Dec. 23, 1969 D. J. KATSANIS 3,485,461

FIRING CONTROL SYSTEM FOR LASER-GUIDED PROJECTILES

Filed April 26, 1968 2 Sheets-Sheet 1

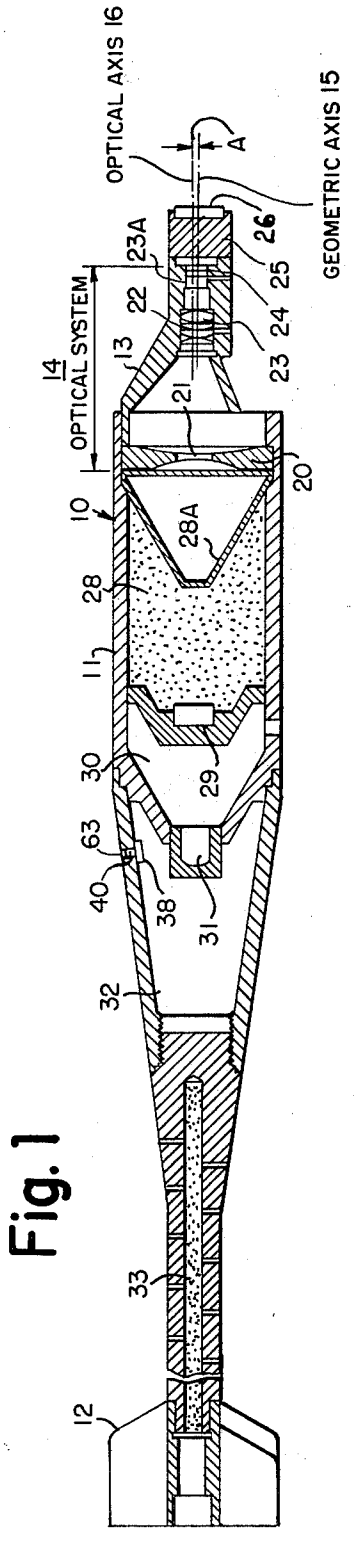

Fig. 1

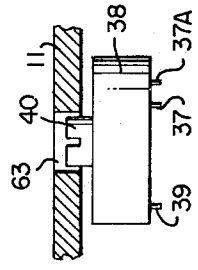

Fig. 4

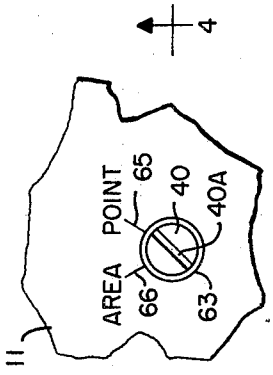

Fig. 3

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FIRING CONTROL SYSTEM FOR LASER-GUIDED PROJECTILES

Filed April 26, 1968 2 Sheets-Sheet 2

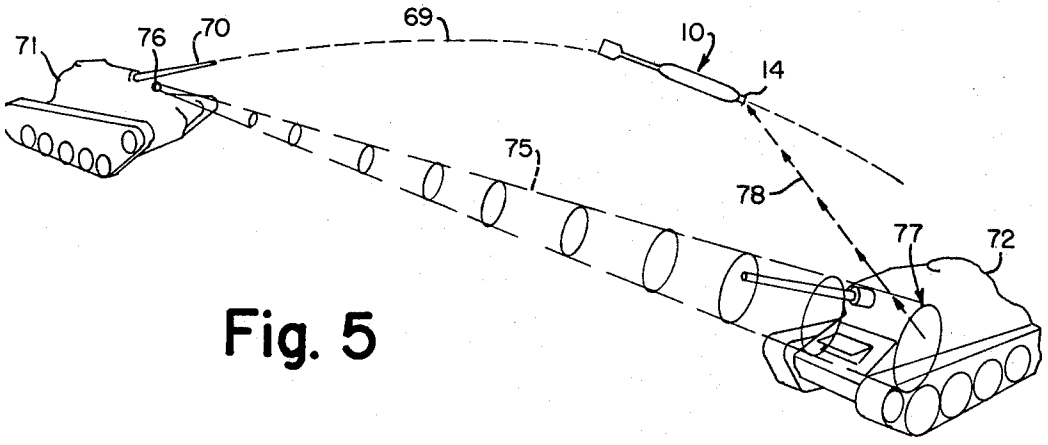

Fig. 5

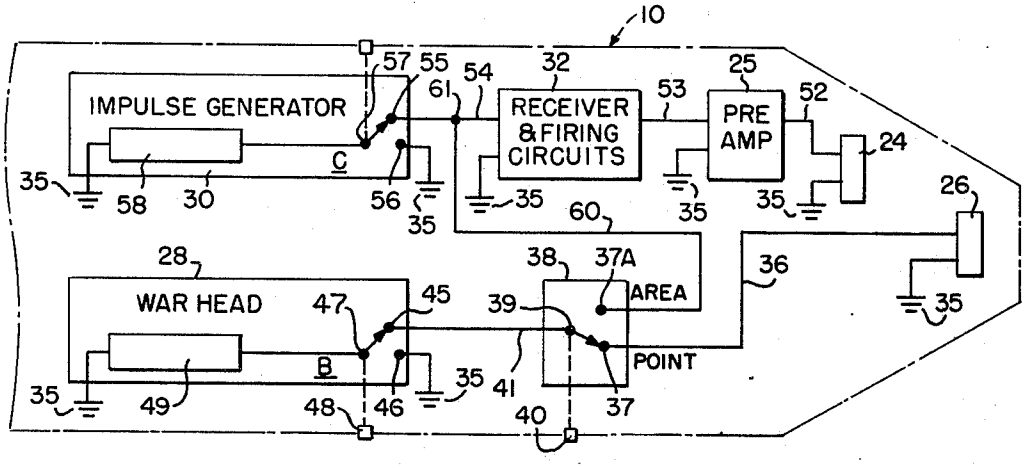

Fig. 2

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FIRING CONTROL SYSTEM FOR LASER-GUIDED PROJECTILES

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Int. Cl. F41g 7/00; F42b 5/02
U.S. Cl. 244—3.15 7 Claims

ABSTRACT OF THE DISCLOSURE

The homing or guidance elements of an impact-detonatable homing-type projectile, responsive to laser or like illumination of off-target areas for guidance, is constructed to provide radiation command for detonation independently of the impact element or elements thereof. The warhead or explosive means for the projectile is arranged to be switched off the impact-responsive initiating train and over to the laser or time radiation-controlled homing or guidance system and to be fired thereby upon illumination of the target area from a command post, such as a tank. The mode of operation is selected by a fuze switch connected between the homing circuits and the fuzing circuits and located for external adjustment through a wall of the carrying projectile. When set for a point or impact target, the munitions or warhead circuit functions normally on impact. When set for an area target, the laser illuminator can be used to command the munition or warhead to fire as a radiation detector responds to the reflected radiation from the illuminator. The illuminator can be manually or timer operated.

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

The present invention relates to homing type projectiles and control systems therefor embodying both guidance and firing circuits and means.

It is an object of this invention to provide an improved control system for increasing the application of homing projectiles to provide for greater accuracy and reliability than is obtainable with existing fuze systems.

The invention relates more particularly to laser-activated and like homing-type projectile control and firing systems which provide directional control of a projectile for long range accuracy on a target area or the like. The projectile is adapted to scan the target area on which a laser illuminating beam is focused. The system arrangement is such that when the projectile is on a hit course, the illuminated area or spot on the target does not fall within the scanned area so that the projectile does not see the spot and flies on an unchanged ballistic trajectory to hit the target. A laser signal seeker on the projectile which is on a miss course recognizes the illuminated spot and actuates a reaction impulse or other means for changing the flight path or trajectory of the projectile to meet the target. Impact means is then depended upon for effecting the final detonation of the projectile on the target area.

The illuminated-spot laser system of the type referred to is limited to hard or point targets such as tanks, armoured personnel carriers, and the like, where impact fuzing is suitable. It is desirable, however, that such equipment have more than one use or application and be extremely flexible for combat purposes.

