TO: USI/Scientific & Technical Information Division  
Attention: Miss Winnie M. Morgan  

FROM: GP/Office of Assistant General Counsel for Patent Matters  

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures contained in the Code GP to Code USI memorandum on this subject, dated June 8, 1970, the attached NASA-owned U.S. patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.: 3,282,541

Corporate Source: Aerojet General Corporation

Supplementary Corporate Source: XGS-01654

Please note that this patent covers an invention made by an employee of a NASA contractor. Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words "...with respect to an invention of..."
Nov. 1, 1966

JAMES E. WEBB
ADMINISTRATOR OF THE NATIONAL AERONAUTICS
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ATTITUDE CONTROL SYSTEM FOR SOUNDER ROCKETS

Filed Feb. 10, 1965

3 Sheets-Sheet 1
One feature of this invention resides in the combination of a spin and/or aerodynamically stabilized ballistic vehicle and a gyroscope controlled attitude control system activated upon burnout of the vehicle propulsion system and operative to sequentially orient the vehicle to a number of predetermined positions.

Still another feature of this invention relates to the combination of a timer-controlled programmer plus position and rate gyroscopes to apply corrective signals from the position gyroscopes to the reaction jet nozzles and thereby effect vehicle attitude corrections.

One other feature of this invention resides in the combination of solenoid-controlled valves with the vehicle propellant pressurization gas source for providing attitude control moments for the vehicle.

These and other features of this invention may be more clearly understood from the following detailed description and by reference to the drawing in which:

FIG. 1 is a perspective view of a sounding rocket after launch and booster burnout and entering the coasting phase of a flight;

FIG. 2 is a perspective view, partially broken away, of the attitude control package of the vehicle of FIG. 1;

FIG. 3 is a perspective view of a sounding rocket after the second stage of a two-stage sounding rocket is shown therein, after launch, separation from the first stage, and burnout of the second stage, in the ballistic portion of the flight at approximately 150,000 feet above the earth.

The sounding rocket or vehicle generally designated 10 comprises a body portion 11 containing propellant storage tanks, an after-end 15 and a nose cone 12. The remainder of the attitude control package of the vehicle of FIG. 1 with portions broken away to show the pitch and yaw jet nozzle assembly; and FIGURES 4 and FIGURE 4a is a simplified block diagram of the system of FIGS. 1-3.

Now, referring to FIG. 1 in conjunction with FIGS. 2 and 3, the second stage of a two-stage sounding rocket is shown therein, after launch, separation from the first stage, and burnout of the second stage, in the ballistic portion of the flight at approximately 150,000 feet above the earth. The sounding rocket or vehicle generally designated 10 comprises a body portion 11 containing propellant storage tanks, an after-end 15 and a nose cone 12. The remainder of the attitude control package of the vehicle of FIG. 1 with portions broken away to show the pitch and yaw jet nozzle assembly; and FIGURES 4 and FIGURE 4a is a simplified block diagram of the system of FIGS. 1-3.

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are oppositely disposed in the after-end and directed to eject gas in opposite directions orthogonal to the yaw axis of the vehicle. The two sections of the attitude control system, although separated physically by the intermediate body portion 11, are interconnected electrically via cable 37 passing through body duct 32, and, the pitch, yaw and roll nozzles are all connected via appropriate tubing 33 to a gas supply 36. These pressure tanks 34 are contained within the body portion 11 and shown in part in FIG. 3.

The reference and electrical control elements of the system are shown in their relative positions within the section 30 in FIG. 5. These include two free gyroscopes 35 and 36 secured to a bulkhead unshown in the drawing but extending perpendicular to the longitudinal or roll axis of the vehicle. The gyroscopes 35 and 36 are thereby mounted, but internally freely gimbaled (during flight) as is more fully explained in connection with FIG. 4. Associated with the free gyroscopes 35 and 36 in the section 30 are a programmer 40 for sequentially applying torquing signals to the gyroscopes 35 and 36, a control box 41, rate gyroscopes, a power supply and other electrical components of the system.

The details of the system and interrelationship of its component parts are best explained by reference to FIG. 4 in connection with description of the typical operational flight of a sounding rocket incorporating this invention. A sounding rocket is erected in a tower for launching after installation of the payload in the nosecone. The attitude control system section 20 is preprogrammed for the particular experiments to be performed.

