Aug. 16, 1955 W. E. BUCK ET AL 2,715,364

RUDDER-EYE COUPLING FOR HOMING BOMB

Filed July 1, 1947 3 Sheets-Sheet 1

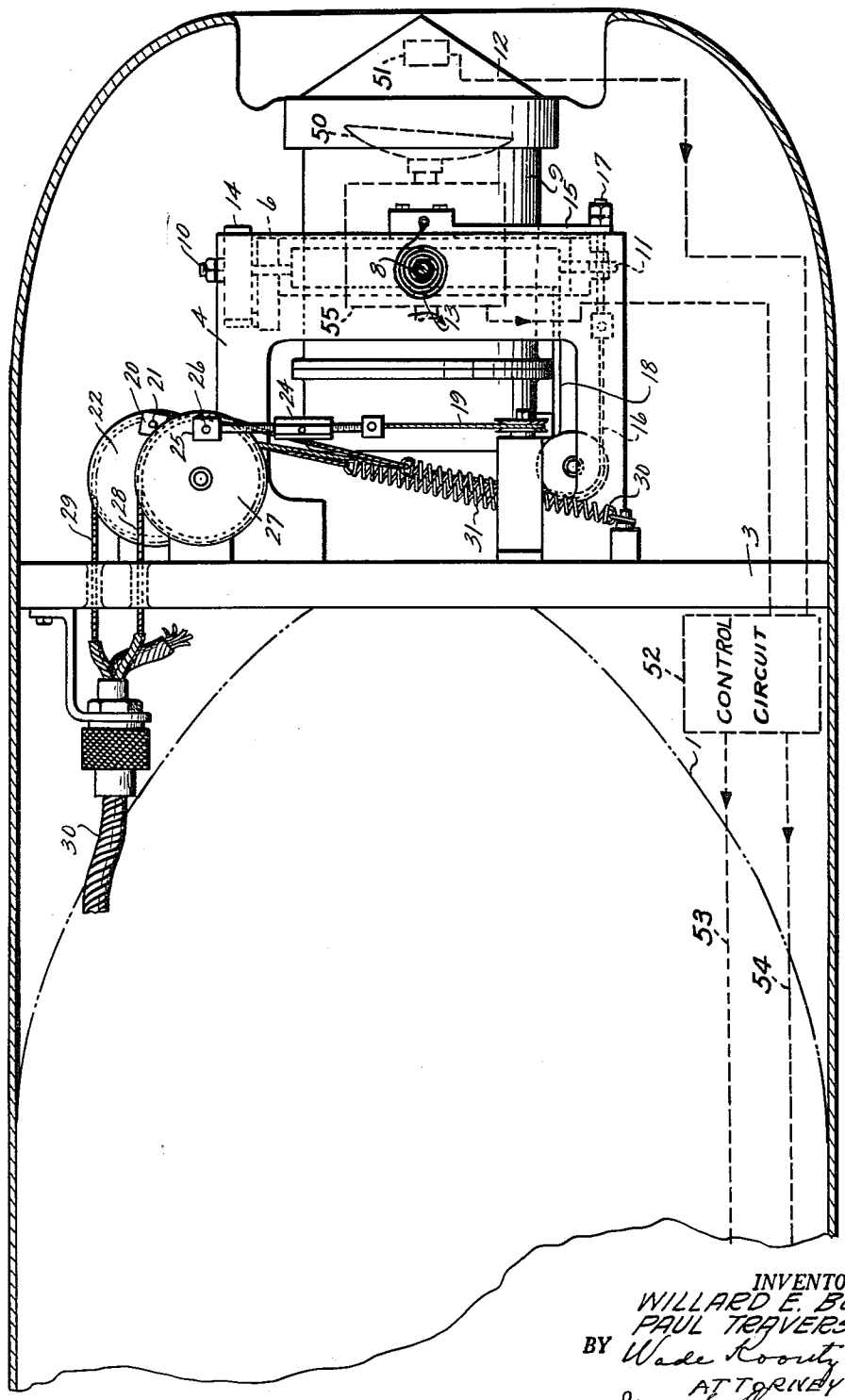