It is therefore a further object of this invention to provide an improved radiation command fuze system for homing type projectiles and the like which can be extended for use beyond the limitations of impact fuzing as normally provided in such projectiles. This has been accomplished to some extent in the past by the use of time fuzes, which are not reliable or as accurate or consistent as combat operations require. Accordingly, the system of the present invention for dual control of the detonation of an explosive projectile has been provided.

In accordance with one form of the invention, a projectile is provided with both homing and firing circuits and interconnected through suitable switch means for effecting a dual control of the warhead or explosive element of the projectile. The firing circuit consists of an impact control device and a detonator connected thereto and adapted to be electrically fired in response to impact. The directional control system includes a radiation detector, preamplifier and receiver and a guidance or impulse generator circuit responsive to received radiation, such as reflected laser beam radiation from the target area. These operate to apply a control impulse to the firing circuits of the impulse generator for the directional control system of the projectile, thereby to effect a change in direction toward the target. A fuze switch is provided between the homing circuit or directional control and the fuzing circuit, and the switch is located on the projectile in such a way that it may be adjusted from the exterior before firing. When set for point target functioning the system operates on impact and is guided and directed by the homing circuit. When set on area firing, the illuminator of the source can be used to command the projectile to explode since the detector part of the homing circuit responds to the reflected radiation from the illuminator. Complete flexibility is thus available. Manual operation of the illuminator can be used or automatic timing may be provided to turn the illuminator on at a particular predetermined time.

The invention will further be understood from the following description of a preferred embodiment thereof, when considered with reference to the accompanying drawing, and its scope is pointed out in the appended claims.

In the drawing,

FIG. 1 is a cross-sectional view of a projectile provided with a control system in accordance with the invention,

FIG. 2 is a schematic circuit diagram of the interior elements of the projectile of FIG. 1 showing their functional relation, in accordance with the invention,

FIGS. 3 and 4 are front and side views, respectively, of a control element provided in the system of FIG. 2 and the projectile of FIG. 1 for control thereof in accordance with the invention, and

FIG. 5 is a perspective view of a projectile of the type shown in FIG. 1 in operation between a control point and a target area, in accordance with the invention, to illustrate its use and function therein.

Referring to the drawing, wherein like reference numerals throughout the various figures indicate like elements, and referring particularly to FIGS. 1 and 2, a finned projectile **10** of the type adapted to be fired from a gun, is provided with an elongated cylindrical outer casing means **11** tapering rearwardly to guidance tail fins **12** and provided at the forward end with a frame **13** carrying an optical system or homing head **14**. All elements of the projectile are arranged along a geometric axis **15** from which the optical axis **16** is at a slight angle A, such as from 7 to 8 degrees, for example.

The optical system includes a reflecting mirror **20** having a central opening **21**, a series of centrally located receiving lenses **22**. A light filter **23** and a light or laser-beam detector **24**, all arranged along the optical axis **16** as indicated in FIG. 1. A second lens **23A** may also be provided for purposes further described. The detector **24** is an electrical device of the silicon type preferably

and is provided with a suitable preamplifier indicated at **25** and directly connected therewith. On the geometric axis is located a piezoelectric device **26** for generating electrical voltage upon impact of the projectile with a target and this is connected as will be seen with further reference to FIG. 2 hereinafter.

The remainder of the projectile in rear of the mirror **20** includes the explosive element or warhead **28** having a safing or arming device **29**, an impulse or guidance generator **30** having a safing and arming device **31** and the receiver electronics or receiver **32** at the rear of the main body of the projectile preceding the fin area and tail element **12**. An ignition cartridge **33** is located along the axis in the tail end of the projectile for providing the propellant force upon firing from the gun or other launching means.

The projectile shown and the arrangement of the elements thereof is typical of the type of projectile for which the invention is particularly adapted and, as shown, represents a present preferred embodiment thereof.