One type of targeting, the scanning mode, is achieved where the attitude control system produces a controlled coning of the entire vehicle about the longitudinal axis. The scanning mode is determined by commands from the programmer 40 to the attitude control system moving the vehicle to the desired cone axis, similar to the vehicle erection process hereinafter described. Questioning the vehicle to one-half of the desired cone angle, and the motor 51 is stopped. The spin rate is sensed by a roll rate gyroscope 50 and the output signal thereof is conducted via an electrical lead 52, amplifier 53, and demodulator 54 to operate a clockwise relay 55 which, in turn, through lead 56, operates the solenoid valve 57 and the clockwise solenoid valve 57. Switch 49, in the position gyroscope 35 output and under the control of the programmer 40 to positions (7) and (8) by the vertical solenoid valve 60 and the clockwise solenoid valve 57. Switch 49, in the position gyroscope 35 output and under the control of the programmer 40 to positions (7) and (8) by the vertical solenoid valve 60 and the clockwise solenoid valve 57.

The de-spinning of the vehicle, is connected to the gas supply in tank 34, shown in FIG. 3. The despinning of the vehicle to approximately 1200 feet per second and by the falling of all position gyroscope correction signals, the desired cone angle is achieved. The despinning operation is accomplished by feedback from level detection circuits in the demodulators 54, 74 and 84 through an AND gate 59 lead 69 to the programmer 40. The presence of a signal on lead 69, indicating that all demodulator signals have fallen below a preselected minimum value, results in the advance to position (5) of the stepping motor 51 and restoring of the timer motor 50. Further advance of the stepping motor 51 to positions (6), (7) and (8) by the
timmer motor 59 allows the programmer 49 to torque the gyroscopes 35 and 36 to slightly modified positions compensating for tower tilt, earth rotation, and gyroscopes 35 and 36 to the new positions with the least remote control adjustments made prior to launch.

Considering these corrections in more detail, upon the advance of motor 51 to a robotic position (46), a roll correction voltage is applied via the roll program lead 46 to the torquer 36 to produce a torque of predetermined duration and magnitude to make the roll correction to the gyroscopic reference axis. Depending on the direction of precession of the outer gimbal 35, resulting from the application of roll torque and resultant polarity of the demodulated signal at demodulator 54, either the clockwise relay 85 or the counter-clockwise relay 65 is operated. These are connected to operate a respective clockwise solenoid valve 57 or a counter-clockwise solenoid valve 67. Both the valves 57 and 67 are connected to the gas supply 24 and through feed tubing 58 and 68, respectively, to nozzle 59 and nozzle 69, supplying the clockwise nozzle 59 and counterclockwise nozzle 69, respectively. When the roll error signal, comprised of the sum of the output signals from synchro 35 and the roll rate gyro, falls to zero the operated solenoid valve is shut off while the remaining valve is in the open position. A complete sequence of the observation phase of a flight and the condition and effect of the attitude control system is shown below, in tabular form, to facilitate the understanding of the system operation:

<table>
<thead>
<tr>
<th>Programmer Switch Position</th>
<th>Attitude Control System Condition</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>04</td>
<td>Powered flight, gyroscopes rotating, reaction nozzles on (on when on)</td>
<td>Inertial</td>
</tr>
<tr>
<td>05</td>
<td>Timer motor started</td>
<td></td>
</tr>
<tr>
<td>06</td>
<td>Despin vehicle, Timer motor 50 stopped</td>
<td></td>
</tr>
<tr>
<td>07</td>
<td>Timer controlled advance</td>
<td></td>
</tr>
<tr>
<td>08</td>
<td>Yaw remote adjust</td>
<td></td>
</tr>
<tr>
<td>09</td>
<td>Pitch remote adjust</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Body torque adjust</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Timer motor 50 restarted</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Hold (first observation)</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Hold (second observation)</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Field of view maneuver</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Field of view maneuver</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Field of view maneuver</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Field of view maneuver</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Field of view maneuver</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Hold until intersatellite pass</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Hold until intersatellite pass</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Hold until intersatellite pass</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Hold until intersatellite pass</td>
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<td>23</td>
<td>Hold until intersatellite pass</td>
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</tr>
<tr>
<td>24</td>
<td>Hold until intersatellite pass</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Hold until intersatellite pass</td>
<td></td>
</tr>
</tbody>
</table>

These functions are all accomplished with basically a deceleration responsive switch, a timer, a programmer switch assembly, a pair of body mounted free gyroscopes, rate gyroscopes, gyroscopic signal processing circuitry, reaction nozzles and associated solenoid valves. These components cooperate to provide a relatively simple effective system integrated into the vehicle without disturbing the aerodynamic design and capable of providing a high degree of pointing accuracy for the vehicle.