Fig. 1

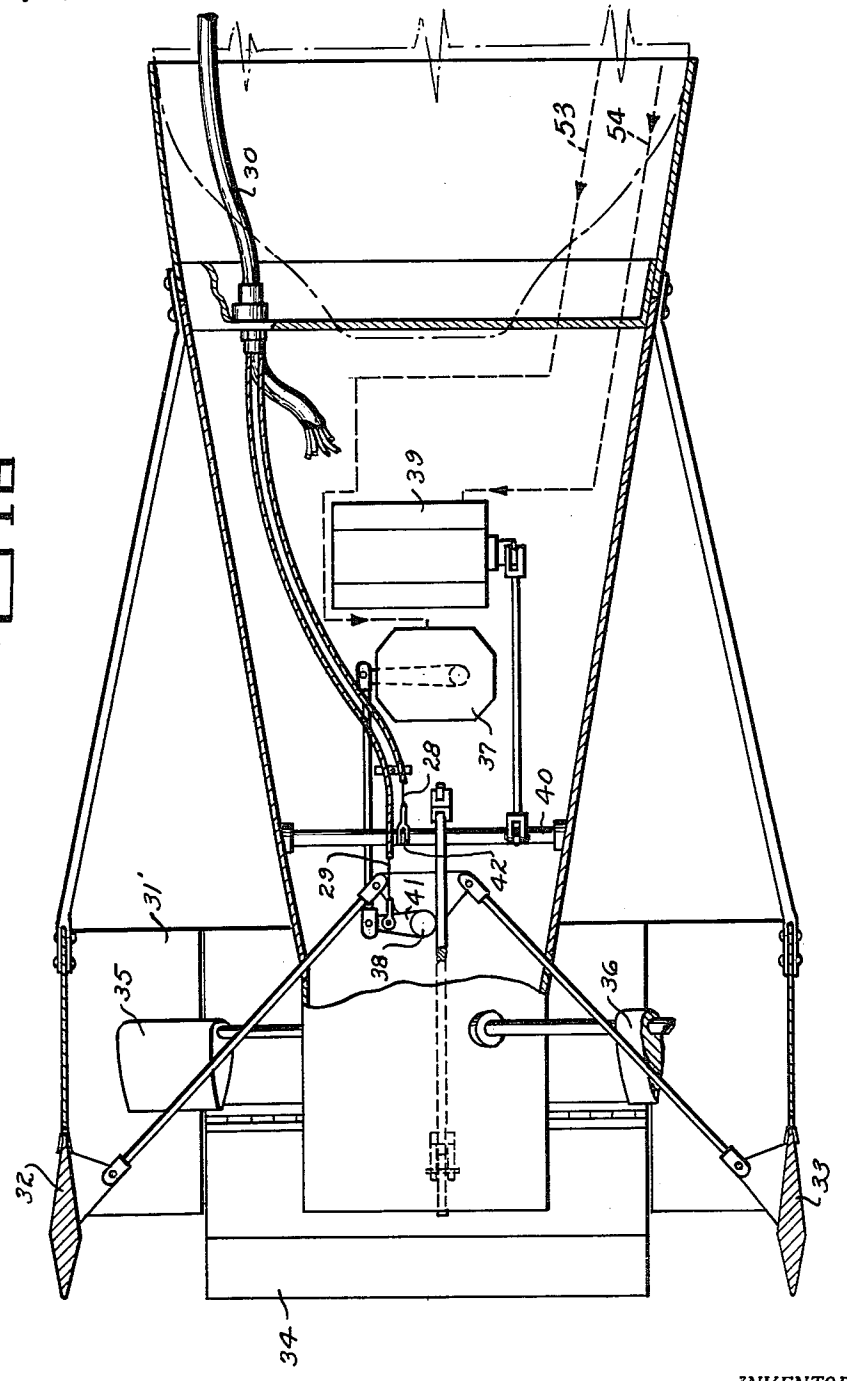
INVENTORS.
WILLARD E. BUCK
PAUL TRAVERS
BY Wade Koontz
ATTORNEY and
James S. Shannon
AGENT

