United States Patent

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[54] ORBITING SYSTEM SIMULATOR

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[52] **U.S. Cl.** .....**35/45**, 35/42.5, 35/46 R

[51] **Int. Cl.** **G09b 27/00**

[58] **Field of Search** .....35/42.5, 46 R, 47, 43

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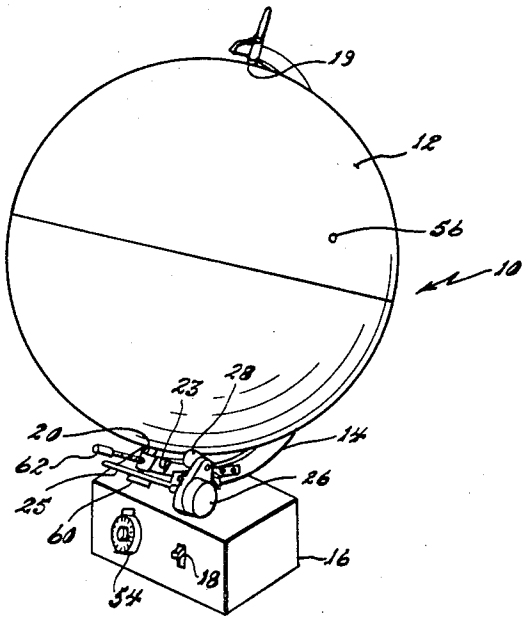
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[57] **ABSTRACT**

The orbiting system simulator provides a graphic, basic representation of the ground track or path followed by the movement, on the earth's surface of a point on an imaginary line drawn from the center of the earth to an orbiting satellite. The earth-globe of the simulator, and its optical indicator are motor-driven to illustrate the relative motion between the earth and the satellite and takes into account the angle of inclination, right ascension, earth rotation, and can include recession of the nodes. Furthermore, the simulator is easily adjustable and can utilize a plurality of accessories to permit simulation of a wide variety of possible ground tracks.

7 Claims, 9 Drawing Figures



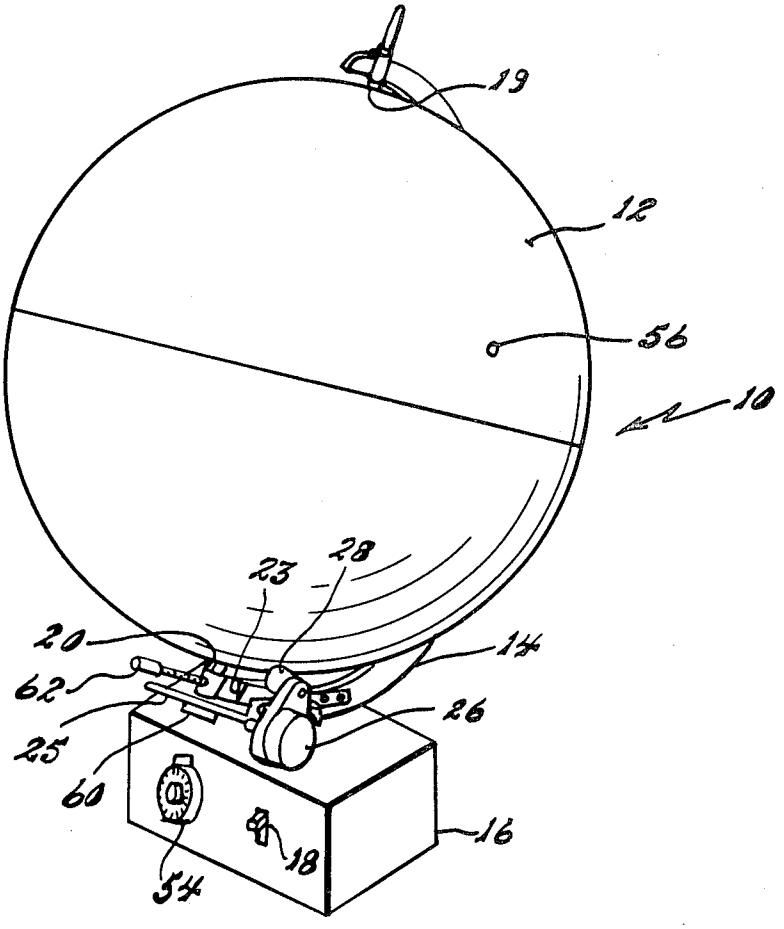


FIG. 1

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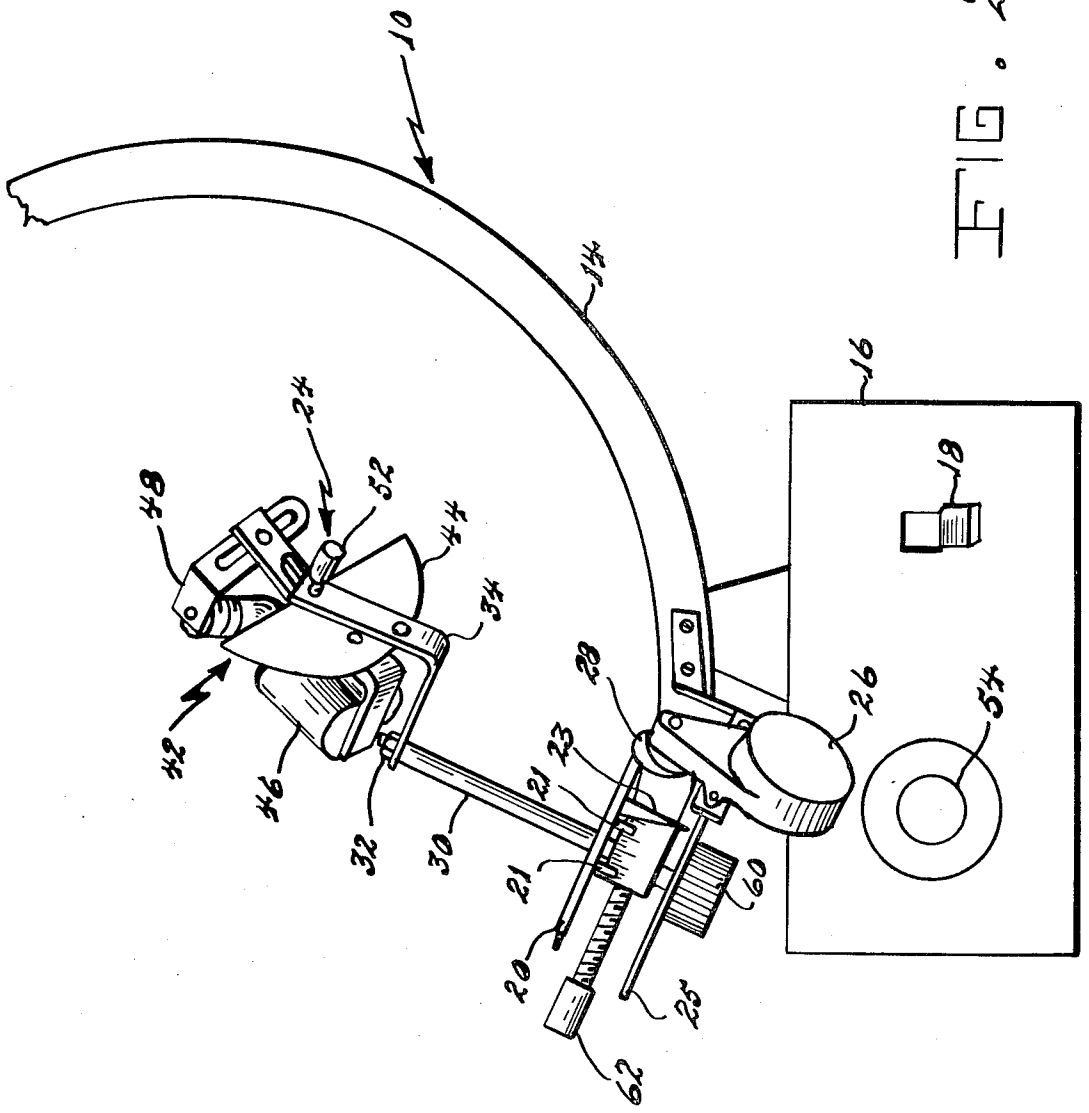


FIG. 2

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FIG. 3

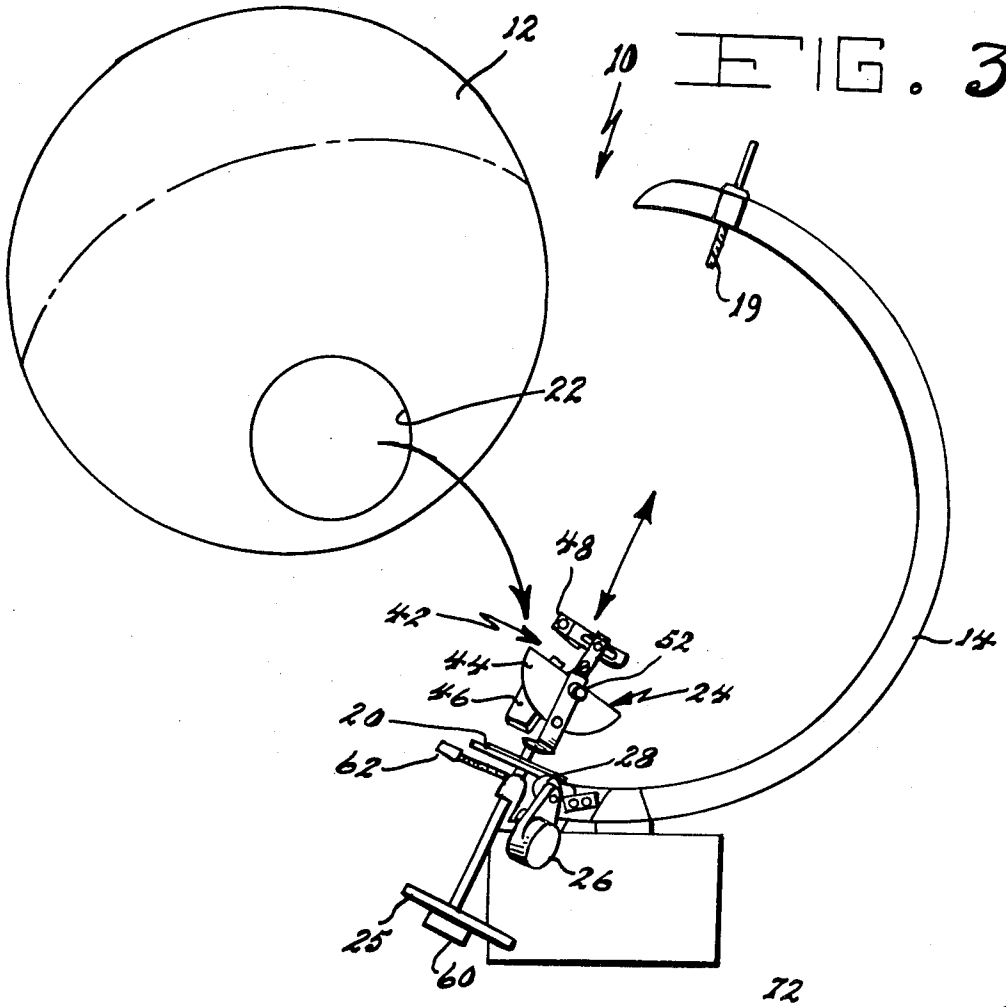
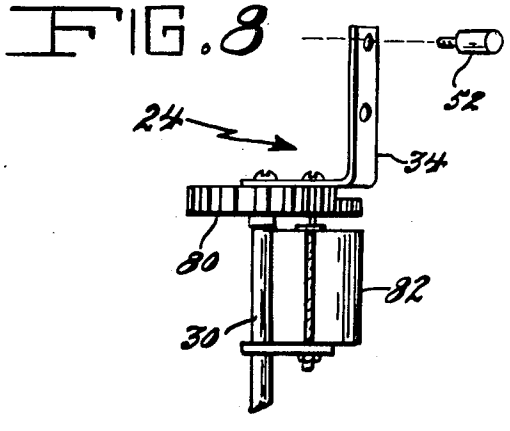


FIG. 8



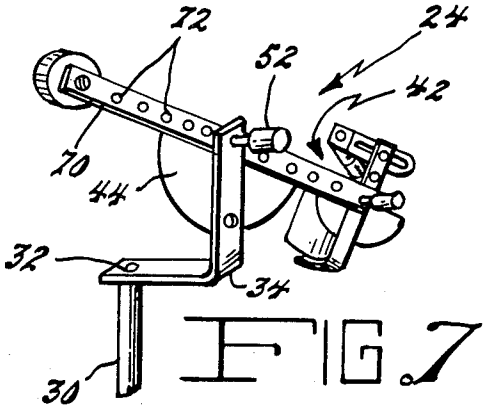


FIG. 7

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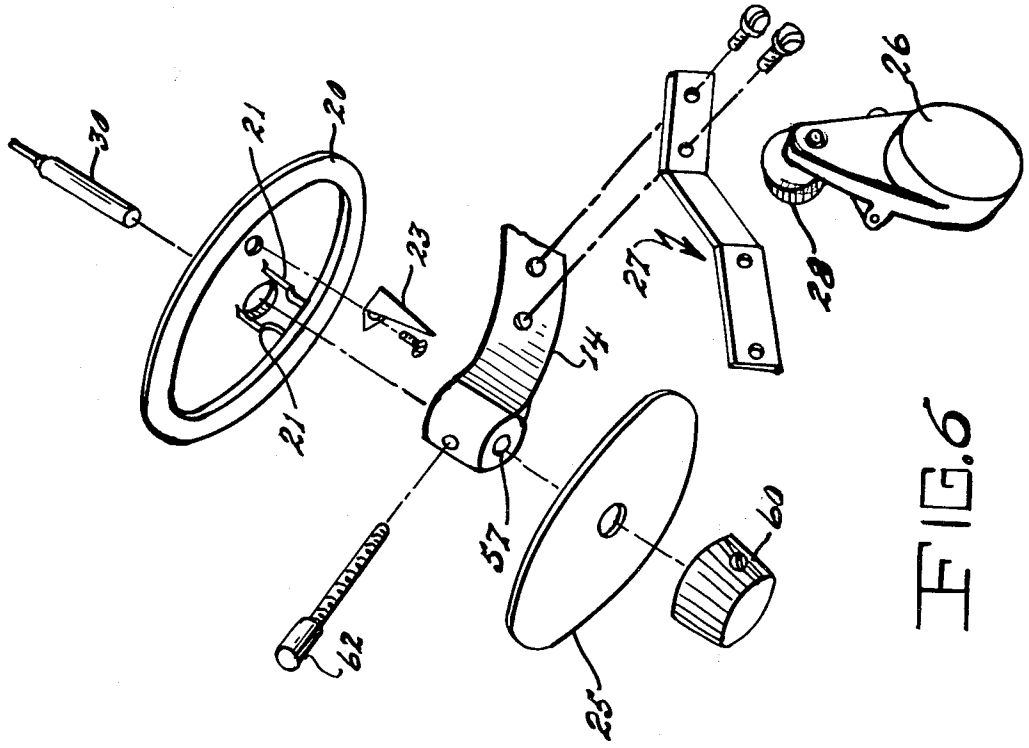


