May 3, 1966 O. C. FOREHAND 3,249,325

MISSILE GUIDANCE SYSTEM

Filed March 12, 1963 2 Sheets-Sheet 1

Fig. 1

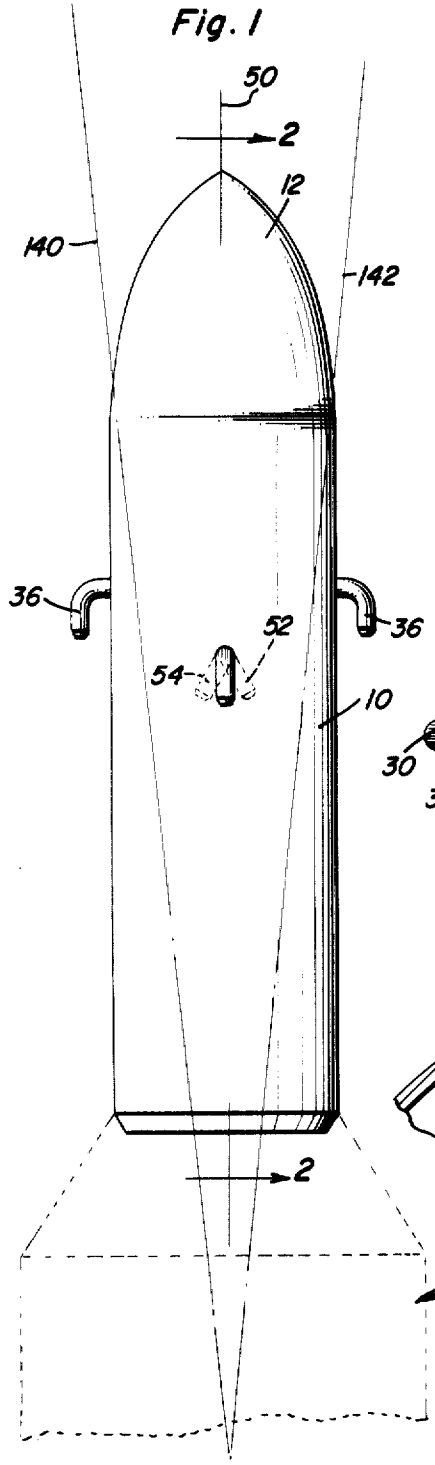


Fig. 4

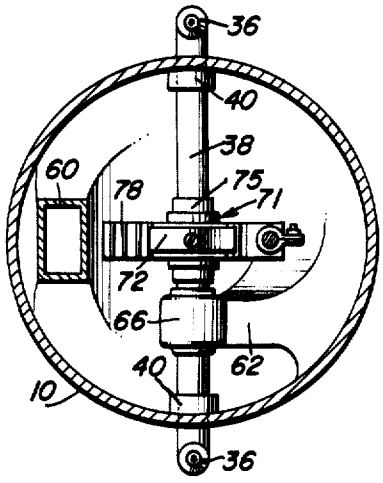


Fig. 5

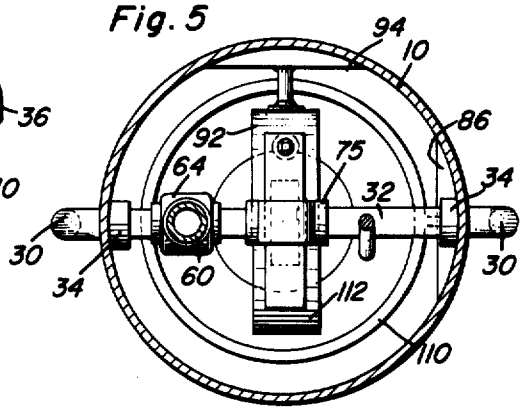
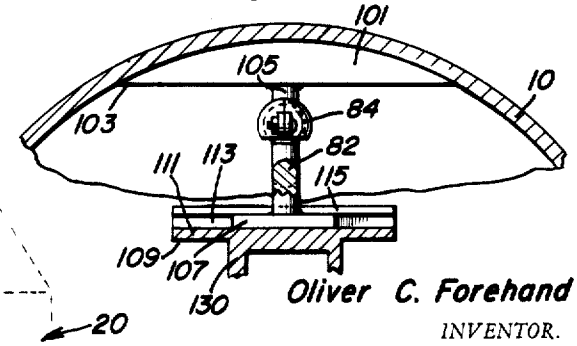


Fig. 6



Oliver C. Forehand

INVENTOR.