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Fig 11



INVENTORS.
WILLARD E. BUCK
PAUL TRAYERS
BY Wade Conuty
ATTORNEY and
James S. Shannon
AGENT

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Fig 2

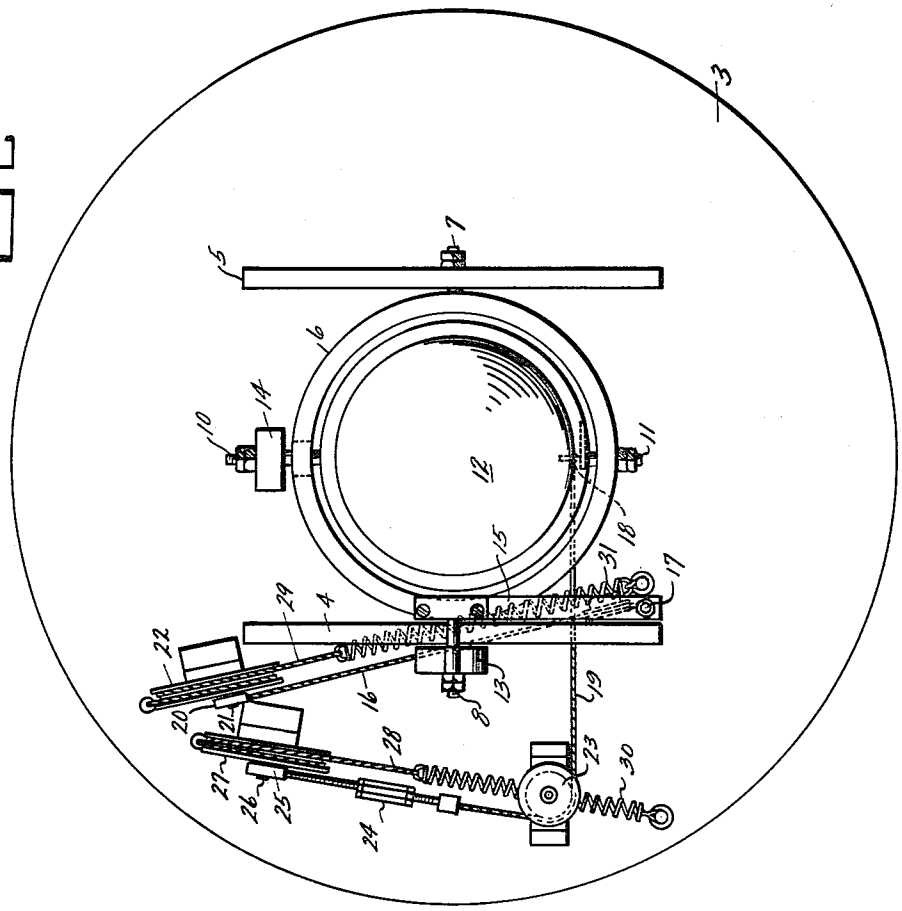
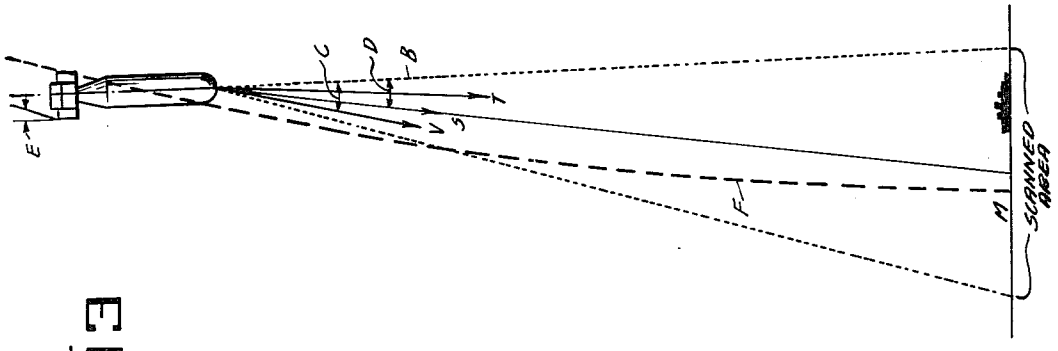


