PATENT SPECIFICATION

(11) 1 591 902

1 591 902

(21) Application No. 37207/77 (22) Filed 6 Sep. 1977 (19)

(31) Convention Application No. 2642061 (32) Filed 18 Sep. 1976 in

(33) Fed. Rep. of Germany (DE)

(44) Complete Specification Published 1 Jul. 1981

(51) INT. CL.³ B64G 1/24 //
G05D 1/08

(52) Index at Acceptance
B7W 2

(54) METHOD FOR CONTROLLING THE ATTITUDE AND ORBITAL PATH OF A SATELLITE

(71) We, MESSERSCHMITT-BÖLKOW-BLOHM Gesellschaft mit beschränkter Haftung, of 8000 Munchen, German Federal Republic a Company organised and existing under the laws of the German Federal Republic, do hereby declare the invention, for which we pray that a Patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a method of transferring a satellite from an initial orbit into a final synchronous orbit, the satellite having an attitude controlling system with a reaction wheel, a propulsion unit by which the transfer is effected, and means to effect triaxial stabilisation of the satellite when in the final orbit.

To provide for a maximum payload, earth-orbiting satellites are first placed in a highly elliptical initial orbit with an apogee approximately equal in height to the final orbit and with a low perigee of about 100 km. After any number of orbits in this initial orbit the satellite is placed, when at the apogee of the parking orbit, by a propulsion unit known as an apogee motor, into the final synchronous orbit. As well as the apogee motor, use is made of an orbit correction system in which, with an accuracy of some cm/sec, the orbiting velocity is set to that necessary for synchronization. The propulsion unit guides the satellite into the desired position and ensures that it is maintained there throughout the useful life of the satellite, despite the influence of solar and lunar gravity and solar radiation effects.

Such a system can also be used to guide satellites into extraterrestial flight.

Different propulsion and attitude control systems have in the past been used for the two fundamentally different orbits, that is one for the initial orbit and one for the final orbit.

The reason for this is that a solid-fuel propulsion unit is generally used as the apogee motor, the thrust of which is large, and thus during the initial orbit and any orbital correcting manoeuvres subsequently necessary, passive gyro stabilization by means of a reaction wheel alone is not sufficient to absorb the high torques occurring during operation of the propulsion unit. Thus, spin stabilization is employed in the initial orbit. If the satellite is elongate which is the most suitable design to be carried in the nose of a launch vehicle, the spin is usually effected about the axis of the smallest principal moment of inertia. Such rotation is unstable, however, so that nutations, which are unavoidable due to interference factors, have to be continuously counteracted by an active nutation damping system. Solid-fuel propulsion units are also used to reduce vibration and dynamic instability caused by liquid fuel tanks.

According to this invention there is provided a method of transferring a satellite from an initial orbit into a final synchronous orbit, the satellite having an attitude controlling system with a reaction wheel, a propulsion unit by which the transfer is effected, and means to effect triaxial stabilisation of the satellite when in the final orbit, in which method the reaction wheel is brought into operation prior to the transfer, and during the initial orbit while the reaction wheel is in operation the satellite is caused to rotate about an axis parallel to the spin axis of the reaction wheel and at a lower rotational speed than that of the wheel, the propulsion unit being liquid fueled and being operated to effect the transfer such that the orientation of the axis of the reaction wheel is maintained the same in both the initial and final orbits.

The method of the invention enables the damping properties of liquid fuels in tanks to be used in conjunction with the rotation of the reaction wheel, whereby the satellite remains in a stable state of motion, with the axis of the wheel adjusting itself to the direction of the rotational impulse vector of the satellite in space as long as the rotational speed of the wheel is greater than the rotational speed of the satellite. Nutations occurring tend to be automatically cancelled as a result of the damping effect of the liquid fuels. Active nutation damping is therefore not necessary. The method thus reduces the number of different manoeuvres necessary to effect transfer and simplifies the construction of the satellite with a reduction in component number and weight.

The invention will now be described by way of example with reference to the drawings, in which:-

Figure 1 shows the transfer of a satellite from an initial parking orbit into a final synchronous geostationary orbit by the method of the invention,

Figure 2 shows a satellite for use in the method of the invention, and

Figure 3 shows schematically an attitude regulating and orbit adjusting system for the satellite of Figure 2.

The method of the invention is used, as shown in Figure 1, for the transfer of a satellite 10 from an initial parking orbit 30 into a final synchronous geostationary orbit 31. At instant 1.0 prior to separation of the satellite from its launch vehicle the pitch axis of the satellite is aligned normal to the plane of the initial parking orbit. This operation is not shown. For this purpose use is made of an attitude regulating system in the launch vehicle. A reaction wheel 11, or two such wheels with one being a back-up, is run up to full speed (Figure 2). At the instant 1.1 the satellite, having been separated from the launch vehicle is rotated about the pitch axis, at a rate, for example, of one revolution per 20 minutes, which for simplicity is kept constant. This can be effected simply by setting the rotational velocity of the wheel with a velocity gyro as a sensor. By means of a suitable directional sensor 12, for example an infra-red sensor, the position of the satellite in relation to the earth may be determined at instant 1.2 and continuously at further instants. During this phase solar cell panels 13 are deployed at the instant 1.3. In addition any required corrections to the direction of the yaw axis are carried out at instant 1.4. In the case of an earth-orbiting satellite, due to power and accuracy requirements arising, the most suitable method for effecting stabilization is the triaxial method. Thus, a transition to triaxial attitude stabilisation takes place at the instant 1.5. The reference points used are the earth and the sun using an infra-red sensor 12 and a digital solar sensor (not shown). These sensors serve as directional sensors, while the triaxial stabilization is effected by actuating as appropriate the propulsion units of the driving system 15 shown in greater detail in Figure 2.

At the instant 1.6 the optimum roll position is selected by a ground command which cancels the inclination of the path hitherto followed. The rotation which the satellite is required to perform for this purpose is effected by simply displacing the reference point of the solar sensor. Displaceability will in any case be necessary in the subsequent path correcting operations owing to seasonal changes in the position of the sun.

The apogee adjustment, that is the desired alteration in the orbit, is carried out at the instant 1.7. For this purpose a liquid fueled propulsion unit 14 is fired by ground command. At the instant 2.1, that is when the satellite is approximately in the required final orbit, the spin is removed from the reaction wheel, by ground command. At the instant 2.2 the pitch axis is aligned normal to the plane of the new final orbit. This is followed by orbit correcting operations, initially for positioning purposes and eventually for the maintenance of the position.

As may be seen from Figure 2 the propulsion unit 14 is positioned on the roll axis. The reaction wheel 11 is positioned with its axis parallel to or actually along the pitch axis. As previously mentioned, two wheels are preferably provided. The wheels may be run up to full speed before the launch vehicle is launched, so that energy balance between the vehicle and the satellite will not be affected from running-up the wheels. The infra-red sensor 12 is provided along the yaw axis. As described, the purpose of this sensor is to measure the pitch axis during the initial orbit of the satellite, data regarding alignment with respect to Earth. Miniature propulsion units 15 constitute a correction system and are duplicated for all attitude correcting operations and also for orbital correction operations. The nozzles of the propulsion units are offset in respect of one another by an angle α of about 10° for the roll and pitch axes.

Figure 3 shows a schematic diagram of the attitude regulating and orbit adjustment system. Through a telemetry and telecommand system 16 on the satellite, the different ways of operating the electronic position regulating system 21 can be selected, and the output data of the sensors 17 to 19 and also other measuring data can be transmitted to the ground station. The gyro stacks 1 and 2 each have two rate gyros serving to determine the angular pitch rate. The sensors 18 and 19 serve for solar and terrestrial data acquisition. The data obtained in these components is conveyed to the attitude regulating system 21. By the system 21 pitch, yaw and roll are regulated in the final orbit, in triaxially stabilized manner. In the initial orbit the rotation speed of the wheel is controlled by the rate gyro.

Altogether, four small propulsion units 15 are used for each operation of pitch, yaw and roll correction, the pitch units at the same time serving for East regulation, and the roll units for the reduction of the inclination. The two West units and also the orbit adjustment propulsion unit 14 are connected to a common drive system 25. The pitch units are positioned in the direction of the apogee propulsion unit, both in order to be able to perform the East regulation and also in order to take over the function of the apogee propulsion unit in the event of failure of the latter. All the propulsion units are fed from common tanks 22 to 24. Examples of the propellants which may be used are nitrogen tetroxide, (N_2O_4) for tank 22, and monomethyl hydrazine (MMH) for tank 23, in addition to which a helium tank 24 is provided, which can maintain a certain controlled pressure, for example during the apogee adjustment or any further desired manoeuvres.