BY Clarence A. O'Brien and Harvey B. Jacobson

Attorneys

May 3, 1966 O. C. FOREHAND 3,249,325

MISSILE GUIDANCE SYSTEM

Filed March 12, 1963 2 Sheets-Sheet 2

Fig. 2

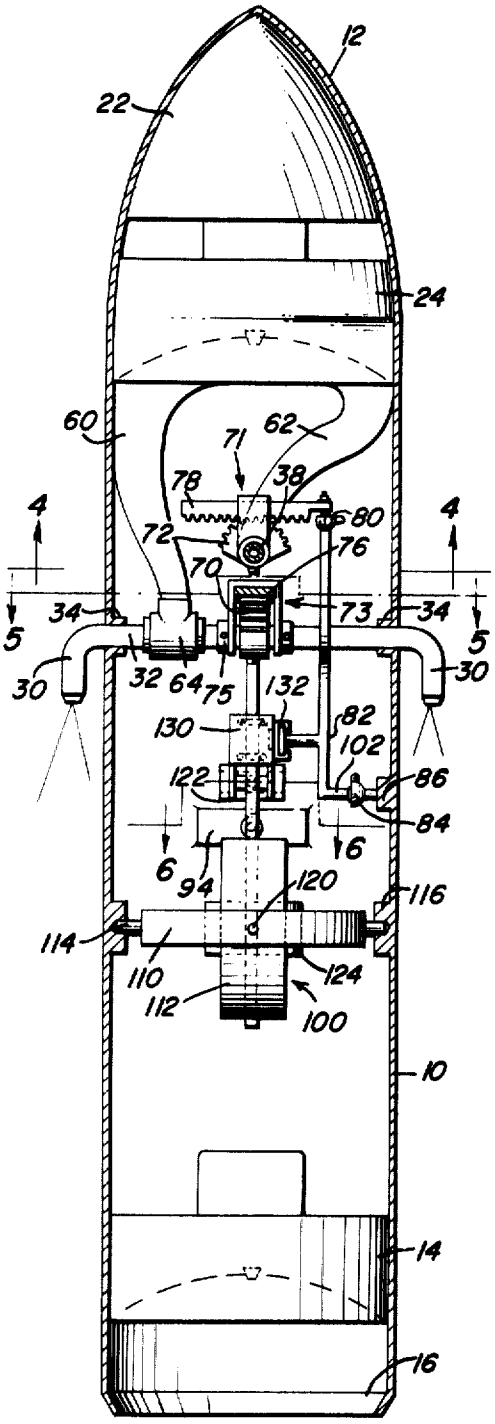
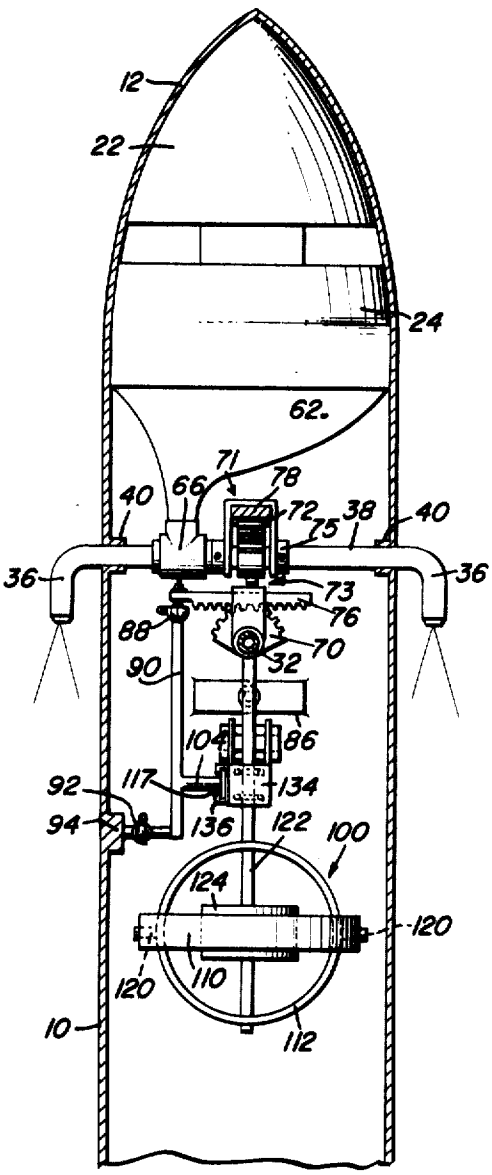