Fig 3



INVENTORS.
WILLARD E. BUCK
PAUL TRAVERS
BY Wade Koontz
ATTORNEY
and
James J. Shannon
AGENT

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RUDDER-EYE COUPLING FOR HOMING BOMB

Willard E. Buck, Inyokern, Calif., and Paul Travers, Cambridge, Mass., assignors to the United States of America as represented by the Secretary of War

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5 Claims. (Cl. 102—3)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without payment to us of any royalty thereon.

This invention relates to the control system of a maneuverable bomb of the type designed to home on a source of infrared radiation and particularly to a means for keeping the infrared sensitive eye of the bomb always looking in the general direction of the velocity vector or direction of travel of the bomb. Bombs of this type have limited maneuverability and are dropped in the conventional manner with the aid of a bombsight. The control system is operative during the last thirteen seconds or so of the bomb's fall and serves to steer the bomb to the target as represented by the strongest source of infrared radiation in the field of view of the bomb's eye. The real function of the control system therefore is to correct for initial errors in the aiming of the bomb by the bombsight.

The flight of the bomb is controlled by rudder, elevator and aileron surfaces located in the tail. The ailerons are gyroscopically controlled and serve to stabilize the bomb as to roll. The rudder and elevator surfaces are controlled by servomotors operating in response to signals received from the infrared sensitive eye and an associated electronic circuit and serve to control the direction of travel of the bomb by angularly displacing its axis away from the direction of the velocity vector, thus producing a yawing or skidding action which alters the direction of travel of the bomb.

If the eye of the bomb were positioned so as to always look in the direction of the axis of the bomb it is evident that a displacement of the bomb's axis for the purpose of controlling the course of the bomb, as described above, would cause the eye either to be pulled off the target completely or else to give a correction tending to keep the bomb's axis pointed at the target rather than its velocity vector as required. This difficulty is overcome in accordance with the invention by providing a mechanical coupling between the control surfaces in the tail and the eye which is mounted in gimbals in the nose. This coupling is such that the eye rotates through an angle opposite to that through which the axis of the bomb is rotated by the action of the control surfaces, thus keeping the eye looking in the general direction in which the bomb is travelling rather than along its axis. In practice the eye is rotated through a somewhat smaller angle than that through which the bomb's axis is rotated to avoid overshooting as will be explained later.

It is the object of this invention therefore to increase the accuracy of control of bombs of the type described by providing means for causing the eye of the bomb to always look in the general direction in which the bomb is travelling.

Means for accomplishing this purpose are described in detail in connection with the accompanying drawings in which:

Fig. 1*a* shows a cutaway view of the nose section of a homing bomb;

Fig. 1*b* shows a cutaway view of the tail section of a homing bomb on a reduced scale;

Fig. 2 is an end view of Fig. 1*a* with the shroud removed; and

Fig. 3 is a diagram showing the homing bomb in the process of altering its course through the action of its control system.

