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Múcio Roberto Dias
Diretor da ETE

AUTOR RESPONSAVEL / RESPONSIBLE AUTHOR
Luiz Danilo D.Ferreira

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ATTITUDE CONTROL SIMULATION OF THE DATA COLLECTING SATELLITE-SCD2

AUTORES/AUTHORSHIP
Luiz Danilo D. Ferreira
Valdemir Carrara

RESUMO-NOTAS/ABSTRACT-NOTES

This work presents the functions of the Attitude Control System (ACS) to be used in the Second Data Collecting Satellite (SCD2) as well as the spin axis reorientation and the spin rate control of the SCD2.

OBSERVAÇÕES/REMARKS

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ATTITUDE CONTROL SIMULATION OF THE DATA COLLECTING SATELLITE - SCD2

Luiz Danilo Damasceno Ferreira
Valdemir Carrara

INSTITUTO DE PESQUISAS ESPACIAIS - INPE/SECT
Av. dos Astronautas, 1758. CP-515
12201 - São José dos Campos, SP - BRAZIL

1 - INTRODUCTION

This work presents the functions of the Attitude Control System (ACS) to be used in the Second Data Collecting Satellite (SCD2).

The functions to be provide by the ACS are:

a) To provide sensors signals that allow determination of the satellite attitude by processing in the ground.

b) To damp the residual nutation of the spacecraft, by using a nutation damper.

c) To control the satellite spin rate, by means of magnetic torque coils.

d) To control the spin axis direction, using magnetic torque coils.

2 - SYSTEM DESCRIPTION

The SCD2 spacecraft shall be spin stabilized with nominal 10 rpm +/- 2 rpm and with the spin axis pointing to the ecliptic north pole. Within a cone of 10 degrees half angle this attitude will provide a high probability of mutual contact ground-station-satellite-plataforms (supposing Cuiabá as main station) as well as good provision of energy by the solar arrays. The thermal design is also simplified, as the spacecraft attitude relative to the sun remains appoximately fixed along the satellite useful life. Due to launch impositions and the orbit parameters the spacecraft shall be injected with a spin axis declination of 25 degrees. Also, for thermal and power purposes, the angle between the sun and the spin axis at injection shall be near 90 degrees (as the nominal attitude). Launch window will present, then, two windows: one to the left and one to the right position relative to the sun, or one near 6:00 and other near 18:00 local time.

After injection, an attitude acquisition maneuver shall be performed to align the spacecraft spin axis to the ecliptic pole (declination 66 degrees and right ascension 270 degrees)

Pertubation torques will precess slowly the sapcecraft spin axis, in such a way that after few days the alignment will be lost. The major torques are due to residual magnetic moment and eddy current. Aerodynamic and solar radiation torques are negligiable due to the spacecraft simetry. To minimize the disturbance torques, the maximum allowed residual magnetic moment of the spacecraft is +/- 0.1 Am2. Whenever the spin axis reaches the limiting cone, a maneuvers is performed, realigning the spin axis with the eclipitic pole.

Spin rate maneuvers shall be conducted to keep the spacecraft angular velocity between the imposed limits. A maneuver is initiated when the spin rate decreases to 8 rpm and is stoped at 12 rpm

The ACS comprises two sun sensors, a three axis fluxgate magnetometer, a nutation damper and four torque coils. The attitude stability is provided by spinning the spacecraft about its axis of maximum moment of inertia.

The sensor data will be transmitted to ground during the satellite enlace with the Ground Station. After being processed, the satellite attitude will be propagated so as to determine the time and duration of a maneuver, if necessary.

3 - ATTITUDE AND SPIN RATE CONTROL OF THE SCD2

The spacecraft attitude behavior was simulated in a digital computer, with the aim of verifying its compliance with the performance requirements. The maneuvers were implemented in the software as well as the attitude dynamic equations [1]. The orbit was analitically propagated, and a numerical integrator was used (7 order Runge Kuta). The orbital parameters are:

semimajor axis:	a	=	7129262.	m
eccentricity:	e	=	0.040861	
inclination:	i	=	23.65	degrees
ascending node:	Ω	=	259.93	degrees
perigee argument:	ω	=	280.63	degrees
mean anomaly:	M	=	87.75	degrees

date: January, 1st, 1989 - 13:17:17.000 (UT)

It was also used in the simulation the following values:

Spacecraft inertia about the spin axis	=	10	kg m2
Eddy current torque parameter (p)	=	1925.9	m4/Ohm
Spacecraft residual magnetic moment	=	-0.1	A m2
Spin axis coil magnetic moment	=	12.	A m2
Spin rate coil magnetic moment	=	4.	A m2
Spin rate coil threshold	=	60.	mG

The torques considered in the simulations were: eddy current torques and a magnetic torque due to a residual spacecraft magnetic moment [1]. Other torques like aerodynamic and solar radiation pressure were neglected due to their small influence on the satellite attitude.The simulated maneuvers were:

a) Attitude acquisition, using the spin axis coil.

b) Attitude maintenance, with the spin axis coil.

c) Spin rate control, using the spin rate coil.

3.1 - ATTITUDE ACQUISITION

In the attitude acquisition simulation, the spin axis direction is reoriented from its nominal position after orbit injection to the operational orientation, normal to the ecliptic plane. During the maneuver, the sun direction must be kept perpendicular to the spacecraft spin axis, due to thermal impositions. Launch window shall guarantee the correct attitude at injection. That imposition leads to an acquisition maneuver performed in steps, with the spin axis being reoriented to intermediate positions before it reaches the final orientation [2]. In the simulated example, the intermediated attitudes are shown in Table 3.1.

TABLE 3.1
INTERMEDIATE ATTITUDE ACQUISITION ANGLES

	Spin axis right ascension (deg)	Spin axis declina tion (degrees)
Initial	1.61	25.40
Intermediate	-3.29	34.04
	-9.71	42.47
	-17.03	50.50
	-27.77	57.83
	-43.33	63.84
	-65.16	67.45
Final	-90.00	66.50

Figure 3.1 shows the spin axis orientation in spherical coordinates during the acquisition maneuver. The total maneuver lasts approximately 1.3 days. The coil polarity is chosen at regular time interval (5 minutes) in such a way to decrease the angular error between the spin axis orientation and the final (or intermediate) attitude. The coil polarity is shown in Figure 3.2, for a few hours before the final attitude acquisition. It was used in simulations a second order magnetic field model based on the IGRF [4].