In the description of the system the programmer 40 is shown only in simplified form with only the necessary input and output connections shown in order to more clearly illustrate its function. In actuality it contains, in a typical installation, an eleven-wafer switch 40a, and at least 15 precision resistors, illustrated in the drawing as variable resistance elements 40b, to control the amplitude of program voltages applied to the leads 44, 45 and 46. Each of the internal connections from the power supply through the wafer switches 40a is replicated such that a full showing of the connections thereof would obscure an understanding of the operation of the system.
From the foregoing description the relative simplicity of the system of this invention can be recognized. The vehicle is spin stabilized during powered flight. At the end of powered flight the attitude control system is activated and using residual pressurization gas in the propellant system is capable of despinning the vehicle, erecting it to a reference attitude and sequentially, under the control of a timer, making roll, pitch and yaw corrections for each of a number of different attitudes.

It is to be understood that the above described embodiments are merely illustrative of the application of the principles of my invention. Numerous other embodiments may be devised by one skilled in the art without departing from the spirit of this invention. The patent grant hereunder shall not be limited to the embodiments shown but rather by the scope of the following claims.

What is claimed is:

1. In combination with a ballistic vehicle having a propellant system, an attitude control system comprising:
   a pair of gyroscopes mounted in said vehicle each having an axis fixed parallel to the roll axis of the vehicle and each having a second axis normally mutually orthogonal to each other, and one of said gyroscopes having an axis parallel to the pitch axis and one of said gyroscopes having an axis parallel to the yaw axis of the vehicle;
   roll nozzle means positioned to expel gas from the vehicle tangentially to produce correction roll torque upon the vehicle;
   pitch nozzle means positioned to expel gas from the vehicle normal to the pitch axis of the vehicle;
   yaw nozzle means positioned to expel gas from the vehicle normal to the yaw axis of the vehicle;
   means for sequentially applying torque signals to said gyroscopes to introduce roll, pitch and yaw corrections into the vehicle orientation; and
   means responsive to the termination of powered flight of the vehicle for commencing operation of said last means.

2. The combination in accordance with claim 1 wherein said torque applying means includes a timer and switching means controlled by said timer for applying predetermined torque signals to said gyroscopes in sequence to orient the vehicle.

3. The combination in accordance with claim 1 including valve means communicating from said gas supply to said nozzles, said valve means responsive to vehicle position deviation signals from said gyroscopes to control the emission of gas from said nozzle means.

4. The combination in accordance with claim 1 wherein said gas supply comprises the vehicle propellant system.

5. The combination in accordance with claim 1 wherein attitude control system includes a cylindrical housing member constituting an extension of the vehicle, said roll nozzle means being positioned at the periphery of said cylindrical housing and operative to produce reaction torque upon said housing member and the vehicle upon the emission of gas therefrom.

6. The combination in accordance with claim 5 wherein said roll nozzle means comprises two pair of roll nozzle means directed tangentially from the outer surface of the cylindrical housing, the nozzles of each pair positioned diametrically opposite and oppositely directed.

7. The combination in accordance with claim 7 wherein said pitch and yaw nozzle means are positioned orthogonally with respect to each other and to the roll axis of the vehicle at a position remote from the pitch and yaw axes of the vehicle.

8. The combination in accordance with claim 7 wherein said pitch and yaw nozzle means comprise two pair of radially directed oppositely positioned nozzles.

9. The combination in accordance with claim 8 wherein said vehicle has a fin assembly and said pitch and yaw nozzle pairs are positioned at the fin assembly of the vehicle.

References Cited by the Examiner

UNITED STATES PATENTS

2,949,785 8/1960 Singleton et al. .......... 74—5.34
2,977,605 4/1961 Lane ...................... 74—5.34
3,038,304 10/1962 Corbett ................. 60—35.55
3,095,346 6/1963 Fugest et al. .......... 244—77
3,164,249 1/1965 Slater et al. .......... 244—77

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