As shown in Figs. 1*a* and 1*b*, the control system of the bomb comprises a nose section and a tail section which may be attached to a standard 1,000 pound bomb 1. Referring to Figs. 1*a* and 2, the plate 3 is fastened to the nose of the bomb and carries two supports 4 and 5 between which are mounted a gimbal ring 6 pivoted by pins 7 and 8 to rotate about a horizontal axis. The housing 9 contains the infrared sensitive eye of the bomb and is mounted in the ring 6 by pins 10 and 11 which permit the eye to rotate about an axis in the vertical plane. The principal elements of the eye contained in housing 9 are a parabolic mirror 50 rotated at constant speed, a bolometer 51 located at the focus of the mirror and a commutating device. The mirror is mounted so that its optical axis makes an angle of about 5° with its axis of rotation and so that the principal focus falls at the intersection of the two axes. The bolometer is placed at this intersection and is of such size as to subtend an angle at the center of the mirror equal to twice the angle between the two axes or about 10°. With this arrangement, the eye scans a circular area 10° in diameter centered on the axis of the eye. The bolometer is a resistance element having a high temperature coefficient and coated with a black substance so as to convert the infrared radiation instant thereon into heat. The resistance of the bolometer is therefore a function of the infrared radiation striking it. The signal from the bolometer is applied to an electronic circuit 52 which controls, through circuits 53 and 54, the servomotors 37 and 39 actuating the rudder and elevator surfaces in the tail. The commutator 55 is mounted on the same shaft as the mirror and rotates therewith and cooperates with the electronic circuit to distinguish between signals received from the four quadrants of the scanned area. Infrared radiations are admitted to the mirror through the conical window 12 which is made of material having a high transparency to this radiation such as fused silver chloride.

The eye housing 9 is biased upward by coil spring 13 and to the right of coil spring 14. The housing is restrained from rotating upward by arm 15, attached to gimbal ring 6, and cable 16 which is fastened to arm 15 by adjusting screw 17. Housing 9 is also restrained from rotating to the right by arm 18, which is fastened to the housing near the bottom pivot point, and cable 19 which is fastened to arm 18. Cable 16 is also fastened to block 20 which fits over crank pin 21 in drum 22, and cable 19, after passing over pulley 23, is connected through turnbuckle 24 to block 25 which fits over crank pin 26 in drum 27.

Cable 28 is fastened to one end of spring 30, the other end of which is anchored to plate 3, and makes 1¼ turns around drum 27. Similarly cable 29 is fastened to one end of spring 31, the other end of which is anchored to plate 3, and makes 1¼ turns around drum 27. If necessary, cables 28 and 29 may each be fastened at one point to its associated drum to avoid slippage. After passing around drums 22 and 27, these cables pass through holes in plate 3 and thence through cable 30 to the tail section of the bomb. Cables 28 and 29 are provided with sheaths for passage through cable 30. Cable 30 also carries all electrical connections between the nose and tail structure. The electronic unit is contained in the nose structure and batteries for supplying power to the control system are located partly in the nose structure

and partly in the tail structure, however, these elements have been eliminated from the drawing for the sake of simplicity. Increasing the tension in cable **28** causes the drum to rotate in a counterclockwise direction, as seen in Fig. 1*a*, which increases the tension in cable **19** and causes eye housing **9** to rotate to the left against the action of coil spring **14**. Decreasing the tension in cable **28** causes drum **27** to rotate in a clockwise direction under the action of spring **30**, thus decreasing the tension in cable **19** and allowing eye housing **9** to rotate to the right under the action of spring **14**. In a similar manner, increasing the tension in cable **29** causes counterclockwise rotation of drum **22**, thus increasing the tension in cable **16** and causing eye housing **9** to rotate downward against the action of the coil spring **13**, while a decrease in the tension of the cable **29** causes drum **22** to rotate clockwise under the action of spring **31** thus decreasing the tension in cable **16** and allowing eye housing **9** to rotate upward under the action of spring **13**.

