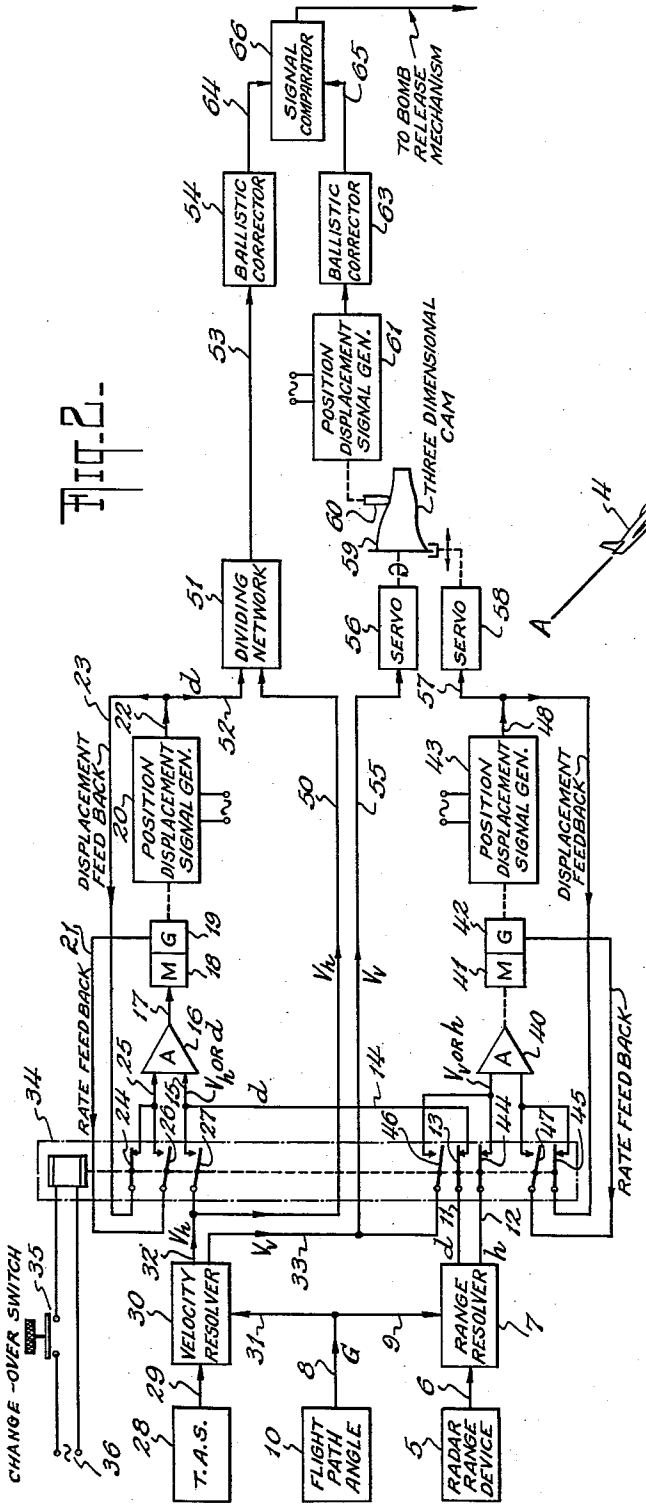


FIG. 2.

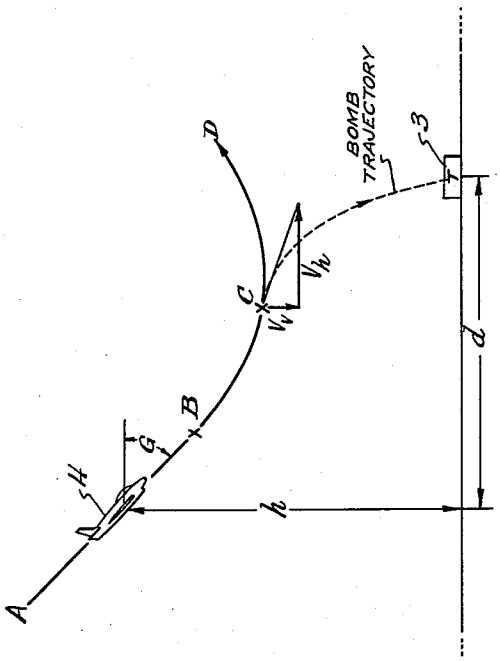


FIG. 1.

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TOSS-BOMBING AID FOR AIRCRAFT

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This invention relates to improvements in toss-bombing aids for aircraft. More particularly, it concerns a novel arrangement for facilitating the accurate determination of that unique point in an aircraft's pull-out from a substantially straight dive toward a target where the trajectory of a given free-falling bomb or missile released from the craft will intersect the target.

The tactic of releasing a bomb from an aircraft during its pull-out from a dive toward the target for which the bomb is intended is generally termed "toss-bombing." The correct release point in a toss-bombing maneuver for a given bomb configuration depends principally upon the horizontal and vertical velocities of the craft relative to the surrounding air mass and upon the horizontal and vertical distances between the craft and the target. To a lesser extent, dependence is also had on such factors, for example, as relative motion between and target and the surrounding air mass, meteorological conditions, and height to target above sea level. However, these lesser factors merely provide corrections to the basic release point determination, and are of no direct interest in regard to the present invention.

Aircraft of the single-place fighter-bomber type are generally employed for toss-bombing operations. As long as such a craft is on the dive portion of its toss-bombing maneuver against a given target, the target is within direct view of the pilot-bombardier. A line of sight to the target during craft dive is thus readily established by optics, radar, or other suitable means. With a knowledge of the direction of this line with respect to the local vertical and of the slant range to the target or the altitude of the craft, the horizontal and vertical distances between the craft and the target may be computed.

However, when the craft enters the pull-out portion of its toss-bombing maneuver, the line of sight to the target may be lost due to obstruction of the pilot's view of the target by the nose assembly of the craft, or due, where radar is employed, to the craft's radar axis being in fixed general alignment with the longitudinal axis of the craft, hence pointed away from the target during craft pull-out from the dive portion of the toss-bombing maneuver. Therefore, if the computation of the horizontal and vertical distances between the craft and the target depends upon the maintenance of the line of sight to the target, the computation will cease with pull-out and it becomes necessary to estimate or dead-reckon these distances thereafter.

Toss-bombing aids for aircraft in the past have attempted to solve the dead-reckoning problem in a number of different ways, most of which impose special restrictions on the parameters of the pull-out portion of the maneuver, such as a requirement for constant radial path acceleration, extremely difficult for the pilot-bombardier to conform to, especially under stress of combat. In such prior arrangements, the release point has been determined by a single quantity, as dive angle or elapsed time since pull-out, and any departure from the requisite programmed maneuver has necessarily resulted in serious bombing error. Furthermore, it has generally been necessary to clamp or store a range or altitude value on a shaft or signal transducer at the instant of initiation of pullout, resulting in discontinuities in the functioning of the equipment, leading to undue stress, inaccuracy, and possible malfunction.

The present invention is directed toward providing a positive solution to the problem of determining the vertical and horizontal distances from a toss-bombing aircraft to a target during the pull-out portion of the craft's maneuver against the target. The problem is solved by first obtaining a direct determination of such distances while the craft is yet on the dive portion of the toss-bombing maneuver, that is, while the distance measuring equipment aboard the craft is capable of providing the range data needed for such determination. Prior to the entry of the diving craft into the pull-out portion of the maneuver, a changeover is made from the craft's distance measuring equipment to the craft's velocity measuring equipment, the velocity data from which is than integrated with respect to time and subtracted from the directly-obtained range data that prevails at the instant of the changeover so that the required range data is supplied without interruption throughout the maneuver.

An object of the present invention is to provide an improved toss-bombing aid wherein the vertical and horizontal distances from aircraft to target may be continuously and accurately determined throughout the dive and pull-out portions of a toss-bombing maneuver of the craft against the target.

Another object of the present invention is the provision of a toss-bombing aid wherein time-integrated velocity data may be substituted for directly obtained range data before the latter is lost due to craft pull-out from its dive toward target in order to provide a continuous supply of range data notwithstanding such loss.

Another object is to provide a toss-bombing aid according to the second object above wherein the transition from directly obtained range data to range data obtained by velocity integration is achieved in a smooth uninterrupted manner.

Another object is the provision of a toss-bombing aid which functions to determine the proper bomb-release point in a craft's toss-bombing maneuver irrespective of the flight parameters of the craft during the pull-out portion of the maneuver.

With the foregoing and other objects in view, the present invention includes the novel elements and the combinations and arrangements thereof described below and illustrated in the accompanying drawings, in which

FIG. 1 is a diagram of the flight path of an aircraft engaged in a toss-bombing maneuver, including the craft's velocity and range-to-target components; and

FIG. 2 is a schematic block diagram of an embodiment of the present invention.