FIG. 6

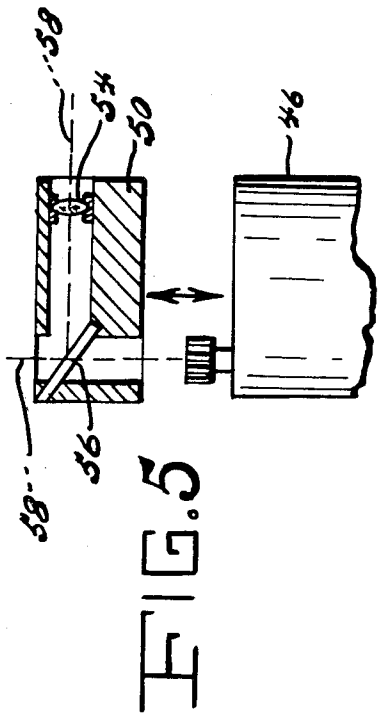


FIG. 5

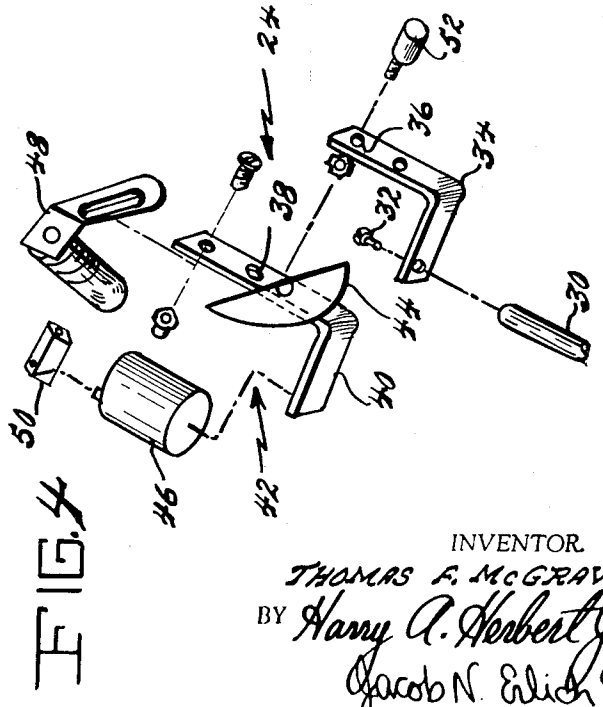


FIG. 4

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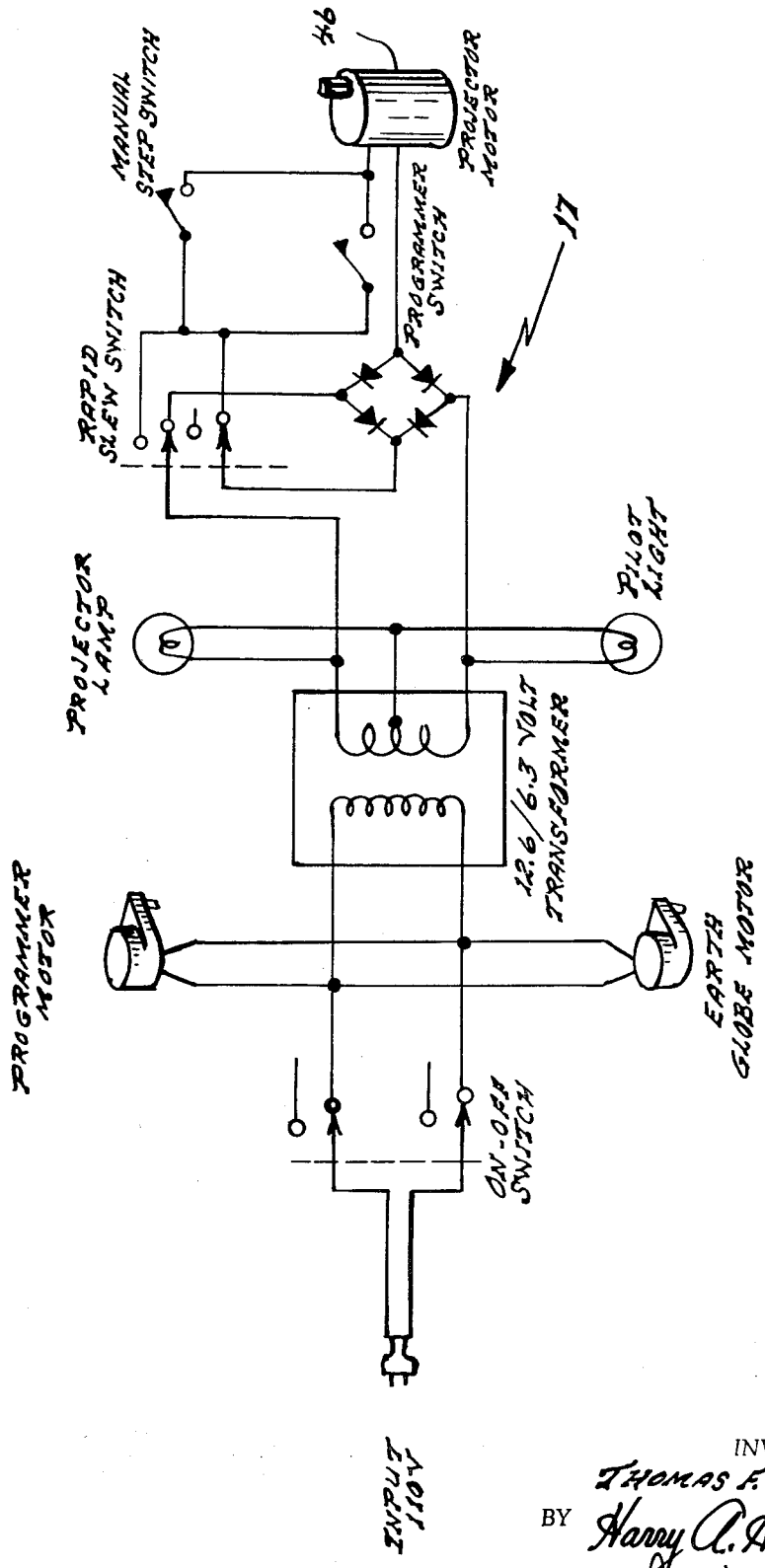