The tail structure of the bomb comprises an octagonal member **31'** in the upper and lower surfaces of which are mounted elevator surfaces **32** and **33** and in the left and right surfaces of which are mounted left rudder surfaces **34** and a corresponding right rudder surface not shown. Also mounted within the octagonal member **31'** are two ailerons **35** and **36** which are gyroscopically controlled and operate from the time the bomb is released to stabilize it in roll. Elevator servometer **37** is arranged to actaute elevator surfaces **32** and **33** through shaft **38** and suitable linkages as shown and, similarly, rudder servometer **39** is arranged to actuate the rudder surfaces through shaft **40** and suitable linkages as shown. The cable **29** is attached to crank arm **41** on shaft **38** and cable **28** is attached to crank arm **42** on shaft **40**, thus when the elevator surfaces **32** and **33** are rotated upward by servomotor **37**, the tension in cable **19** is increased and the eye is rotated downward against the action of spring **13**. When the elevator surfaces are rotated downward, the tension in cable **19** is decreased and the eye rotates upward due to the action of spring **14**. Likewise left rotation of the rudder causes right rotation of the eye and vice versa. Rotation of the elevator surface upward causes the axis of the bomb in flight to be rotated upward and rotation of the elevator surfaces downward causes the axis of the bomb in flight to be rotated downward. Similarly, right or left rotation of the rudder surfaces causes right or left rotation of the bomb's axes.

Because of the coupling between the control surfaces and the eye, rotation of the bomb's axis in flight is accompanied by rotation of the eye in the opposite direction. The relation between the angle through which the control surfaces rotate and the resulting angle through which the bomb's axis rotates is non-linear and approximates a sine relationship. Therefore, in order to have the angle through which the eye rotates proportional to the angle through which the bomb's axis rotates, it is necessary that the coupling between the control surfaces and the eye be such that the angle through which the eye rotates is approximately proportional to the sine of the angle through which the control surfaces rotate. This is accomplished by the drums **22** and **27**. Considering for example the elevator surfaces, the angle through which surfaces **32** and **33** rotate is equal to the angle through which crank arm **41** rotates. The resulting movement or displacement of cable **29** is proportional to the sine of the angle through which arm **41** rotates. The circumferential movement of drum **22** is equal to the movement of cable **29** and hence the angle through which drum **22** rotates is proportional to the sine of the angle through which elevator surfaces **32** and **33** rotate. For small angles, the angle through which the eye rotates as a result of the rotation of drum **22** is very nearly proportional to the angle through which the drum rotates, being very nearly equal to the angle through which drum **22** rotates times the distance from the center of drum **22** to the center of crank pin **21** divided by the effective length of arm **15**. Therefore, the angle through which the eye rotates as a result of rotation of the elevator surfaces is approximately proportional to the sine of the angle through which the elevator surfaces rotate. Similarly, the action of drum **27** causes the angle through which the eye rotates as a result of rotating the rudder surfaces to be approximately proportional to the sine of the angle through which the rudder surfaces rotate.

The ratio of the angle through which the eye rotates, or the sighting angle, to the angle through which the axis of the bomb is rotated by the control surfaces, or the angle of attack, is referred to as the coupling ratio and is determined by the radii of crank arms **41** and **42**, the radii of drums **22** and **27**, the distances from the center of drums **22** and **27** to the center of crank pins **21** and **26** respectively, and the effective lengths of arms **15** and **18**. A satisfactory value for the coupling ratio has been found to be about 0.7. It is desirable to have the coupling ratio less than unity in order to avoid overshooting as may be seen by reference to Fig. 3. In this figure, a simple situation is shown in which the free fall trajectory F of the bomb lies in a vertical plane including the target. Due to errors in the initial aiming of the bomb, it would strike beyond the target at M in free fall. Therefore, when the control system becomes operative about thirteen seconds before impact, the signal from the eye causes a downward rotation of the elevator surfaces through an angle E which causes the axis B of the bomb to rotate downward through the angle C between the velocity vector V and the bomb's axis B. Operation of the elevator surfaces also causes an upward rotation of the line of sighting S of the eye through an angle D equal to the coupling ratio times the angle C. Due to the angle of attack C, aerodynamic forces on the body of the bomb cause its velocity vector V to swing toward the target direction T. Since the coupling ratio is less than unity as shown by angle D being less than angle C, the line of sighting S, which is the extended axis of the eye, reaches the target before the velocity vector and causes the eye to change its signal from down to up shortly before the velocity vector is pointed at the target. Consequently, the elevator surfaces start back toward their neutral position before the bomb is on course and no appreciable overshoot occurs. The same principles apply in more complicated corrections involving both elevator and rudder controls.