The toss-bombing maneuver as customarily executed comprises two distinct portions as illustrated in FIG. 1. These are an initial dive, designated by the flight path segment AB, in a substantially straight line directly toward a target 3, and a pull-out, designated by the curved segment BCD in a vertical plane containing the target. During the pull-out, a unique point C will be passed at which a bomb, when released from the aircraft 4 will strike the target.

As earlier stated, the release point depends principally upon the horizontal and vertical velocities (V_h and V_v) of the craft relative to the surrounding air mass and upon the horizontal and vertical distances (d and h) between craft and target. The requisite horizontal and vertical velocity information may be continuously obtained, for example, by measuring true air speed and thereafter resolving such measurement into the quadrature components thereof for whatever the flight path angle G of the craft relative to the horizontal may be during the dive and pull-out portions of the toss-bombing maneuver. On the other hand, the requisite horizontal and vertical distance information, in the usual case, may be obtained

by direct measurement and resolution during the dive portion, only, of the maneuver.

By referring now to FIG. 2, it will be seen how the present invention may provide a continuous flow of data concerning the horizontal and vertical distances between craft and target throughout both portions of the toss-bombing maneuver.

A signal proportional to the slant range from the craft to the target is obtained during craft dive from a distance measuring equipment, such as a radar range device 5, and is supplied via a lead 6 to a resolver 7. Besides the range signal, resolver 7 receives another signal input, proportional to the flight path angle G of the craft, supplied via leads 8, 9 from an apparatus 10 which may include a vertical gyroscope and angle of attack sensor. In response to its range and flight path angle inputs, resolver 7 provides a signal proportional to the horizontal range component d on a resolver output lead 11, and a signal proportional to the vertical range component h on a resolver output lead 12.

A normally-closed switch 13 connects lead 11 to a lead 14 which is connected to an input lead 15 of an amplifier 16. The output of amplifier 16 is fed via a lead 17 to a motor 18 for energizing the same to drive a pair of signal generators 19, 20. Generator 19 is of the tachometer type for providing a signal on its output lead 21 proportional to the rate at which it is driven by motor 18, while generator 20 is of the position displacement type for providing a signal on its output lead 22 proportional to the amount it is driven by motor 18. The displacement signal on lead 22 is fed via a lead 23 and a normally-closed switch 24 to a second input lead 25 of amplifier 16 in negative feedback fashion, so that motor 18 is normally driven an amount proportional to d, whereby the displacement signal on lead 22 is likewise proportional to d.

In order to maintain the displacement signal on lead 22 proportional to d after craft pull-out is initiated, that is, when device 5 ceases to provide a direct measurement of slant range, the normally-closed switches 13, 24 are opened during craft dive and preferably just before pull-out by change-over means for operating switches including an electromagnetic relay 34. At the same time, a pair of normally-open switches 26, 27 are closed, which, as it will be seen, results in the generation of a signal on lead 22 proportional to the difference between the value of d then prevailing and the time integral of the horizontal component of true air speed.

A signal proportional to the true air speed of the craft is continuously obtained from a true air speed meter 28, and is supplied via a lead 29 to a resolver 30 similar to resolver 7. Besides the air speed signal, resolver 30 receives another signal input, proportional to the flight path angle G of the craft, supplied via leads 8, 31 from apparatus 10. In response to its air speed and flight path angle inputs, resolver 30 provides a signal on a resolver output lead 32 proportional to the horizontal component V_h of the true air speed, and a signal proportional to the vertical true air speed component V_v on a resolver output lead 33.

The closing of normally-open switch 27 connects the lead 32 to input lead 15 of amplifier 16, while the closing of normally-open switch 26 connects the tachometer output lead 21 to feedback lead 25 of amplifier 16. Hence, by opening the switches 13 and 24 while closing the switches 26 and 27, motor 18 is driven at a speed proportional to V_h. The sense with which the V_h signal is fed to amplifier 16 is such that motor 18 is driven in the same direction as for a decreasing d signal on lead 14. By this arrangement, therefore, the displacement signal that prevails on lead 22 when the switches are simultaneously actuated from their respective normal conditions is thereafter diminished steadily by an amount proportional to the time integral of V_h, the latter being proportional to the horizontal distance traveled by the craft since such switch actuation. The operating transition of the servomechanism, that is formed by amplifier 16, motor 18 and generators 19 and 20, from a signal repeating mode to a signal integrating mode, occurs smoothly and without producing any discontinuity in the horizontal range signal output on lead 22.