FIG. 6

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ORBITING SYSTEM SIMULATOR

BACKGROUND OF THE INVENTION

This invention relates generally to a means for monitoring and displaying on a reduced scale, the motion of an object as it moves with respect to the earth, and more particularly to a device which utilizes a motor-driven earth-globe and optical indicator to depict through simulation the ground tracks of various earth satellites.

In the use of artificial satellites for scientific research, communications research and in many other fields, it is necessary to monitor and display the various positions of artificial satellites at all times during their orbit. Furthermore, such a monitoring and displaying on a reduced scale of a satellite system could be utilized as a training aid, an operational planning aid and possibly as a navigational display for manned satellites. Also, in the study of man-made or artificial satellites the altering effects due to the rotation of the earth or the earth's "out-of-roundness" can be easily studied with such a monitoring device.

Without such a device the wide variety of available altitudes, orbital periods, and eccentricities of the satellites would be extremely difficult to understand since these orbits can range from a single point over the earth, to straight lines over the equator, to sine waves and to figure eight shapes. All of these patterns vary with the vantage point of the observer. On the earth, for example, one would see only a stationary "star" or a few degrees of motion across the heavens. With the utilization of a monitoring and display device mission planners could visually predict the areas of the earth covered by the satellite and determine specific antenna angles for communication with it and its relationship with celestial space. It would be also possible to utilize such a monitoring device as a navigational aid for the manned orbiting satellite.

Heretofore, such monitoring and displaying techniques have taken the form of a ground track, that is the tracing out on a map of the earth's surface, for example, the path that a satellite travels overhead during its orbit. As our efforts to perfect other types of satellites progressed, we begin to see more and varied complicated ground tracks. Furthermore, because the ground track is dependent on the relative motion between the satellite of the earth, the visualization of ground tracks became quite complicated. Up until this time most of the illustrations have been confined to two-dimensional maps or globe-balancing wire-satellite devices.

About the only earth satellite that has found widespread stimulation is the moon. The sun-to-earth-to-moon simulators called orreries, are sufficient in tracking, for example, the moon, but fail to be versatile enough to track a multitude of various orbiting satellites. There are also three-dimensional lobby displays but these are generally limited to a representation of a single hyperthetical orbit. These monitoring and displaying devices fail to depict the integration of satellite motion with the motion of the earth and are not capable of illustrating a wide variety of orbits, and finally, fail to be realistic and accurate in their displays.

SUMMARY OF THE INVENTION

The orbiting system simulator of this invention overcomes the problems heretofore encountered and is capable of realistically simulating a large number of astrological satellite systems in real or scale time and with a minimum of difficulty.

The orbiting system simulator which will be set forth in detail hereinbelow is basically made up of an earth-globe mounted for rotational movement about its axis and has a light source or optical indicator mounted therein which projects an image representing a satellite on the surface of the globe during its rotation.

The entire system is mounted so as to allow for two degrees of freedom. One degree of freedom permits adjustment about the axis of the earth-globe and represents the input for right ascension. This right ascension being a measurement of the orbit relationship of a satellite with a fixed point in space. The second degree of freedom in the satellite simulator of this invention is about an axis perpendicular to the earth's axis. This is the inclination adjustment. The inclination of an orbit is the angle between the plane of the earth's equator and the plane of that particular orbit.

The third orbital parameter which can be simulated by the instant invention is the regression of the nodes. Satellites in non-equitorial and non-polar orbit experience a slow rotation of the orbital plane about the earth's axis, and into the direction from which the satellite crosses the equator. This regression is caused by the earth's "oblateness" or "out-of-roundness." Simulation of the regression can be accomplished by the mounting of the projector mechanism on a gear and driving it by a second steppor motor which is programmed for the desired rate, typically, extremely slow.