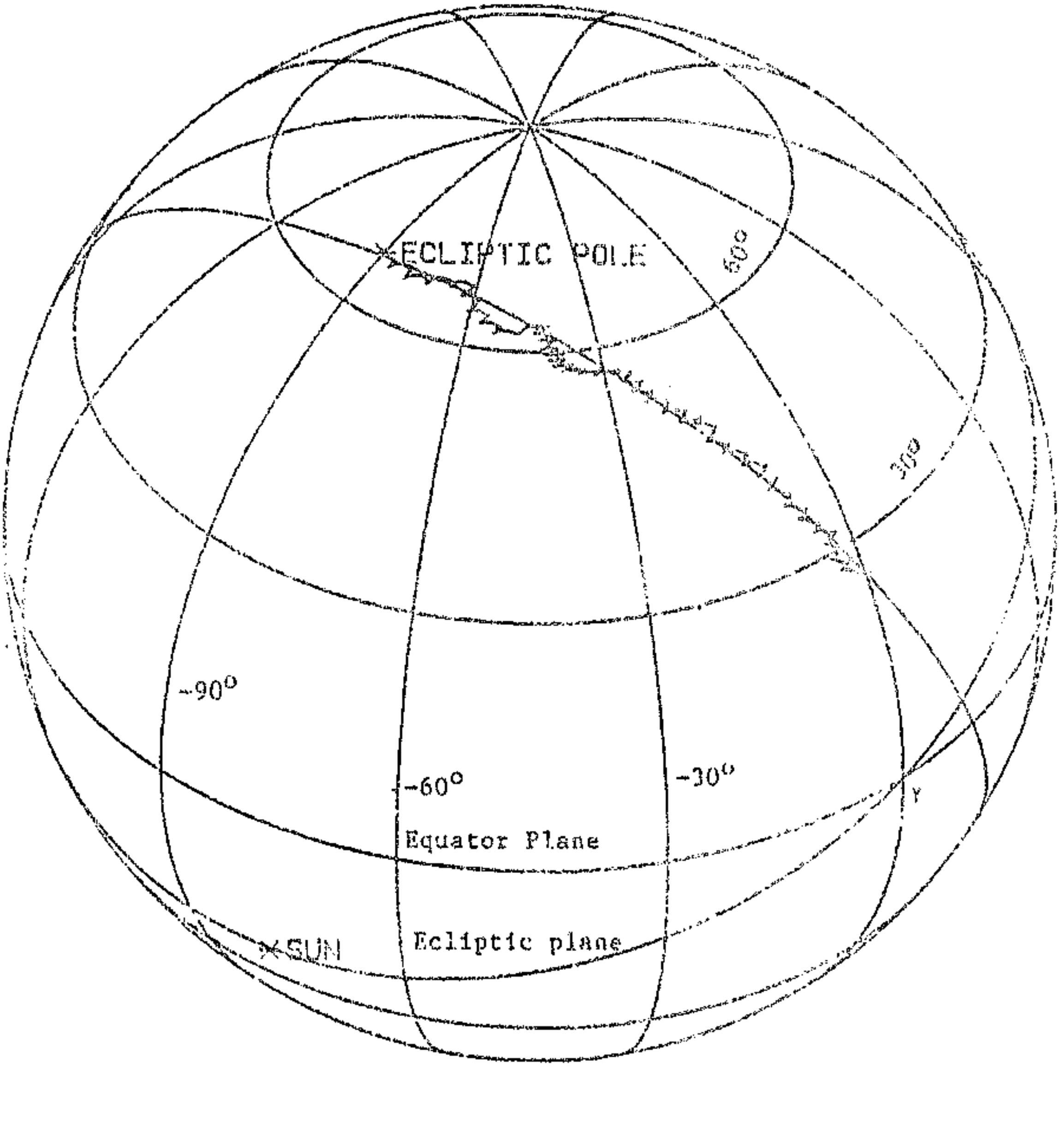

Fig. 3.1 - Spin axis orientation in the attitude acquisition simulation.

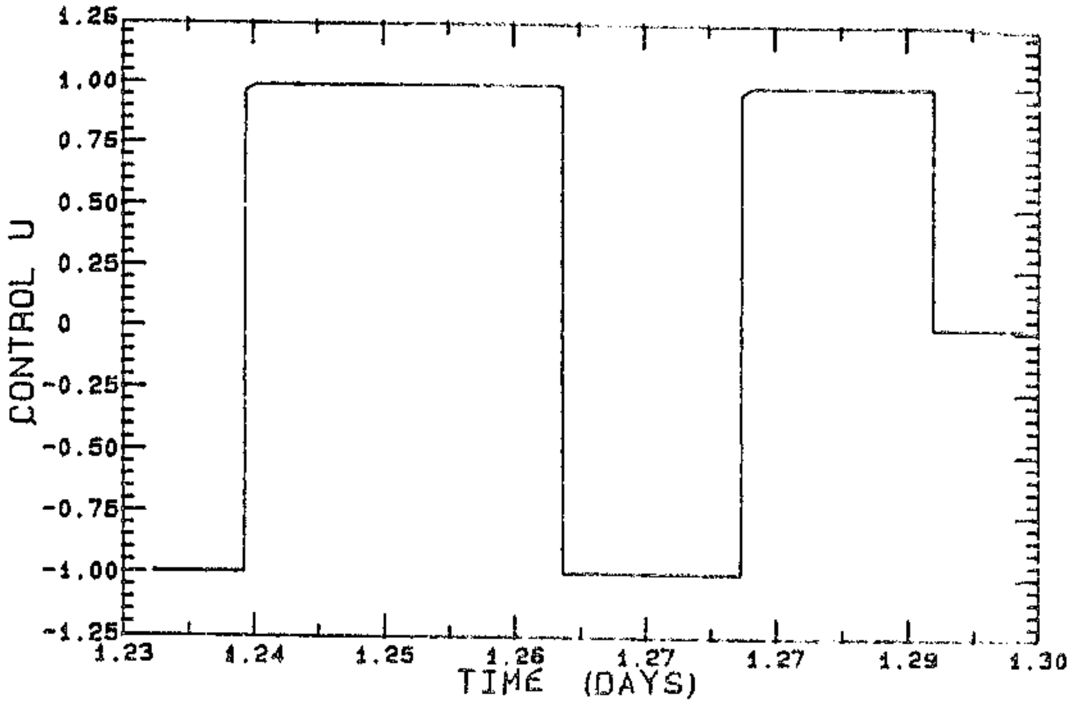

Fig. 3.2 - Spin axis coil polarity during the acquisition maneuver.

