POLITECNICO
MILANO 1863

Reverse Engineering of Juno Mission

Homework 4

Course of Space System Engineering & Operations
Academic Year 2023-2024

Group 5

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1 Introduction of AOCS

The Attitude and Orbital Control System of Juno comprehends various sensors and actuators that are vital to maintain the satellite in operability conditions and to execute all the basic tasks. In this chapter, the main modes of the satellite are deduced through the analysis of the mission already done in previous chapters. These modes will be then arranged on the timeline consequently. Based on the identified modes and pointing budget, the architecture of the actual system will be presented and then progressively analyzed, verifying the compliance with the previously found requirements. Finally, a reverse sizing of AOCS will be carried out.

2 Breakdown of Juno modes

Throughout the mission phases, Juno has to accomplish different tasks through various modes. The principal ones that have been identified are here described.

2.1 Sun Pointing Mode (SPM)

This mode aims at pointing the spin axis of S/C (+Z axis) to the Sun. This mode is used in order to:

- keep the solar panels pointed to the Sun to provide energy; this is even more crucial in the initial phases of the mission, when all the system checkouts have to be performed;
- thermally protect the satellite's vault using the HGA as a shield when the satellite is relatively close to the Sun.

This mode is applied mainly when the SPE angle is too large to ensure the communication through the HGA. This condition occurs during the first phases of the mission and nearby the EGA, when the satellite is in proximity of Earth and relatively close to the Sun. The LGAs are therefore used during this mode to communicate with ground.
The pointing requirement for this mode is not very strict since the solar panels are sized for much higher distances and can provide enough energy, the LGAs have a wide beamwidth to communicate with ground and the HGA is large enough to protect the vault. The spin rate of the satellite is set to 1 RPM for this interplanetary mode. This improves the passive stability of the pointing, reducing the burden on the active attitude control.

2.2 Earth Pointing Mode (EPM)

The EPM is a contiguous interplanetary mode to the SPM, the +Z axis of the S/C is pointed to Earth. It triggers when the distance from the Sun is high enough to ensure a safe thermal dissipation without the aid of the HGA (≈ 1.4 AU) **REFERENCE** . Moreover, the S/C will be far enough from Earth to ensure both HGA communications and the fulfillment of power requirements, hence the SPE is low.

2.3 GRAVity science Mode (GRAVM)

2.4 MicroWave Radiometer Mode (MWRM)

2.5 Turn-Burn-Turn Mode (TBTM)

2.6 VECtor Mode (VECM)

2.7 Spin Change Mode (SCM)

2.8 Safe Modes

3 Architecture and rationale of AOCS

3.1 Sensors

Juno's AOCS employs the following main attitude sensors:

- 2 **Stellar Reference Units (SRUs)** custom built by Selex Galileo (now Leonardo S.p.A.) mounted on the top deck of the spacecraft facing radially outwards. These units are based on the A-STR **REFERENCE** , modified with further radiation shielding to survive the harsh environment of Jupiter, bringing the total weight up to 7.8 kg. One of the most important characteristics of these sensors is the ability to operate in a Time Delay Integration (TDI) mode, which allows them to compensate for the spin of the spacecraft when capturing an image. Other specifications of the standard A-STR are reported in Table 1.

FOV [deg]	Update rate [Hz]	Bias Error [arcsec]	FOV error [arcsec]
16.4 × 16.4	4 or 10	8.25 (pitch/yaw) 11.1 (roll)	< 3.6 (pitch/yaw) < 21 (roll)

Size (L × W × H) [cm]	Mass [kg]	Power consumption [W]	Operational temperature [°C]
19.5 × 17.5 × 29.1	3.55	8.9 @ 20°C 13.5 @ 60°C	-30°C to +60°C

Table 1: A-STR specifications (ALEX METTI A POSTO)

- **2 Spinning Sun Sensors (SSSes)** by Adcole Maryland Aerospace, also positioned on the edge of top deck with a similar orientation as the SRUs. They are specialized for attitude determination on a spinning spacecraft and allow for a fail safe recovery. Sun sensors are required during ME burns, when SRUs might be pointing the Sun. Useful specifications are shown in Table 2.

FOV [deg]	Accuracy [°]	Size of sensor (L × W × H) [cm]	Size of electronics (L × W × H) [cm]
± 64°	± 0.1 at 0° ± 0.3 at 40° ± 0.6 at 64°	6.6 × 3.3 × 2.5	5.1 × 8.2 × 8.9

Mass of sensor [g]	Mass of electronics [g]	Power consumption [W]
109	475 to 725	0.4

Table 2: SSSes specifications (ALEX METTI A POSTO)

- **2 Inertial Measurement Units (IMUs)** by Northrop (Hypothesizing heritage from Cassini **REFERENCE**) inside Juno's main body.

All of this sensors are doubled to provide cold redundancy, meaning that only one unit is powered during nominal operations while the other one is switched off.
Additional sensors, Camera Head Units (CHUs), are present on Juno, to allow a precise attitude determination for magnetic sensors.

3.2 Actuators

4 Reverse sizing of AOCS

Bibliography

[1] Richard Grammier. *Overview of the Juno Mission to Jupiter*. Site: `https://www.jpl.nasa.gov/missions/juno`. 2006.