Fig. 3



Oliver C. Forehand

INVENTOR.

BY Clarence A. O'Brien and Harvey B. Jacobson

Attorneys

United States Patent Office 3,249,325
Patented May 3, 1966

3,249,325

MISSILE GUIDANCE SYSTEM

Oliver C. Forehand, 104 Pope St., Sylvester, Ga.

Filed Mar. 12, 1963, Ser. No. 264,632
5 Claims. (Cl. 244—14)

This application contains improvements over and constitutes a continuation-in-part of my prior copending application Serial No. 41,282, filed July 7, 1960, for Missile Guidance System, and now abandoned.

This invention comprises a novel and useful missile guidance system and more particularly pertains to a combined steering and propulsive means for steering missiles upon a predetermined trajectory by a gyroscope control means for adjustably positioning combined steering and propulsion nozzles carried by the missile.

The primary object of this invention is to provide a guidance system for missiles and particularly for rocket propelled and similar missiles of the type now employed as space satellites and space probes and which shall be effective for imparting a steering force to such missiles for maintaining them upon a predetermined trajectory or line of flight.

A further object of the invention is to provide a missile guidance system wherein gyroscope control means are employed for effecting a positive adjustable control of the direction of the discharge of fluid under pressure from sets of nozzles carried by the missile.

Still another object of the invention is to provide a missile guidance system in accordance with the preceding objects wherein a single gyroscope arrangement shall be capable of accurately controlling the direction of thrust of the plurality of sets of steering and propulsion nozzles carried by the missile.

A still further object of the invention is to provide a missile guidance system which may be employed with various types of missiles, rockets and the like and which when rendered operative shall effect an accurate control of the associated portion of the trajectory or path of travel of the missile and which shall not interfere with but shall act as a supplement for various other automatic and semi-automatic control means with which such a missile may be provided.

Yet another and more specific object of the invention is to provide a mechanical linkage for connecting a gyroscope which is mounted for universal movement within the shell of a missile to a pair of adjustable steering and propulsion nozzles capable of rotation in relatively perpendicular planes and which linkage shall be of a type which will compensate for the relative angular movements throughout 360° of the directions of thrust imparted by the gyroscope to the adjustable nozzles.

These together with other objects and advantages which will become subsequently apparent reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout, and in which:

FIGURE 1 is an elevational view showing a suitable type of missile in which the guidance system of this invention has been applied, the view being somewhat diagrammatic in nature;

FIGURE 2 is a central vertical longitudinal sectional view through the missile of FIGURE 1 being taken upon an enlarged scale substantially upon the plane indicated by the section line 2—2 of FIGURE 1 and showing various internal features of the system in accordance with this invention;

FIGURE 3 is a view similar to FIGURE 2 but with parts broken away and omitted, and taken at right angles thereto substantially upon the plane indicated by the section line 3—3 of FIGURE 2 and showing the operating

means for rotationally adjusting a second set of steering and propulsion nozzles from the gyroscope means of the invention; and

FIGURES 4, 5 and 6 are horizontal sectional detail views taken substantially upon the plane indicated by the section lines 4—4, 5—5 and 6—6, respectively, of FIGURE 2.