3.2 - ATTITUDE MAINTENANCE

As to keep the spacecraft spin axis in its nominal orientation, perpendicular to the ecliptic plane, it was considered the following strategy [3]:

i) The nominal spin axis orientation must be kept within two cones with angular apertures of 1 and 10 degrees, centered in the ecliptic normal.

ii) The maneuver is initiated whenever the spin axis exits the outer cone (except if a spin rate control maneuver is being performed).

iii) The maneuver is completed when the spin axis lies inside the small cone, making with the ecliptic normal an angle less than 1 degree.

It was considered in the simulations a spacecraft residual magnetic moment of -0.1 Am2.

The attitude maintenance maneuvers are shown in Figure 3.3, in spherical coordinates, as well as the attitude limits (cones). In that figure, point 1 is the initial spin axis position. At point 2 a maneuver is initiated, leading the spin axis inside the small region (point 3). At this point the coil is turned off and the residual magnetic moment changes the spacecraft attitude slowly until the point 4 in 12 days approximately. The procedure is then restarted, and a new attitude maneuver is initiated (between points 4 and 5 and also 8 and 9). Each maneuver lasts approximately 12 hours, and the mean time between two consecutive spin axis reorientations is 15 days.

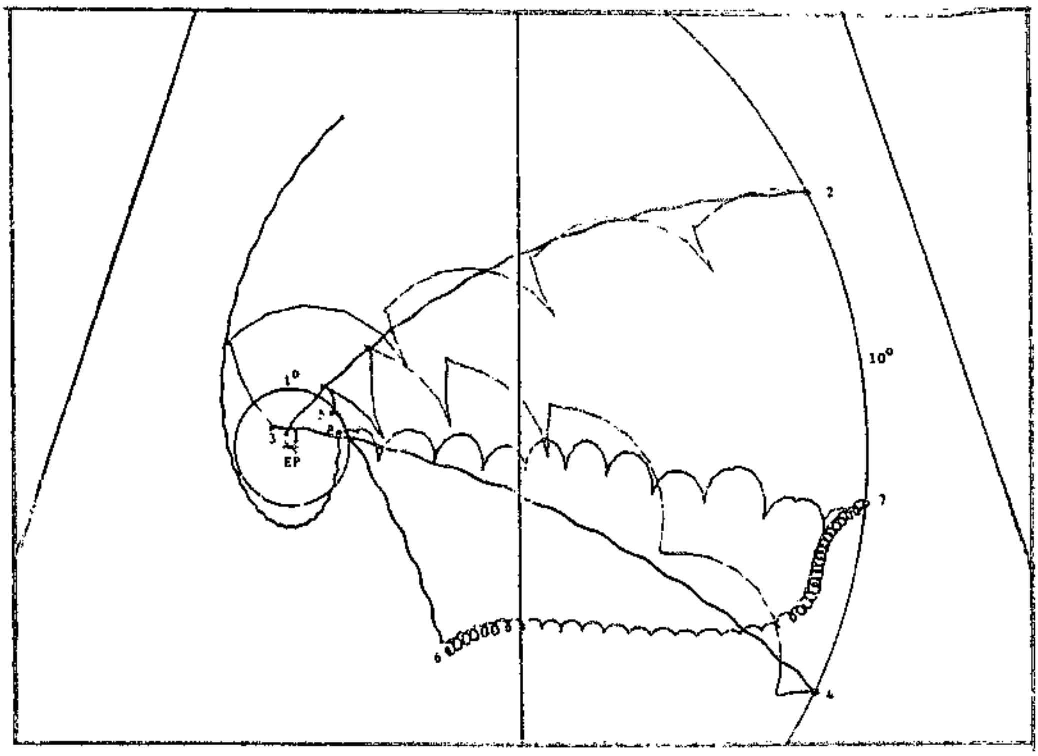

Fig. 3.3 - Spin axis orientation during the operational phase.

In the Figure 3.3 is also shown the behavior of the spin axis direction under the influence of an angular velocity maneuver, between the points 6 and 7. In this case, the maneuver doesn't lead the spin axis out of the outer cone, but it changes the spin axis direction strongly in a few hours. Figure 3.4 presents the error angle between the spin axis direction and the ecliptic normal. The control action, bringing the error near to 1 degree whenever the angle reaches 10 degrees can be seen clearly. Finally, the coil polarity for the first maneuver (at the 13th day) is shown in the Figure 3.5. The time spent on this maneuver was 3.2 hours.