Switches 13, 24, 26, 27 are ganged together and preferably form a part of the electromagnetic relay 34 controlled by a single manually-operated switch 35 in series with a power supply 36 and the winding of the relay. To close the normally-open switches 26, 27 and open the normally-closed switches 13, 24 as required during craft dive and before pull-out, the pilot-bombardier has merely to close the switch 35, hereafter termed the change-over switch.

An arrangement identical to that just described for providing a continuous horizontal range signal is employed for providing a continuous vertical range signal. However, instead of the arrangement being responsive in the alternative to the d signal output of resolver 7 and the V_h signal output of resolver 30, depending on the condition of pull-out switch 35, it is alternatively responsive to the h signal output of resolver 7 and the V_v signal output of resolver 30. To this end, an amplifier 40, a motor 41, and a pair of generators 42, 43 are provided which respectively correspond to the amplifier 16, motor 18, and generator pair 19, 20. Two normally-closed switches 44, 45 correspond respectively to switches 13, 24 and two normally-open switches 46, 47 correspond respectively to switches 27, 26. The vertical component switches are ganged together with the horizontal component switches to complete the relay 34 so that all eight of the switches are controlled by pull-out switch 35.

Thus, when the change-over switch 35 is open, the servomechanism formed by amplifier 40, motor 41, and generators 42 and 43 is in its signal repeating mode of operation, so that the h signal output of resolver 7, fed via switch 44 to amplifier 40, is repeated on the output lead 48 of displacement generator 43. And when the change-over switch is closed in preparation for pull-out, the servomechanism is placed in its signal integrating mode of operation, so that the V_v signal output of resolver 30, fed via switch 46 to amplifier 40, is integrated with respect to time and subtracted from the h signal output on lead 48 prevailing at the instant of change-over switch closure, whereby to maintain the output of generator 43 proportional to the horizontal range component.

Having provided for a continuous supply of range component data, the remaining portion of the toss-bombing aid depicted in FIG. 2 is concerned with the use of this data together with the velocity component data available for determining the proper release point in the pull-out portion of the craft's toss-bombing maneuver. In this connection, the arrangement to be described continuously computes the time it would take the bomb if released to travel the horizontal distance to the target, while also computing the time it would take the bomb if released to travel the vertical distance to the target. The respective times are compared; and when they are determined to be equal, marking the proper release point, the mechanism for releasing the bomb is actuated.

Accordingly, the V_h signal on lead 32 is fed via a lead 50 to a dividing network 51 which also receives the d signal on lead 22 via a lead 52. The signal output of network 51 is proportional to

$$\frac{d}{V_h}$$

or the horizontal time of flight t_{fh} for a vacuum trajectory, and is fed via a lead 53 to a ballistic correction device 54 which applies a correction to the t_{fh} signal according to the usual factors including air temperature and density, bomb configuration and wind. The V_v signal on lead 33 is fed via a led 55 to a position servomechanism 56, and the h signal on lead 48 is fed via

a lead 57 to an identical position servomechanism 58. The mechanical output of servomechanism 56 is proportional to V_v and is employed to rotate a three-dimensional function cam 59. The mechanical output of servomechanism 58 is proportional to h and is employed to translate cam 59 along its longitudinal axis. For a vacuum trajectory, the time of fall t_{fv} of a bomb through the distance h when released with the vertical velocity V_v is

$$t_{fv}=\frac{-V_v+\sqrt{V_v^2+2gh}}{g} \quad (1)$$

where g is the acceleration of gravity. Thus, cam 59 is designed, in view of Equation 1, to impart a motion to its follower 60 proportional to t_{fv} in response to the mechanical inputs of h and V_v. The follower motion is transduced by a signal generator 61 into an electrical signal proportional to t_{fv} which is fed via a lead 62 to a ballistic correction device 63 for applying a correction to the t_{fv} signal according to the usual factors as performed by device 54.

The corrected t_{fh} and t_{fv} signals are fed via leads 64 and 65, respectively, to a signal comparison device 66. When input signals to device 66 are such as to represent equal values of horizontal time of flight and vertical time of flight, device 66 generates a signal on its output lead 67 which is connected to a signal-responsive bomb release mechanism so as to release the bomb.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In a toss-bombing system for aircraft, means providing a signal in accordance with the horizontal component of the slant range from the craft to the target during the dive portion of the maneuver, means providing a signal in accordance with the horizontal component of the velocity of the craft during the pull-out portion of the maneuver, a servomechanism operable in a signal repeating mode and a signal integrating mode to produce a continuous signal in accordance with the horizontal component of slant range from the craft to the target, and change-over means operable to connect said horizontal slant range component signal means and said servomechanism in the signal repeating mode during the dive portion of the maneuver and to connect said horizontal velocity component signal means and said servomechanism in the signal integrating mode during the pull-out portion of the maneuver.