WHAT WE CLAIM IS:-

1. A method of transferring a satellite from an initial orbit into a final synchronous orbit, the satellite having an attitude controlling system with a reaction wheel, a propulsion unit by which the transfer is effected, and means to effect triaxial stabilization of the satellite when in the final orbit, in which method the reaction wheel is brought into operation prior to the transfer, and during the initial orbit while the reaction wheel is in operation the satellite is caused to rotate about an axis parallel to the spin axis of the reaction wheel and at a lower rotational speed than that of the wheel, the propulsion unit being liquid fueled and being operated to effect the transfer such that the orientation of the axis of the reaction wheel is maintained the same in both the initial and final orbits.

2. A method as claimed in Claim 1, in which the reaction wheel is brought into operation prior to separation of the satellite from a launch vehicle therefor, the launch vehicle and satellite being orientated at the moment of separation such that the axis about which the satellite is to rotate is normal to the plane of the initial orbit.

3. A method as claimed in Claim 1 or Claim 2, in which rotation of the reaction wheel is stopped when the satellite is in the final orbit, triaxial stabilisation of the satellite then beginning.

4. A satellite constructed and arranged to function according to the method of any preceding claim, and in which the propulsion unit is liquid fueled.

5. A satellite as claimed in Claim 4, in which the means to effect triaxial stabilisation comprises further propulsion units having the same fuel tanks and supply system as the transfer propulsion unit.

6. A method of transferring a satellite from an initial orbit into a final synchronous orbit, substantially as hereinbefore described with reference to the drawings.

7. A satellite substantially as hereinbefore described with reference to the drawings.

KINGS PATENT AGENCY LIMITED,
by J.B. KING
Director
Registered Patent Agent.
146a Queen Victoria Street,
London EC4V 5AT.
Agents for the Applicants.

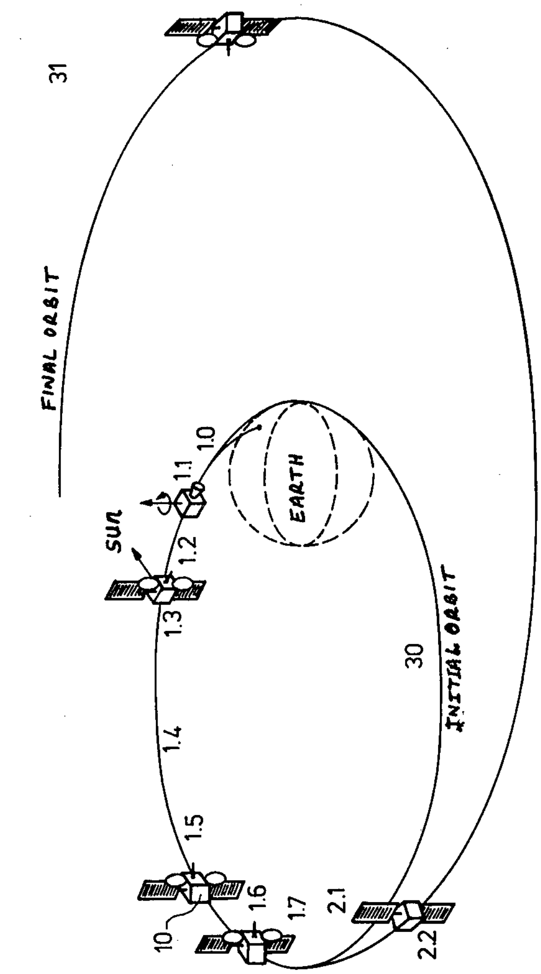
Printed for Her Majesty's Stationery Office,
by Croydon Printing Company Limited. Croydon, Surrey. 1981.
Published by The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.