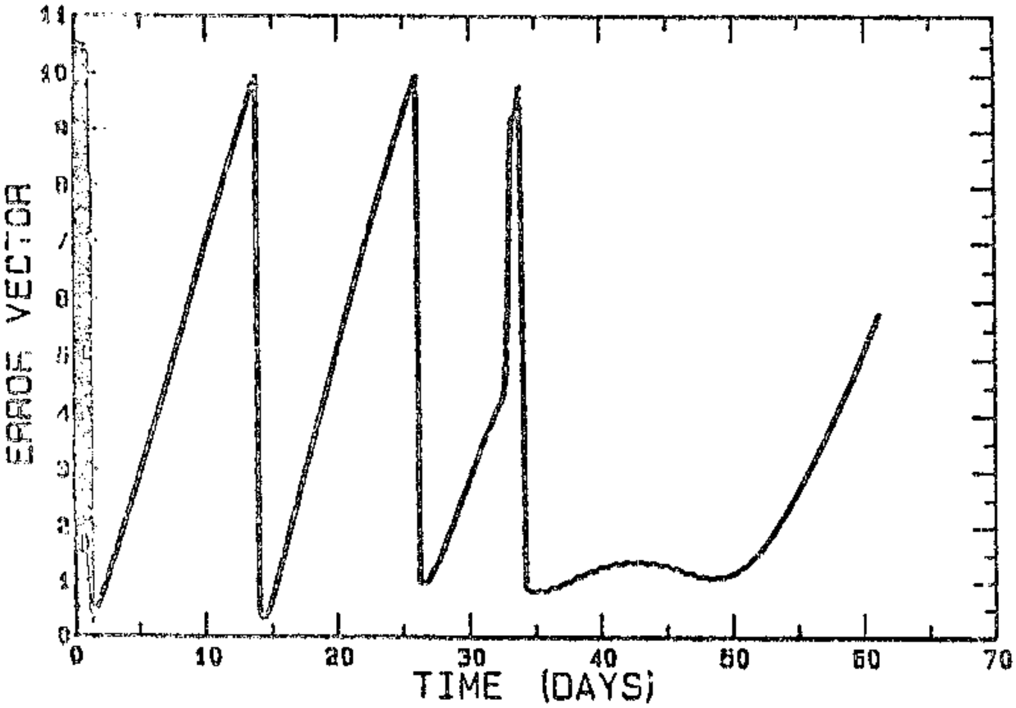

Fig. 3.4 - Error angle between the spin axis and the ecliptic normal.

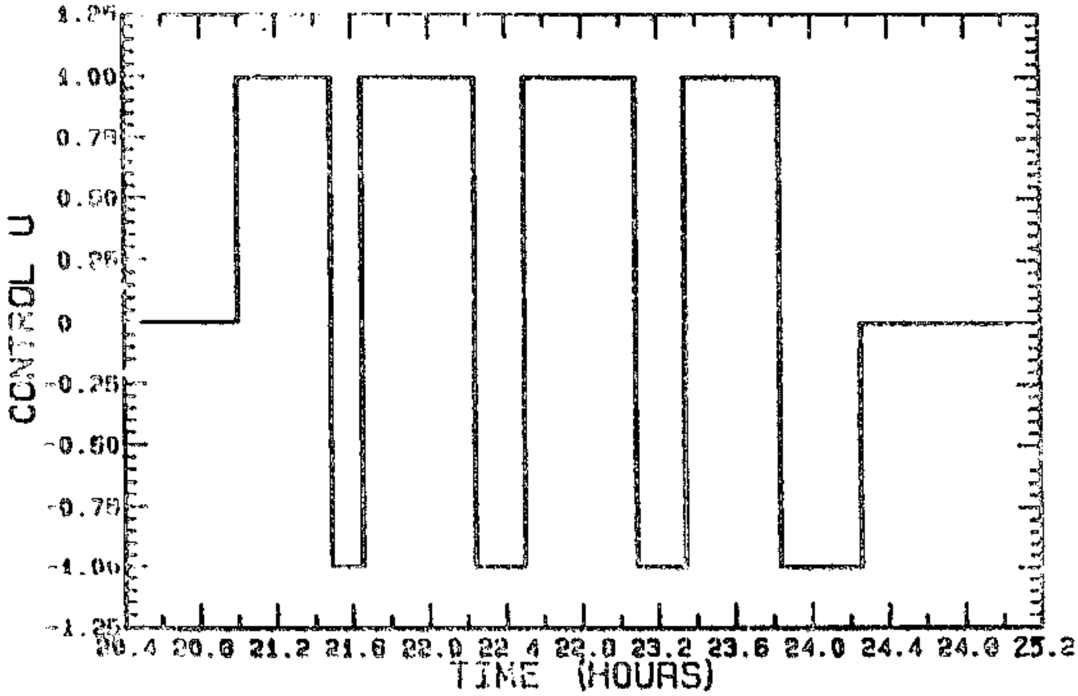

Fig. 3.5 - Coil polarity for a spin axis orientation maneuver.

3.3 - SPIN RATE CONTROL

The spin rate control uses the magnetometer signal to generate the coil polarity. For a coil with its axis in the spacecraft X axis direction, the polarity has the same signal of the magnetometer Y axis (the Z axis is the spin axis). A thereshold value of 60 mG around the null output of the magnetometer is considered to avoid magnetic interferences from the spacecraft equipments [3].

Maneuvers can be started both by the OBC (On Board Computer) or by ground telecommand whenever the spin reaches 8 rpm. The spin rate is measured directly through the Digital Sun Sensor.

The simulation of the spin control is shown in Figure 3.6. The eddy current torque decreases the spacecraft angular rate from 10 to 8 rpm in 33 days. The spin rate maneuver is then initiated, and lasts 1.3 days. The maneuvers are repeated each 68 days, approximately.

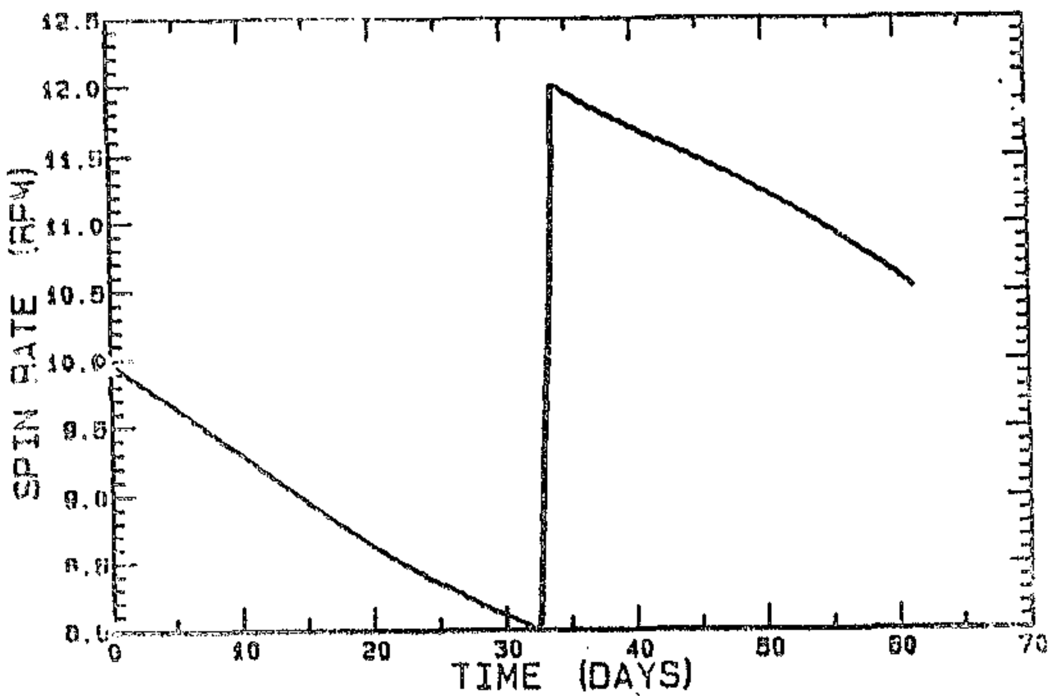

Fig. 3.6 - Spacecraft angular velocity before, during and after a spin rate maneuver.

4 - CONCLUSIONS

An example of practical application of the ideas contained in to the reorientation of the spin axis as well as the spin rate control of the SCD2 has been presented. The simulation results suggest the feasibiliby of performing the reorientation maneuvers by ground command; furthermore the spin rate control can be done by an on-board computer using magnetometer phase signals to properly switch the plane coil.

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Luiz Danilo D. Ferreira
Valdemir Carrara

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