Referring further to FIG. 2, along with FIG. 1, the electrical circuit connections of the various components are shown with return circuits provided through the usual chassis or system ground connections **35** as indicated throughout the figure. Thus the piezoelectric device **26** for generating a signal on impact is connected through ground **35** and an output lead **36** to one terminal point or contact **37** of a fuse switch **38**. This is a two-point or two-position switch the other point of which is indicated at **37A**. The switch points or contacts are alternately selectable by a movable switch contact or arm **39** which is controlled by a control element or shaft **40** extending therefrom. An output lead **41** from the switch contact **39** extends to a switch contact **45** in the explosive element or warhead **28**. The switch contact **45** is one of a pair in a selector switch B within the warhead and the remaining terminals of which comprise a fixed contact **46** and movable contact or arm **47**. The latter is arranged to be controlled by a control shaft indicated at **48** and is connected to a detonator **49** for the warhead **28**. The opposite terminal of the detonator **49** is connected to system ground **35**. The switch contact **46** is also connected to system ground **35** so that when the contact **47** is closed thereto the detonator **49** of the warhead is short circuited and thus safely precluded from operation, whereas when moved to connect with the terminal **45** as shown, it is ready for operation or firing in response to any voltage output from the impact device or piezoelectric generator **26** through the circuit lead **36** and the switch **38** by way of contacts **39** and **37** and the lead **41** thereto. The safing position, with the contacts **47** and **46** closed, is used when the projectile is in storage and not in preparation for use. This switch is thus an arming switch when closed to the active contact **45** just prior to firing or launching the same as for other well known devices for this purpose.

The electrical circuits for the detector **24** are also included within the diagram and utilize system ground **35** for all return connections. Thus the detector **24** is connected through a lead **52** and ground to the preamplifier **25** and thence through a lead **53** and ground to the receiver and firing circuits **32**. The firing signal resulting from the detection of a laser-beam through the device **24** results in an output signal through an output circuit lead **54** and system ground, which is applied to one switch contact **55** of a selector switch C within the impulse generator **30**. The switch contact **55** is one of two selectable contacts, of which the other is indicated at **56** and connected to system ground **35**. The contacts are selectable by a movable contact or arm **57** which is connected to a detonator or operating device **58** in the impulse generator. This is also grounded as indicated at **35**. A cross connection from the switch contact **37A** is provided through a lead **60** to a terminal **61** on the output circuit lead **54**.

The switch **38** is arranged to be operated by suitable means externally of the projectile. As shown in FIGS. 3 and 4 to which attention is now directed, as well as FIG. 1, the outer casing **11** is provided with an opening **63** through which the switch operating element or shaft **40** is visible from the exterior, and in the present example is slotted as indicated at **40A** to be screw-driver operable.

As shown more clearly in FIG. 3, the screw-driver slot **40A** provides an indicia mark which may be turned as an indicator toward a fixed POINT or limited AREA indicator line **65** or a fixed AREA indicator line **66**. These represent the switching of the contact **39** respectively with the terminals **37** and **37A**. Thus when the switch shaft **40** is turned to the POINT line **65**, the piezo-electric firing element **26** is connected directly to the warhead detonator **49**. When the switch shaft **40** is turned to the AREA line **66**, the switch contact **39** is then connected with the terminal **37A** and the detonator **49** is then connected to the output circuit of the receiver and firing circuits through the terminal **61** and the lead **54**. Thus the detonator **49** is actuated in response to a signal from the detector **24** for the laser radiation. This use will be described in connection with FIG. 5 to which attention is now directed.

In FIG. 5 the projectile **10** is shown in flight along a trajectory **69** from a gun **70** carried by a tank **71** which operates as a control point for the projectile. A second tank **72** at some distance from the first represents the target for the projectile, which for close ranges, hits the target directly on course and detonates the warhead through operation of the forwardly located piezoelectric impact device **26** and the circuits outlined in connection with FIG. 2 for the POINT position of the switch **38**, as shown in drawing. The switch **38** is thus set, as shown in FIGS. 2 and 3, for POINT or limited area firing, upon impact with the target which is directly in its path or on course. This close range point mode does not require the use of the impulse generator. Accordingly, switch contacts **57–56** are connected together so as to connect the impulse generator to ground. Thus no directional control is provided the projectile in this mode.