1591902 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

Fig.1



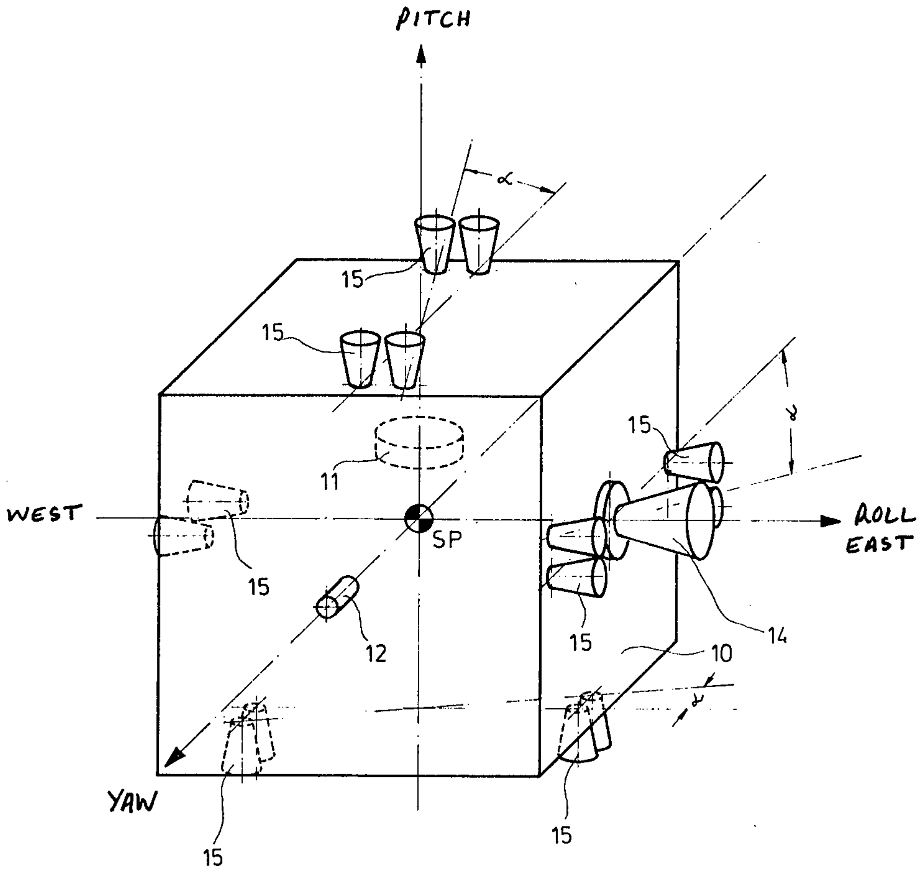


Fig. 2

1591902 COMPLETE SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

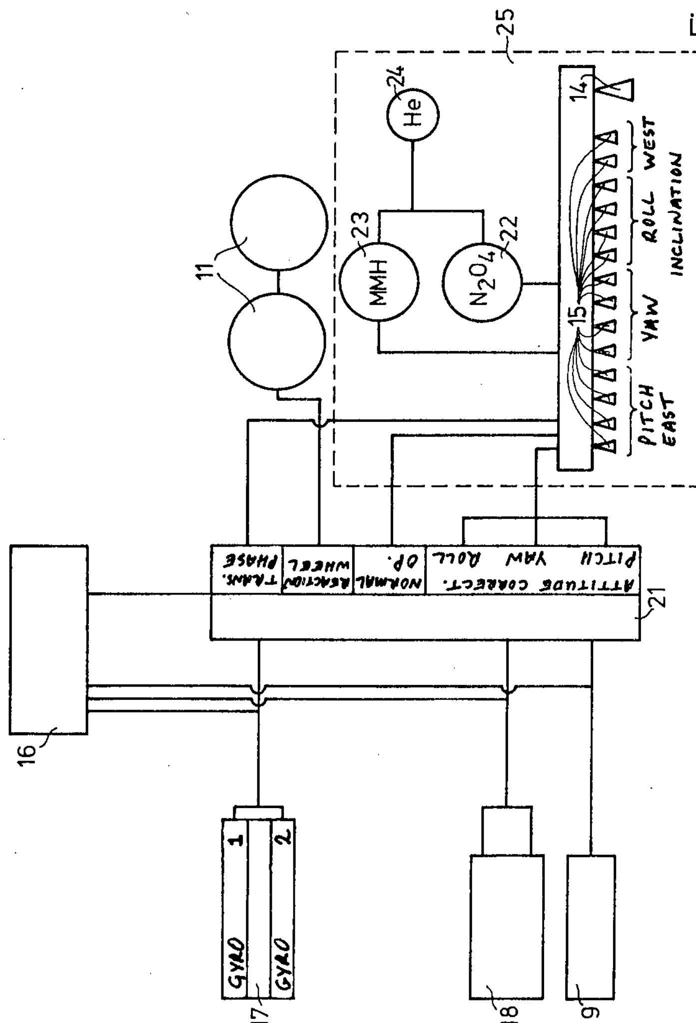


Fig. 3