In comparing the drawings of this application with those of my above-identified prior copending application, it will be observed that the general arrangement of the missile, the gyroscope and its mounting, the adjustable steering and propulsion nozzles and the mechanical linkage connecting the gyroscope to the nozzles is identical. The improvement set forth in the present application consists of changes made in the actual mechanical linkage by which the gyroscope is connected to these nozzles in order to afford a greater freedom of movement and to facilitate the necessary relative angularity of motions occuring in such mechanism.

In the accompanying drawings, there has been illustrated a satisfactory manner of applying the principles of this guidance system to missiles, rockets or space vehicles. For this purpose the numeral **10** designates generally a cylindrical casing having the usual conoidal nose portion **12**. The casing **10** and nose portion **12** may constitute a complete missile in some instances, with there being provided as shown in FIGURE 2 the usual rocket motor or combustion chamber unit **14** by means of which combustion products of a suitable fuel are discharged through the rearwardly opening exhaust nozzle portion **16** of the casing. Inasmuch as the combustion motor **14** and the discharge nozzle or orifice assembly **16** are of conventional and known design, and do not in themselves constitute any portion of the invention claimed herein, a further description of the same is deemed to be unnecessary.

However, as shown in FIGURE 1 it will be readily understood that the casing **10** may constitute merely the final stage of a more complex missile having a rearward body portion indicated generally by the numeral **20** and shown partially in dotted lines in FIGURE 1. In missiles of this type it is understod that after the rearward sections or components of the missile have exhausted their fuel supply and completed their function of imparting a thrust to the missile, such sections will be discarded or released from the final section consisting of the casing **10** with the nose portion **12**. Again, since the structure of missiles of this type are in themselves well known and since the principles of the invention set forth in the claims herein do not depend upon any particular type thereof, a further description of the same is deemed to be unnecessary.

Referring now more specifically to FIGURES 2 and 3 it will be seen that the missile casing **10** to which the principles of this invention have been illustrated as being applied, may have the usual chamber **22** in its nose portion **12** which may carry the payload of the missile such as a war head or the like. Also disposed in the forward portion of the missile but rearwardly of the nose portion **12** is a generator indicated generally by the numeral **24** provided for the purpose of generating a gaseous fluid under pressure which fluid is to be employed as the propellant for effecting steering and/or propulsion of the missile casing **10** which may constitute the final stage of a missile or rocket. It will be understood that a suitable fuel for supply to the generator **24** is housed in the forward portion of the missile and upon being converted to a fluid under pressure is discharged from the generator **24** to the sets of nozzles as set forth hereinafter.

Again, inasmuch as the means for producing this fluid under pressure may be of numerous conventional types and the present invention is not dependent upon any particular type, a further description as to the details of the generator **24**, the means for supplying fuel there-

to and for converting this fluid to a fluid under pressure, as well as the means for controlling the timing of this fluid generation are omitted as being unnecessary. Briefly, however, it is to be understood that some form of conventional control means will be incorporated into the missile itself so that at a predetermined time under predetermined conditions during the flight of the missile, as for example, after the earlier stages of a composite missile have been discarded and the final stage of the missile is in independent flight, the fluid pressure generator **24** may be energized to thus initiate operation of the steering and propulsion system in accordance with this invention for the missile **10** in order to correct or maintain a correct trajectory of the same, as for example, to place the missile in orbit about the earth or some planet or satellite; or for other purposes.

As previously mentioned, in some instances, the rearward portion of the casing **10** may be provided with a rocket motor or combustion chamber **14** which through the previously mentioned control means is brought to operation at any desired time, as for example, when the casing **10** has been separated from the remaining body portion **20** of a composite missile, in order to give the final propulsive thrust to the missile. Thereafter, after the rocket motor **14** has exhausted its fuel supply, or before the same if desired, the steering and propulsive nozzles in accordance with this invention are placed into operation as aforesaid to steer and maintain the missile upon a predetermined trajectory.