The final parameter of the simulator of this invention is not a satellite characteristic but a characteristic of the earth itself. A small timing motor is situated in such a manner as to rotate the earth about its axis in a realistic fashion. The motor and its drive wheel can be adjusted for real time rotation or some scale factor. If an eccentric orbit is to be simulated by this invention, the optical indicator is cantilevered out from the geometric center of the globe by the insertion of an eccentric bar. The off-center location of the projection point and the discrete number of pulses necessary to turn the motor permits a duplication of Kepler's equal areas rule for eccentric orbits.

With the instant invention, the various parameters of an orbiting satellite may be set at any desired combination. Polar orbits may be selected as easily as equatorial ones, merely by resetting the inclination protractor and locking it down with its locking knob. Orbital period and regression of the nodes may be set in by merely adjusting the timing on a transistorized timing circuit or by changing the number of contacts on a mechanical timing switch. Right ascension is merely a matter of rotating the earth globe to a certain angular relationship with the meridian arc, and the internal projector to a related angle. With all the orbital and earth parameters set, the simulator of this invention may be turned on and the projector will beam a small circle of light off a 45° angled mirror on the motor shaft to the surface of the globe at the desired starting point. On close observation, the circle can be seen slowly moving across the

globe's longitude and latitude lines, borders and cities. Armed with the knowledge of the plane in which the projector is rotating, the observer gains an insight into the movement and gyrations of a satellite as seen from the earth's surface.

It is therefore an object of this invention to provide an orbiting system simulator which is capable of producing a realistic simulation of complex satellite ground tracks.

It is a further object of this invention to provide an orbiting system simulator which gives an accurate means of satellite flight planning and tracking of an existing vehicle.

It is another object of this invention to provide an orbiting system simulator which can be utilized as a navigational aid on board a manned orbital vehicle.

It is still another object of this invention to provide an orbiting system simulator which is economical to produce and which utilizes conventional, currently available components for its construction that lend themselves to standard mass producing manufacturing techniques.

For a better understanding of the present invention, together with other and further objects thereof, reference is made to the following description taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

DESCRIPTION OF THE DRAWING

FIG. 1 is a pictorial view of the orbiting system simulator of this invention;

FIG. 2 is a pictorial view of the orbiting system simulator of this invention with the globe removed;

FIG. 3 is an exploded pictorial view of the orbiting system simulator of this invention with the globe about to be mounted in position and the projector mechanism in its retracted position;

FIG. 4 is an exploded pictorial view of the projector mechanism of the orbiting system simulator of this invention;

FIG. 5 is a side elevational view, partly in cross-section, of the mirror and lens arrangement of the orbiting system simulator of this invention;

FIG. 6 is an exploded pictorial view of the globe bearing disk, ascension protractor and globe motor drive which form a part of the orbiting system simulator of this invention;

FIG. 7 is a pictorial view of the eccentric bar of the orbiting system simulator of this invention;

FIG. 8 is a pictorial view of the gear and additional stepper motor of the orbiting system simulator of this invention; and

FIG. 9 is a schematic drawing of the electrical circuitry to permit rapid slewing of the orbiting system simulator of this invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is now made to FIG. 1 of the drawing which shows in pictorial fashion the orbiting system simulator 10 of this invention. This simulator 10 is made up of a globe 12 manufactured from any commercially made translucent globe of the internally lit variety and represents the body about which a satellite is orbiting. In this instance the globe 12 is a replica of the earth; however, it is to be noted that the globe 12 may take the form of any other planet or the like. The globe 12 is mounted for rotation about its axis on a meridian arc 14 (as best shown in FIGS. 1 and 3) which, in turn, is mounted on a box-like base structure 16 which contains an "on-off" switch 18, a timing circuit 17 (shown in FIG. 9), and a transformer for the light source.

As shown in FIGS. 1–3 and 6, the globe 12 is held in a rotatable position by a locking screw 19 and rests on a globe bearing disk 20. The bearing disk 20 is fixedly secured by any conventional securing arrangement such as clamps 21 to the meridian arc 14, and the globe rotates freely about it. A pointer 23 is secured to the fixed bearing disk 20 and is utilized in conjunction with a right ascension protractor 25 in a manner to be explained hereinbelow. The globe 12 has an opening 22 at the bottom thereof (shown in FIG. 3) so that the globe 12 can be inserted over a projector mechanism 24 when positioned upon bearing disk 20. In some instances, which will be described hereinbelow, it is necessary for the globe 12 to be formed of two halves for insertion over the projector mechanism 24. A small timing motor 26 is fixedly secured to the meridian arc 14 (see FIG. 6) by any suitable securing means 27 and in conjunction with any suitable drive means, such as rubber tire drive 28 or a gear arrangement rotates the globe 12 about its axis in a realistic fashion.

In order to simulate the orbiting satellite motion a projector mechanism 24 (shown in FIGS. 2–4) is mounted upon a support rod 30 by any conventional securing means such as bolt 32.

Referring to FIG. 4, the projector mechanism 24 is made up of a support and an optical indicator 42. The support has an L-shaped frame 34 which is attached by one leg to the support rod 30. The other leg of frame 34 has a plurality of holes 36 therein which are aligned with a plurality of holes 38 on an inner frame 40 for adjustable mounting therebetween. The inner frame 40 supports the optical indicator 42 utilized in the projection of the satellite. This optical indicator 42 is made up of an inclination protractor 44 mounted on the inner frame 40, a stepping motor 46, a light source 48, and a lens and mirror box 50. An inclination locking knob 52 secures the protractor 44 and inner frame 40 to the frame 34, with the light source 48 and stepping motor 46 being fixedly secured to the inner frame 40 by any suitable securing means. The orbital period or time for one complete orbit of the satellite is dialed into the timing circuit 17 (shown in FIG. 9) by the dial 54 mounted on the base structure 16.

The timing circuit 17 provides time pulses to the projector stepping motor 46 mounted on the inner frame 40. The time interval may be adjusted by adding or deleting "little bumps" which close micro switches to pulse the motor 46. A manual advance is accomplished by manually pulsing the motor voltage. All planning for the orbital period is simplified with the knowledge that the stepping motor 46 used in the projector mechanism 24 of this invention requires 500 "on" and 500 "off" impulses to make one rotation or simulated orbit. Thus, for a two-hour orbit, timing must be selected to get 500 "offs" in two hours.

The light source 48 is also mounted upon the inner frame 40 and is utilized in conjunction with a small lens

54 and mirror 56 located within box 50 and mounted upon the projection motor 46 by any suitable securing arrangement as shown in FIG. 5. The light beam 58 emanating from the source 48 is directed from mirror 56 through lens 54 so as to focus a small disk of light 56 on the surface of the globe (see FIGS. 1 and 5).

Referring to FIG. 6, the support rod 30 with the projector mechanism 24 at one end is mounted through the globe bearing disk 20, and through an opening 57 in the arc 14. A right ascension protractor 25 and knob 60 are fixedly secured to the other end of rod 30. Locking knob 62 mounted perpendicular to rod 30 on the meridian arc 14 securely holds in position the support rod 30 at any predetermined right ascension angle set on protractor 25. When it is necessary to lower the support rod 30 and the projector mechanism 24, the locking knob 62 is released and the projection mechanism 24 is lowered to the position shown in FIG. 3 so that the globe 12 may be inserted or removed from position for necessary adjustments of the projector mechanism 24.

In establishing the proper coordinates for the orbiting satellite, the first item of importance is the right ascension of the ascending node, which is defined as the arc of the celestial equator measured eastward from the vernal equinox to the ascending node. The ascending node is the point where the projections of the satellite path crosses the celestial equator from south to north. In other words, right ascension of the ascending node is the angle measured eastward from the first point of Aries to the point where the satellite crosses the equator from south to north.

The next item of importance is the angle the path of the orbit makes with the equator. This is the angle of inclination (i), which is defined as the angle that the plane of the orbit makes with the plane of the equator, measured counterclockwise from the equator at the ascending node. Equatorial orbits have $i = 0°$, posigrade orbits have $i = 0°$ to $90°$ polar orbits have $i = 90°$, and retrograde orbits have $i = 90°$ to $180°$.

Once the period of the satellite is programmed into the projector motor 46 by way of dial 54 on the base structure 16, the inclination (0° to 180°) may be input into the simulator 10 of this invention. The globe 12 is removed by releasing the locking screw 19 at the top of the meridian arc 14 and loosening the locking knob 62, thereby lowering the projector mechanism 24 as shown in FIG. 3. This clears the way to remove the globe 12 and program the projector mechanism 24. Programming inclination is accomplished by loosening the locking knob 52, adjusting the protractor 44 and thereby the inner gimbal 40 to the desired angle, and relocking the locking knob 52. The globe 12 is replaced and the projector mechanism 24 is again raised into position. The right ascension parameter is now entered into the simulator of this invention by turning the right ascension protractor knob 60 so that the desired angle is shown by the pointer 23 on the protractor 59. With the projector mechanism 24 now at the proper right ascension angle the locking knob 62 is tightened.

If an eccentric orbit is to be simulated by this invention the optical indicator 42 is cantilevered out from the geometric center of the globe by the insertion of an eccentric bar 70 mounted upon frame 34, as shown in FIG. 7. If the eccentric bar 70 is used with this invention, it is necessary that the globe 12 be sectioned through the equator in order to permit the insertion and adjustment of this elongated projector/eccentric bar 70. In this case, the projector mechanism 24 is placed between the globe center and the desired apogee in order to achieve the illustration of velocity changes in the ground track. The eccentric bar 70 has a counter weight 71 at one end and is drilled and tapped at a plurality of positions 72 along its length to permit a wide variety of possible eccentricities. The locking knob 52 and protractor 44 allow for the proper inclination to be programmed into the projector mechanism 24.

The regression of the nodes which is a gradual movement of the plane of the orbit of a satellite is caused by the oblate shape of the earth. This regression can be simulated by mounting the projector mechanism 24 on a gear 80 and driving it by a second stepper motor 82 as shown in FIG. 8. This second stepper motor 82 is programmed at the very slow desired rate in order to simulate the regression.