We claim:

1. A homing bomb having a control system comprising an eye sensitive to radiant energy, said eye being capable of scanning an area about the extended axis of the eye, a tail structure containing rudder and elevator control surfaces, means for controlling said surfaces in accordance with signals from said eye, and coupling means between each of said control surfaces and said eye for rotating the axis of the eye through an angle with respect to the bomb's axis that is opposite in direction to the angle with respect to the bomb's axis through which the corresponding control surface is rotated.

2. A homing bomb having a control system comprising an eye sensitive to radiant energy and capable of scanning an area about its extended axis, control surfaces for displacing the axis of said bomb with respect to its direction of travel for changing said direction of travel, means connecting said eye to said control surfaces to vary the positions of said control surfaces in accordance with homing information from said eye, and means for keeping the axis of said eye pointing in the direction of travel of the bomb said means comprising coupling means between said control surfaces and said eye for changing the angular realtion between the axis of said eye and the axis of said bomb in response to changes in the positions of said control surfaces, said changes in angular relation between the axis of said eye and the axis of said bomb being in such direction as to counteract the effect on the eye axis direc-

tion of changes in the bomb axis direction resulting from the action of said control surfaces.

3. Apparatus as claimed in claim 1 in which the coupling means between each of said control surfaces and said eye comprises a means for producing a motion proportional to the sine of the angle through which the corresponding control surface is rotated and further means for rotating said eye through an angle substantially proportional to said motion, whereby the angle of rotation of said eye is substantially proportional to the sine of the angle of rotation of said control surface.

4. A homing bomb having a control system comprising an eye sensitive to radiant energy, said eye being capable of scanning an area about its extended axis and of producing an error signal indicative of the position of a source of radiant energy in said scanned area; control surfaces for angularly displacing the axis of said bomb with respect to its direction of travel for changing said direction of travel; means connected between said eye and said control surfaces to vary the angular positions of said control surfaces relative to the axis of the bomb in accordance with said error signal; and means for keeping the axis of the eye pointing in the direction of travel of the bomb in the presence of angular displacements of said bomb axis from said direction of travel by the action of said control surfaces; said last named means comprising a coupling between each of said control surfaces and said eye such that changes in the angular position of said control surfaces relative to said bomb axis act through said coupling to change the angular position of the axis of said eye relative to said bomb axis, said last named change being in such direction as to counteract the effect on eye axis direction of changes in bomb axis direction resulting from the action of said control surfaces.

5. A homing bomb having a control system comprising an eye sensitive to radiant energy, said eye being capable of scanning an area about its extended axis and of producing an error signal indicative of the position of a source of radiant energy in said scanned area; rudder and elevator control surfaces for angularly displacing the axis of said bomb with respect to its direction of travel for changing said direction of travel; means connected between said eye and said control surfaces to vary the positions of said control surfaces in accordance with said error signal; and means for keeping the axis of said eye pointing in the direction of travel of the bomb, said means comprising a coupling between said rudder and said eye such that rightward movement of said rudder produces leftward movement of said eye and leftward movement of said rudder produces rightward movement of said eye and a coupling between said elevator and said eye such that upward movement of said elevator produces downward movement of said eye and downward movement of said elevator produces upward movement of said eye.

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