Referring now more specifically to FIGURES 2 and 3 it will be observed that there are provided one or more sets of steering and propulsive nozzles. Thus, there has been illustrated a pair of steering and propulsion nozzles of the fluid pressure reactive type indicated by the numerals **30** and which are each provided with a means for mounting the same upon the missile casing **10** for rotation about a transverse axis. This mounting means may conveniently comprise a hollow shaft **32** journalled in suitable bearings **34** in the side wall of the casing, which shaft may be disposed diametrically of the casing. The outer ends of the shaft extend through the sides of the casing and are either provided with integral nozzles **30** or have such nozzles fixedly secured thereto for rotation therewith.

A second set of nozzles as shown in FIGURE 3 indicated by the numeral **36** is likewise carried by a hollow shaft **38** comprising a mounting means therefor which shaft is likewise journaled in bearings **40** and may also extend diametrically of the casing **10** and in angularly rotated relation with respect to the transverse axis of the mounting means **32** for the first set of nozzles. The axis of the hollow shaft **38** is preferably disposed forwardly of the center of gravity of the missile casing **10**. It will be observed that the two mounting means and their sets of nozzles are spaced slightly longitudinally from each other in order to provide proper clearance between the mounting means and the associated structure as set forth hereinafter.

In the arrangement illustrated, it will be observed that only two sets of nozzles and mounting means are provided, these therefore being disposed perpendicular to each other, with the axes of the mounting means being each perpendicular to the longitudinal axis of the missile, which latter is indicated by the dash and dot line **50** of FIGURE 1. In FIGURE 1 the rotationally adjusted positions of the reversely turnable first set of steering and propulsive nozzles **30** is shown with the full line showing being that with the nozzles rotationally adjusted to exert their thrust along the central line **50** of the missile, while shown at **52** and **54**, respectively, in dotted lines in FIGURE 1 is the alternatively reversely adjusted extreme or limiting positions of the nozzles **30** upon reverse rotation of the mounting means **32** when it is desired to produce a thrust which is inclined to the longitudinal axis **50** for the purpose of correcting the steering or imparting a predetermined trajectory to the missile.

It will be understood that a similar adjustment of the second set of nozzles **36** and their mounting means **38** is likewise provided for the same purpose. Thus, by selectively controlling the rotational positions of the two sets of nozzles **30** and **36**, independently of each other, any desired resultant directional thrust can be given to the missile whereby any desired changes in trajectory either for corrective purposes or to give a new and final trajectory to the missile can be obtained.

Although but two sets of nozzles have been shown in the drawings for the purpose of simplicity, it will be understood that additional sets of nozzles at different rotational angles about the longitudinal axis **50** of the missile with respect to each other is possible.

Each of the sets of nozzles **30** and **36** has a free and continuous communication with the interior of its hollow shaft **32** and **38** which comprises its mounting means. In addition, the shafts constitute the means for supplying the fluid under pressure to the nozzles for discharge therefrom to produce the necessary and desired reactive force.

For this purpose, the fluid pressure generator **24** is provided with conduits **60** and **62**, see FIGURES 2 and 3, which respectively communicate as by annular manifolds or connecting sleeves **64** and **66**, respectively, with the hollow shafts **32** and **38**. Thus, when the fluid pressure generator **24** is energized, a fluid under pressure will be supplied by the conduits **60** and **62** to each of the hollow shafts and thus to the respective sets of nozzles carried thereby.

The hollow shafts **32** and **38** are employed also in addition to their function as means for supplying the fluid under pressure to the nozzles for the reactive steering and propulsive effect, as a means to effect and permit the precise rotationally adjusted positioning of the sets of nozzles.

One convenient means for this purpose consists of a pinion gear **70** secured to the shaft **32**, and a corresponding pinion gear **72** for the shaft **38**. These pinions may completely encircle the shafts but preferably, as shown in FIGURES 2 and 3 may be segmental gears of a sufficient circumferential extent to give the desired amplitude of rotational adjustment to the shafts.

The pinions **70** and **72** are engaged by the rack bars or racks **76** and **78** respectively. Each of these racks is provided with a suitable means for slidably and guidably mounting it in the casing to effect reciprocatory movement of the rack with respect to its associated pinion and to retain the rack in engagement therewith. This guide and retaining means consists of a pair of U-shaped brackets **71** and **73** which respectively embrace the racks **78** and **76**. The brackets are of identical construction, each including a pair of legs which are apertured to loosely embrace the respective shafts **38** and **32**. The brackets thus serve to retain the racks in guided sliding engagement with their respective gears **72** and **70**.