The electrical circuitry 17 of this invention, as shown in FIG. 9, permits the rapid slewing of the projector mechanism and therefore the simulated satellite 56. When a rapid slewing switch is activated, the manual step switch is depressed until the satellite 56 reaches the desired spot. This works in supplying only one-half wave rectified direct current to the motor 46. Thus, it is automatically pulsed 60 times per second.

It should also be noted that the simulator 10 of this invention is not limited in its use to an illustration of earth satellites. It could also be useful to simulate the orbit of any planet or moon for which a reasonably accurate globe 12 could be mapped out. Thus, it is entirely possible that the orbiting system simulator 10 could simulate probes of the Moon, Venus or Mars.

MODE OF OPERATION

When it is desired to simulate the orbital movement of a satellite, the orbiting system simulator 10 of this invention is of great usefulness. In order to program the projector mechanism 24 of the simulator 10, it is first necessary to remove the globe 12. This is accomplished by loosening the locking screw 19 and lowering the projector mechanism 24, as shown in FIG. 3. The projector mechanism 24 is lowered by the loosening of locking knob 62 which allows the support rod 30 along with projector mechanism 24 to be lowered. The globe 12 is now removed from its mounted position.

The first orbital parameter which is programmed into the projector mechanism 24 is the inclination angle of the satellite. The inclination locking knob 52 is loosened and the entire projector mechanism 24 including the optical indicator 42 is set by means of inclination protractor 44 at the desired angle (0°–180°). Once in place, the locking knob 52 is again tightened. The globe 12 is now replaced and the projector mechanism 24 is raised into position. However, before locking knob 62 is secured the projector mechanism 24 is set at the proper right ascension angle, another orbital parameter, by rotating knob 60 until the desired angle (0°–360°) aligns with pointer 23 on the ascension protractor 25. Once the right ascension has been set it is locked into position by tightening locking knob 62. The orbital period is dialed into the

timing circuit **17**. If necessary any rapid slewing of the satellite may be accomplished by activating the rapid slew switch and depressing the manual step switch until the satellite reaches the desired spot (see FIG. **9**).

If an eccentric orbit is to be simulated, the optical indicator **42** is cantilevered out from the center of the globe **12** by the insertion of the eccentric bar **70**. With the use of this bar **70**, the globe **12** must be sectioned through the equator in order to permit its insertion and the adjustment of the projector mechanism **24**. The regression of the nodes is programmed into the simulator **10** of this invention by mounting the projector mechanism **24** on a gear **80** and driving it by a second stepper motor **82** at the desired rate.

With the above procedures accomplished, the orbiting system simulator **10** is ready to depict most achievable ground tracks. The timing motor **26** is activated and turned on by switch **18** on the support **16** for initiation of satellite simulation.

Although the invention has been described with reference to a particular embodiment, it will be understood to those skilled in the art that this invention is also capable of a variety of alternate embodiments within the spirit and scope of the appended claims.

I claim:

1. An orbiting system simulator comprising a hollow translucent globe, means for rotatably supporting said globe about its axis, a support rod, said support rod being slideably and rotatably mounted along said globe axis on said globe support means, a first support frame mounted at one end of said support rod, a second support frame mounted on said first support frame for adjustable movement about an axis perpendicular to said globe axis, a projector mechanism having means for projecting a disk of light on surface of said globe, said projector mechanism being mounted on said second support frame for movement therewith, a knob fixedly secured to the other end of said support rod for rotating and sliding said support rod about said globe axis and means for adjustably moving said second support frame about said axis perpendicular to the globe axis whereby the inclination angle and right ascension angle of a satellite can be programmed into said orbiting system simulator.

2. An orbiting system simulator as defined in claim **1** wherein said means for projecting a disk of light comprises a light source, a reflector in optical alignment with said light source so as to focus the beam of light emanating from said source onto the surface of said globe and means for rotating said reflector at a predetermined rate thereby simulating the orbital rotation of a satellite.

3. An orbiting system simulator as defined in claim **2** wherein said means for supporting said globe comprises an arc-shaped member and a globe bearing disk immovably secured to said arc-shaped member, said globe resting upon said bearing disk for rotational movement about its axis.

4. An orbiting system simulator as defined in claim **3** wherein said means for projecting a disk of light further comprises a lens optically aligned with said reflector thereby producing a small disk of light on the surface of said globe.

5. An orbiting system simulator as defined in claim **1** further comprising an eccentric bar, said eccentric bar being pivotally secured to said first support frame, said second support frame being pivotally mounted on one end of said eccentric bar and a counterweight being mounted on the other end of said bar.

6. An orbiting system simulator as defined in claim **5** wherein said means for projecting a disk of light comprises a light source, a reflector in optical alignment with said light source so as to focus the beam of light emanating from said source onto the surface of said globe and means for rotating said reflector at a predetermined rate thereby simulating the orbital rotation of a satellite.

7. An orbiting system simulator as defined in claim **6** wherein said means for supporting said globe comprises an arc-shaped member and a globe bearing disk immovably secured to said arc-shaped member, said globe resting upon said bearing disk for rotational movement about its axis.

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