At longer ranges the dispersion of impact points increases and an increasing number of rounds or projectiles may miss the target. While the point mode is still being utilized, the longer range between launcher and target necessitates the use of the impulse generator to insure an accurate hit. Accordingly, prior to launch, the switch contact **57** is moved to the point **55** thereby tying the impulse generator into the system and thus enabling the laser beam control to direct the projectile to the target upon receiving compensation and/or correction signals from the impulse generator. Thus with the switches all closed as shown in FIG. 2, the normal fire control and sighting equipment of the tank **71** is held on the target during the following ranging, aiming, firing and flying of the projectile into impact, a range finder being used to determine the range of the target. As is known, the gunner merely holds his sighting on the target, and the firing control and sighting equipment automatically adjusts for variations in environmental forces and conditions that may apply to the flight of the projectile. Normally the projectile travels at a rate less than 3000 feet per second and, being fin stabilized, it spins slowly as it goes forward.

In accordance with the invention, a laser illuminator beam **75** from a source **76** on the tank or carrier **71** is focused to provide a spot on the target **72**. By using information from the range finder to produce an approximately one-meter-diameter spot **77** of radiation on the target, or any size spot as desired may be provided. Also the beam may be modulated to enhance target discrimination and the signal-to-noise ratio and is preferably shutter controlled to illuminate the target for only short periods of time, such as from one to two seconds, for example. The homing head of the projectile, which is the

optical system **14** in the present example, provides a seeker which scans the area ahead at all angles between 40 and 120 milliradians, for example, or a substantially 6° angular variation around a center null area which is on course to the target or straight ahead on the axis of the flight path or trajectory.

Referring to FIG. 1 along with FIG. 5 the projected beam **75** of laser energy is reflected from a target area, as indicated at **77** on the tank **72**, back to the projectile along a path indicated by the arrowed line **78** and meets the mirror **20** to be reflected therefrom into the optical axis and through system **22** and the optical filter **23** which is of the narrow-band type, and to the radiation detector **24**, which is responsive to the modulation and frequency of the laser beam to produce an electrical signal pulse output in response thereto.

If the projectile is on a direct hit course that is, what is known as on-target, the illuminated spot **77** in the target area does not fall within the scanned area and so if the impulse generator **30** or the homing circuit is turned on, as in FIG. 2, it has no effect since the seeker or optical system **14** of the projectile will not see the spot and the projectile flies on an unchanged ballastic trajectory to hit the target. The forwardly-placed piezoelectric device **26** then fires the warhead or explosive element upon impact.

However when flying in an off-hit or off-target course the seeker or optical system **14** of a projectile which is on a miss course, as is indicated in FIG. 5, sees and recognizes the illuminated spot reflection, and responds to the modulation signal and the frequency of the illuminator radiation to provide a signal as described above. This is amplified through the preamplifier and applied to the receiver and firing circuits **32** to direct an output signal via the lead **54**. In this case control shaft **40** of switch **38** is turned in a direction to align with the area indicator **66** and to move the contact **39** to the contact point **37A**, thereby connecting the firing of the warhead into the circuit **54** and making it ready to receive a signal from the detector **24** whenever the laser beam **75** is applied to the target. In this case the impulse generator need not be used to reorient the projectile and may be turned off before launching by turning the switch C so that the contacts **57** and **56** are closed. The reason the impulse generator need not be utilized in this mode is because the accuracy of the ballistic computer within the tank **71** is well within the overall idealistic limits of the system to insure that for an area hit the projectile will fall within the designated area without the need of other electrical guidance.

Thus the reflected radiation from the laser illumination is collected by the mirror **20**, in any case, and brought to a focus on the detector **24** which may be a surface-barrier split silicon detector or the like for the projectile indicated. The first two lenses **22** which receive the collected energy from the mirror collimate this energy such that it is essentially normal to the surface of the filter **23**. This optical filter transmits only in narrow bands of energy centered around the laser illuminator wave length. In some cases a third lens **23A** may be used to bring the rays to a focus on the detector surface. A split silicon detector is utilized to obtain an accurate angle determination of the target position.

The warhead or explosive element **28** directly behind the mirror **20** functions through a hole in the mirror. The distance from the mirror and the angle of the cone **28A** are not optimum in this particular arrangement as shown. The warhead may be of whatever diameter is required to meet military specifications and this concept of control may be applied to any diameter projectile. It is preferable that the receiver electronics be in rear of the other control function as they are more readily serviceable at the joint in the casing or near the rear end of the casing.