In order to secure the brackets in proper position upon their respective shafts and thus restrain their associated racks from lateral shifting movement with respect to the associated gears, each of the shafts is provided with a pair of collars **75** releasably secured thereto and which engage the outsides of the legs of the U-shaped brackets to thereby releasably retain the latter in proper position. It will be noted that the brackets can swing together with any oscillatory movement of their associated racks while slidably and guidingly retaining the racks against their associated gears.

Each rack is also pivotally connected to an actuating lever. Thus the pivot **80** connects the rack **78** to the lever **82** which lever is also fulcrumed as by a swivel **84** to a suitable fulcrum support **86** carried by the wall of the casing **10**. In a similar manner, the rack **76** is pivoted as at **88** to the actuating lever **90** which in turn is swivelled

or pivoted at **92** to a support **94**. Fixed fulcrum pins may be used instead of the swivels **84, 92** if desired.

All of the pivots previously mentioned are preferably of a ball and socket or universal joint connection allowing considerable latitude of swiveling or pivotal action between the associated elements of the linkage. The reason for this freedom of movement in the pivotal connections will be more readily apparent hereinafter.

The two actuating levers have laterally projecting arms by which they are connected to a gyroscope means indicated generally by the numeral **100**. Thus, the actuating lever **82** has a laterally projecting actuating arm **102** while a corresponding arm **104** is provided for the other actuating lever **90**. In the interest of compactness, it will be observed, the arm **102** of the lever **82** is disposed at the end of the same with the fulcrum **86** being connected to a midportion of this lever, while on the contrary for the lever **90**, the fulcrum is pivoted at **92** at one end of the lever while the actuating arm **104** projects from a midportion of the same. However, the operation of both forms of levers is the same in that a lateral thrust is imparted to the actuating arm **102** or **104** which, in turn, causes a pivoting of the associated lever about its fulcrum and thus imparts a reciprocatory movement to the rack members **76, 78** connected to the two levers.

The gyroscope means **100** may be of any conventional design. Briefly, it preferably includes a pair of perpendicularly disposed gimbal rings as at **110** and **112**. The former is journaled by its trunnions **114** and suitable bosses **116** carried by the interior wall of the casing **10** so that this ring is limited to rotational adjustment or movement about an axis extending through the two bosses **116** and which axis is diametrical of and transversely of the casing **10**. The gimbal ring **112** has a pair of diametrically disposed trunnions **120**, see FIGURE 3, by which it is journaled upon the ring **110**. The ring **112** in turn has a gyroscope shaft **122** extending therethrough upon which is secured the flywheel **124** of the gyroscope forming part of an energizable rotor.

The gyroscope shaft **122** has a pair of sleeves rotatably mounted thereon for both free rotation and for axial displacement. Thus there is provided an upper sleeve **130** having an articulated connection **132** with the actuating arm **102** of the actuating lever **82**, while a similar sleeve **134** is connected at **136** to the actuating arm **104** of the lever **90**.

The arrangement is such that when once the gyroscope flywheel has been placed in motion and retained in motion by a conventional means which forms no essential part of this invention, the axis of the gyroscope shaft **122** will be relatively fixed as to direction. Consequently, as the missile deviates from its course, as indicated by the dot and dash lines **140, 142** in FIGURE 1, the relative movement of the fulcrums **86** or **94** or both with respect to the axis of the gyroscope shaft **122** will cause a corresponding pivoting of the associated actuating levers **82** or **90** about their fulcrum pins **84** or **92**. This, in turn, will effect a movement of the racks **78** or **76** thereby producing the rotational adjustment of the associated sets of nozzles **30** or **36**. By this arrangement, once the gyroscope has been placed in motion it will correspondingly adjust the various sets of nozzles **30** or **36** to compensate for any deviation of the missile and its trajectory from a predetermined setting of the gyroscope.

It will be understood that the gyroscope itself and its control system may be placed in motion at any predetermined time after the missile has been fired or launched, as for example, at the same time the fluid pressure generator **24** has been placed in operation.

The initiation of the operation of the gyroscope and of the generator **24** may be effected by any one of numerous remote control or delayed control systems which are now employed in missile work. Consequently, after the final stage of a rocket is operating after the previous stages have been discarded, it may be given a predetermined flight path, as for example, the final steering and propulsive effect required to place a satellite in orbit or direct a missile, rocket or space vehicle to its final trajectory and path of flight.

The two connections **132** and **136** of the actuating levers **82** and **90** respectively, are of identical construction, serve the same purpose and therefore a description of the structure of the connecting means **132** will suffice for an understanding of the structure and operation of both.

Referring to FIGURE 6, it will be seen that the interior of the missile casing **10** is radially inwardly enlarged or is provided with a support bracket to provide a mounting support or lug **101** having a forward flat planar surface **103** thereon. To this planar surface is secured a fulcrum post or bracket **105** which is connected to and supports the actuating arm **102** by the connector **84**. The actuating arm **102** carries a slide plate or shoe **107** which is horizontally or transversely slidable in the guideway or track **109** carried by the sleeve **130**. The guideway **109** is C-shaped in cross section having a flat planar web or back wall **111**, a solid bottom wall **113** together with a front wall **115** which is medially and longitudinally or horizontally slotted to receive the arms **102** or **104**.

Referring now to FIGURES 2 and 6 it will be observed that tilting of the gyroscope shaft **122**, such that there is a component of movement in the vertical plane of the rack **78**, actuating lever **82** and actuator arm, will effect rocking of the lever and proportionate adjustment of the associated nozzle shaft **38**. However, any movement component of the gyroscope shaft in the vertical plane perpendicular to the last-mentioned plane will not move the rack **78** or the actuating lever due to the free sliding of the sleeve **130** on the gyroscope shaft and the free transverse shifting of the slide **107** in the guideway **109**. The reverse movements will apply to the other lever **90**. Thus the levers **82** and **90** will be independently actuated by an amount which is proportionate to the component of gyroscope shaft tilting movement in its associated vertical plane.

The purpose and function of this mounting of the fulcrum for shifting movement is to enable the fulcrums and the connected ends of the actuating levers to shift within the missile shell in accordance with the changing angularity of the gyroscope shaft **122** and the thrust which is imparted by the latter to the rack actuating linkages.

It will be appreciated that the same type of swiveling connections is utilized for the connections **132** and **136** as for the other pivotal connections of the linkages as previously set forth.

From a more specific consideration now of the showing of FIGURES 4, 5 and 6 it will be appreciated that when the missile changes its trajectory as when its axis **50** moves between the two extremes **140, 142**, the mass and energy of the rotating gyroscope flywheel which is maintaining the gyroscope axis **122** in a substantially constant attitude, will in turn effect shifting of the actuating levers to move either or both of the sets of nozzles depending upon the degree and extent of the deviation of the path of travel of the missile from the axis of the gyroscope shaft. The resultant relative tilting of the gyroscope shaft with respect to the central longitudinal axis of the missile and thus the associated linkages will in turn be resolved into components by these linkages to effect the sliding movement of one or both of the racks **76, 78**. As one rack is actuated, it is obvious that the connections of the linkage of the other rack to the gyroscope will result in sufficient lost motion in the sleeve and slide connections to prevent interference with the operation of the other rack.

The foregoing is considered as illustrative only of the principles of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact construction and operation shown and described, and accordingly all suitable modifications and

equivalents may be resorted to falling within the scope of the invention as claimed.

What is claimed as new is as follows:

1. A missile guidance system comprising a set of steering nozzles, means mounting said nozzles upon the exterior of a missile for rotation about an axis lying transversely of and between the ends of said missile, means for supplying said nozzles with fluid under pressure for producing a reactive thrust upon said missile by the discharge of fluid from said nozzles, a gyroscope in said missile, rigid means mechanically connecting said gyroscope to said nozzles for effecting a positive mechanical selective rotational adjustment of said nozzles and thereby controlling the direction of flight of said missile, said gyroscope being disposed rearwardly of said nozzle mounting means, said connecting means including gearing interposed between and connected to said gyroscope and said mounting means, said gearing including a pinion secured to said mounting means and a rack suitably and guidably mounted in said missile and engaging said pinion for reversibly rotating said pinion about said transverse axis said rack being connected to said gyroscope for reciprocation by the latter.