2. In a toss-bombing system for aircraft, means providing a signal in accordance with the vertical component of the slant range from the craft to a target during the dive portion of the maneuver, means providing a signal in accordance with the vertical component of the velocity of the craft during the pull-out portion of the maneuver, a servomechanism operable in a signal repeating mode and a signal integrating mode to produce a continuous signal in accordance with the vertical component of the slant range from the craft to the target, and changeover means operable to connect said vertical slant range component signal means and said servomechanism in the signal repeating mode during the dive portion of the maneuver and to connect said vertical velocity component signal means and said servomechanism in the signal integrating mode during the pull-out portion of the maneuver.

3. In a toss-bombing system for aircraft, means providing signals in accordance with the vertical and horizontal components of the slant range from the craft to a target during the dive portion of the maneuver, means providing signals in accordance with the vertical and horizontal components of the velocity of the craft during the pull-out portion of the maneuver, a servomechanism operable in a signal repeating mode during the dive portion of the maneuver and a signal integrating mode during the pull-out portion of the maneuver to produce a continuous signal in accordance with the vertical component of the slant range from the craft to the target, a servomechanism operable in a signal repeating mode during the dive portion of the maneuver and a signal integrating mode during the pull-out portion of the maneuver to produce a continuous signal in accordance with the horizontal component of the slant range from the craft to the target, and change-over means operable to connect the vertical component signal of said slant range signal means to said vertical component servomechanism in the signal repeating mode; to connect the horizontal component signal of said slant range signal means to said horizontal component servomechanism in the signal repeating mode; to connect the vertical component signal of said velocity signal means to said vertical component servomechanism in the signal integrating mode; and to connect the horizontal component signal of said velocity signal means to said horizontal component servomechanism in the signal integrating mode.

4. A system for controlling the release of bombs from an aircraft in a toss-bombing maneuver with a dive portion and a pull-out portion, means for producing a signal in accordance with the vertical component of the velocity of the craft in the maneuver, means for producing a signal in accordance with the horizontal component of the velocity of the craft in the maneuver, means for producing a primary signal in accordance with the vertical component of the slant range from the craft to a target during the dive portion of the maneuver, means for producing a primary signal in accordance with the horizontal component of the slant range from the craft to the target during the dive portion of the maneuver, integrating means operable during the pull-out portion of the maneuver for providing an alternative vertical slant range component signal responsive to the vertical component craft velocity signal means, integrating means operable during the pull-out portion of the maneuver for providing an alternative horizontal slant range component signal responsive to the horizontal component craft velocity signal means, change-over means operable during the dive portion of the maneuver prior to the pull-out portion thereof for switching the system from the primary vertical component slant range means and the primary horizontal component slant range means to the alternative vertical component slant range means and the alternative horizontal component slant range means, means for continuously combining the velocity and slant range signals of said respective vertical component signal means effective in the respective portions of the maneuver to provide an output, means for continuously combining the velocity and slant range signals of said respective horizontal component signal means effective in the respective portions of the maneuver to provide an output, and means for comparing the outputs of said respective combining means to control the release of the bomb during the pull-out portion of the maneuver.

5. A system for controlling the release of bombs from an aircraft in a toss-bombing maneuver with a dive portion and a pull-out portion, means for producing signals in accordance with the vertical and horizontal components of the velocity of the craft in the maneuver, means for producing primary signals in accordance with the vertical and horizontal components of the slant range from the craft to a target during the dive portion of the maneuver, integrating means operable during the pull-out portion of the maneuver for providing alternative vertical and horizontal slant range component signals responsive to the respective vertical and horizontal components of said craft velocity signal means, change-over means operable during the dive portion of the maneuver prior to the

pull-out portion thereof for switching the system from the primary slant range means to the alternative slant range means, means for continuously combining the vertical component velocity and slant range signals of said respective signal means effective in the respective portions of the maneuver to provide an output, means for continuously combining the horizontal component velocity and slant range signals of said respective signal means effective in the respective portions of the maneuver to provide an output, and means for comparing the outputs of said respective combining means to control the release of the bomb during the pull-out portion of the maneuver.

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