The use of the projectile described, without modification in accordance with the invention, is limited to a certain degree to so-called hard targets such as tanks, armoured personnel carriers and like vehicles, where direct impact fuzing is suitable. However, as pointed out, it is desirable that the equipment of this type be adapted for more than one use or application and that it be as flexible in use as possible. The present circuits and switch controls provide for this.

In following the above idea of flexibility and adaptability for such munitions, limitation of impact fuzing and time fuzes had to be considered and eliminated before a successful system could be evolved. Time fuzes are generally not as reliable, as accurate, or consistent, as could be desired. By the application of this definite circuit improvement to the system and the use of the homing control laser beam for an additional purpose other than for homing the projectile the limitations of impact fuzing and of such devices can thus be removed without introducing other problems normally associated with time fuzes and their use.

Prior to firing, the fuze switch **38** is set for point or area response using any convenient instrument. When set for POINT, the munition or projectile system functions as normal. When set on AREA, the illuminator beam can be used to command the projectile to be exploded since the detector part of the homing circuit will respond to the reflected radiation from the illuminator. Complete flexibility is thus available. Manual operation of the illuminator may be provided or automatic timing may be provided to turn the illuminator on at a particular predetermined time.

I claim:

1. In a projectile flight control system, the combination with an explosive projectile having an elongated outer casing extending along a longitudinal geometric axis, of

directional flight control means and an electrical control circuit therefor mounted in said casing,

an electrical detonating circuit for said projectile,

an electrical laser beam detector at the forward end of said casing on an optical axis at an angle to said geometric axis,

means for reflecting and directing off-axis laser beam signals onto said detector along said optical axis from a forward direction in flight,

electrical signal-amplifying and receiving means connected with said detector and having an output circuit connected with said directional electrical control circuit to provide control operation thereof,

an electrical pulse-generating device positioned forwardly on said projectile for meeting the impact of a target and connected with said detonating circuit to deliver firing current thereto on impact,

a switch for said detonating circuit operable to breaking connection with said pulse generating device and make connection with the output circuit of the signal amplifying and receiving means, thereby to provide for response to laser beam command illumination of an area on the optical axis, and

means for setting said switch to control said circuit connections from a position outside said projectile.

2. In a projectile flight control system, the combination with an explosive projectile of the type having an elongated cylindrical outer casing extending along a central longitudinal geometric axis, of

directional flight guidance and control means for said projectile of the impulse generator type and an electrical control circuit therefor,

an explosive detonator for said projectile having an electrical detonating circuit,

an electrical laser beam detector on an optical axis at an angle to said geometric axis,

a mirror and a lens system including a light filter located at the forward end of said projectile for reflecting and directing off-axis laser beam signals on to said

detector along said optical axis from a forward direction in flight,

electrical signal-amplifying and receiving means connected with said detector to receive and amplify signals therefrom in response to received laser radiation,

said signal-amplifying and receiving means having an output circuit connected with said directional electrical control circuit to provide control operation thereof in response to said signals,

a piezoelectric impact signal-generating device positioned forwardly of said projectile for meeting the impact of a target and connected with said detonating circuit to deliver firing current thereto on impact,

a two-position switch for said detonating circuit for breaking connection with said piezoelectric device and connecting said circuit with the output circuit of the signal-amplifying and receiving means, thereby to effect response to laser beam command illumination of an area on the optical axis for firing, and

means for setting said switch from a position outside said casing including a rotary operating shaft for the switch aligned with an opening in the casing and adapted for operation therethrough by a tool inserted through said opening.

3. In a flight vehicle of the projectile type having an elongated outer casing, the combination of,

laser radiation-responsive control means positioned for receiving activating radiation on an optical axis at an angle to the longitudinal axis of said casing and the flight axis,

said control means including an electrical signal output circuit and providing a firing current therethrough in response to received laser radiation forward of said casing and in a direction off the flight axis,

guidance means for directing the flight of said vehicle connected with said control means for operation thereby,

electrical impact-operable signal generating means having an output circuit,

electrical detonator means for an explosive element of the vehicle connected with said last-named output circuit for operation thereby,

a selector switch connected for breaking said last-named connection and alternatively connecting said detonator means with said first-named signal output circuit, whereby detonation of said explosive element is made dependent upon received laser radiation through said control means, and

means for operating said switch externally of said casing by an insertable tool through an opening therein.

4. In a flight vehicle of the projectile type having an elongated outer casing, the combination as defined in claim **3**, wherein the laser-radiation-responsive control means includes an optical system having a split-silicon detector with at least one narrow-band optical filter for said detector along said optical axis, and wherein the selector switch is of the two-position two-point type providing limited area response on impact with the impact operable signal generator connection intact and wide area response on laser illumination command with said alternative connection for activating said electrical detonator means and firing said explosive element.

5. In a flight vehicle of the explosive projectile type having a forward internal explosive element and an elongated outer casing, the combination of,

laser radiation-responsive control means including a silicon detector device,

a reflecting mirror and a lens system positioned for receiving and directing activating radiation onto said detector device along an optical axis at an angle to the longitudinal axis of said casing and the flight axis,

said control means further including an electrical signal output circuit and means providing a firing current therethrough in response to received laser radiation on said detector device,

impulse guidance means for directing the flight of said vehicle connected with said control means for operation thereby, impact-operable piezoelectric signal generating means having an output circuit,

electrical detonator means for said explosive element of the vehicle connected with said last-named output circuit for operation thereby,

a two point selector switch connected for making said last-named connection in a first position and for alternatively breaking the same and connecting said detonator means with said first-named signal output circuit in a second position, whereby detonation of said explosive element is made dependent upon received laser radiation through said control means and detector device, and

means for operating said switch externally of said casing including a rotary switch shaft therefor having an end slot for screw driver operation through an opening in said casing and indicia marks on the casing in visual relation thereto for indicating limited area and wide area operating positions for said switch in the said first and second positions respectively.

6. The combination with a projectile having an elongated tubular casing extending along a geometric axis from a forward operating and control end to a rear finned end in spaced relation thereto, of

means providing an optical system at said forward end having an optical axis at a relatively small angle to said geometric axis and a laser radiation detector on the optical axis for response to laser illumination of off-course target areas in flight,

means connected with said detector for deriving an amplified electric-current output therefrom in response to received laser radiation,

said last-named means having an amplified signal output circuit,

current-responsive impulse guidance means for said projectile connected with said output circuit,

an explosive element carried by said projectile in rear of the optical system and having an electrical detonator device,

electro-mechanical transducer means forward of the optical system connected to fire said detonator device on impact, and

means operable externally of said casing for switching off said transducer means and connecting said detonator device with said amplified signal output circuit and the detector for firing in response to received off-target laser radiation from command laser illumination thereof.

7. The combination with a projectile having an elongated tubular casing extending along a geometric axis from a forward operating and control end to a rear finned guidance end, of

means providing a laser-beam-responsive optical system at the forward end having an optical axis at a relatively small angle to said geometric axis,

a laser radiation detector on said optical axis for response to laser illumination of off-course target areas in flight,

a reflecting mirror with a lens system and light filter means on said optical axis for receiving and directing laser radiation from a forward direction onto said detector,

means connected with said detector for deriving an amplified signal output therefrom in response to received laser radiation,

said last-named means having a signal output circuit,

signal-responsive impulse guidance means for said projectile connected with said output circuit,

an explosive element carried by said projectile in

rear of the optical system and having an electrical detonator device,

electro-mechanical transducer means forward of the optical system connected to fire said detonator device on impact,

a two-position selector switch in said casing having an operating shaft mounted to be operable through an opening in the casing wall and having indicia means thereon alignable with position-indicating means carried by the casing for setting said switch selectively in each of the two positions, and

means providing circuit connections with said switch for switching off said transducer means from the detonator device and connecting said device with the detector through said signal output circuit and signal output deriving means with said switch set in one of said positions thereby to fire said explosive element in response to received laser radiation from command

laser beam illumination and in the other of said positions for restoring said impact firing connection with said transducer.

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102—70.2