2. A missile guidance system comprising a set of steering nozzles, means mounting said nozzles upon the exterior of a missile for rotation about an axis lying transversely of and between the ends of said missile, means for supplying said nozzles with fluid under pressure for producing a reactive thrust upon said missile by the discharge of fluid from said nozzles, a gyroscope in said missile, rigid means mechanically connecting said gyroscope to said nozzles for effecting a positive mechanical selective rotational adjustment of said nozzles and thereby controlling the direction of flight of said missile, said connecting means comprising a linkage having a series of elements pivotally connected to each other, said linkage being pivotally connected to said nozzles and to said gyroscope, said linkage including a lever and a fulcrum means, said fulcrum means including a guide track secured to and extending transversely of a missile, a slide guidingly and slidably retained in said guide track for freely sliding movement therein, a pivot connecting said lever to said slide.

3. A guidance system for missiles comprising a plurality of sets of propulsive nozzles, means mounting each set of nozzles upon the exterior of a missile for rotation about an axis lying transversely of and between the ends of the missile, the axes of said sets of nozzles being angularly spaced from each other about the longitudinal axis of the missile, means for supplying fluid under pressure to said nozzles for producing a reactive thrust upon said missile by the discharge of fluid from said nozzles, a gyroscope means in said missile, an entirely mechanical rigid means connecting said gyroscope to each set of said nozzles for effecting selective rotational adjustment of each set and thereby controlling the direction of flight of said missile, said gyroscope means being disposed rearwardly of said mounting means, said connecting means including a gearing assembly for each mounting means, each gearing assembly being interposed between and connected to one of said mounting means and to said gyroscope means, at least one of said gearing assemblies including a pinion secured to one of said mounting means and a rack slidably and guidably mounted in said missile and engaging said pinion for reversibly rotationally adjusting said pinion about its transverse axis, said rack being connected to and reciprocated by said gyroscope means.

4. A guidance system for missiles comprising a plurality of sets of propulsive nozzles, means mounting each set of nozzles upon the exterior of a missile for rotation about an axis lying transversely of and between the ends of the missile, the axes of said sets of nozzles being angularly spaced from each other about the longitudinal axis of the missile, means for supplying fluid under pressure to said nozzles for producing a reactive thrust upon said missile by the discharge of fluid from said nozzles, a gyroscope means in said missile, an entirely mechanical rigid means connecting said gyroscope means to each set of said nozzles for effecting selective rotational adjustment of each set and thereby controlling the direction of flight of said missile, said gyroscope means being disposed rearwardly of said mounting means, said connecting means including a gearing assembly for each mounting means, each gearing assembly being interposed between and connected to one of said mounting means and to said gyroscope means, said gearing assemblies each including a pinion secured to one of said mounting means and a rack for each pinion, each rack being slidably and guidably mounted in said missile and engaging one of said pinions, said gyroscope means including a single gyroscope to which all of said racks are connected for reciprocation by said gyroscope.

5. The combination of claim 4 including retaining means for each rack comprising a U-shaped bracket embracing said rack and guidingly retaining said rack on its associated pinion, said bracket being rotatably mounted upon said mounting means.

References Cited by the Examiner

UNITED STATES PATENTS

997,733	7/1911	Beidl	244—79.5
1,096,253	3/1912	Long	244—79.5
2,383,409	8/1945	Newell	244—79.5
2,754,789	7/1956	Minisini	114—24
2,995,319	8/1961	Kershner et al.	244—14

BENJAMIN A. BORCHELT, *Primary Examiner.*

SAMUEL FEINBERG, *Examiner.*

L. L. HALLACHER, W. C. ROCH, *Assistant Examiners.*