Peculiarities of spacecraft “Ocean-O” control in geomagnetic storms

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Summary

Russian-Ukraine spacecraft “Ocean-O” (S/C) was launched on July, 17, 1999. S/C is controlled from Mission Control Centre and Modeling (MCC-M), town Korolev, Moscow region.

Purpose of the S/C “Ocean-O” is operative reception of Earth and World ocean remote probe information.

After the launch the control group came across complexity of S/C attitude control. In condition of atmosphere density difference control system nominal work turned out to be impossible because of lack of flywheel uncharge by electromagnetic plant in tangage channel.

Russian-Ukraine commission suggested and the control group accomplished unique scheme of S/C attitude control. The main idea of this scheme is performing periodic correction of the solar array position during communication session by issuing discrete commands to make necessary aerodynamic and gravitational moments combination that compensates disturbing moment. To support energy balance limits on angle of solar array turning were taken into consideration.

Analytic dependences were come out by input a number of simplifications into general system f differential equations, that describe the change dynamics of kinetic moment of flywheel. This dependences help to determine solar array inclination angle to provide necessary aerodynamic and gravitational moments combination.

Using such scheme turned out to be effective in S/C control in geomagnetic storms (July, 15-16, 2000; March, 30-31, 2001; November, 24-25, 2001). It is worth to note that during the geomagnetic storm on July, 15-16, 2000 Japanese X-Ray Telescope, that had worked on orbit since 1993 and studied black holes and other distant astrophysical objects, spun out of control.

Key words:
Control, Spacecraft, Modeling, Geomagnetic storms, Aerodynamic moment, Solar Array.
1. Introduction

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2. Task

Research is based on using general differential equation, that describes the change dynamics of kinetic moment of flywheel H in tangege channel [1-3].

\[
\frac{dH}{dt} = M - \omega H \quad (1)
\]

Where M – summary external moment acting in tangege channel, \(\omega\) – rate of the S/C spinning in tangege channel.

Some simplifications that fit to nominal S/C work were made:

- rates of S/C in relation to its center of mass are near to zero;
- summary external moment M is considered to be constant at limited time periods and flight periods with constant position of solar array inclination angle;
- aerodynamic moment changes value abruptly during solar array turning.

Note, piece constancy of summary external moment helps to increase accuracy of calculations in condition of atmosphere density difference by phased recalculation of value M.

By differential equation (1) reform following analytic dependences were come out to determine solar array inclination angle to provide necessary aerodynamic and gravitational moments combination in tangege channel.

3. Algorithms of control

To get some necessary value of kinetic moment \(H(t) = H_2\) the angle \(\alpha\) determining solar array position, is calculated with the following formula (angle \(\alpha\) is zero if solar array is transversely to oncoming blast and increase during solar array turning anticlockwise):

\[
\alpha = \arccos\left[\frac{1}{M_{cb}} \left( \frac{H_2 - H_1}{t_2 - t_1} - M^* \right) \right]. \quad (2)
\]
If kinetic moment gradient aim to zero the formula for angle is:

\[
\alpha = \begin{cases} 
0 & \text{if } -\frac{M^*}{M_\text{CB}} > 1 \\
\arccos\left(-\frac{M^*}{M_\text{CB}}\right) & \text{if } 0 \leq -\frac{M^*}{M_\text{CB}} \leq 1 \\
\frac{\pi}{2} & \text{if } -\frac{M^*}{M_\text{CB}} < 0,
\end{cases}
\] (3)

Where \(M_\text{CB}\) – aerodynamic moment made by solar array if \(\alpha=0\); 
\(M^*\) - summary external moment in tangage channel mines aerodynamic moment made by solar array;  
t\(_1\) – moment of solar array turning;  
t\(_2\) – time at which value or gradient of kinetic moment change is forecast.

So calculated by formula (2), (3) solar array inclination angles value in relation to oncoming blast helps to provide necessary combinations of summary external moment parts, when turning speed of flywheel in tangage channel to not get it extreme value.

4. Conclusion

Using such scheme turned out to be effective in S/C control in geomagnetic storms (July, 15-16, 2000; March, 30-31, 2001; November, 24-25, 2001). It is worth to note that during the geomagnetic storm on July, 15-16, 2000 Japanese X-Ray Telescope, that had worked on orbit since 1993 and studied black holes and other distant astrophysical objects, spun out of control.

References: