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Reverse Engineering of Juno Mission

Homework 5

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

Group 5

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Notation

TCS	Thermal Control System
SYM	to remove this cite[1]
TP	Thermal Phase
LEOP	Launch and Early Orbit Phase
IC	Inner Cruise
OC	Outer Cruise
S/C	SpaceCraft
SPM	Sun Pointing Mode
EPM	Earth Pointing Mode
HGA	High Gain Antenna
SOI	Sphere Of Influence
JOI	Jupiter Orbit Insertion
IR	InfraRed

1 Introduction of TCS

The Thermal Control System of Juno adopts various strategies in order to maintain the instrumentation within operative ranges of temperature. This is done through both active and passive systems, which will be analyzed in section 3. First thing first, an analysis of the mission will be conducted to enlighten the thermal conditions the satellite is exposed to, which range from really hot environment nearby the Sun to extremely cold environment nearby Jupiter. A selection of the two most extreme situations will be done through a preliminary evaluation of the heat fluxes in these phases. In the light of this, the architecture of the Juno's TCS will be studied and justified through a brief rationale analysis. Finally, a reverse sizing will be carried out imposing some simplifying assumptions in order to find the temperatures on Juno and to verify the compliance with its mission.

2 Analysis of thermal conditions along the mission

In this section, the mission will be analyzed and divided in perspective of thermal environment encountered. During this study, the internal heat flux won't enter the reasoning as its maximum value is small and does not affect the sectioning of the TPs and the selection of the hot case and the cold one. The architecture of the S/C won't affect the reasoning and only the heat fluxes from the external environment (Sun flux, planets' albedo and IR emission) will enter this preliminary analysis. A deeper study will be conducted during the reverse sizing in section 4.

2.1 Thermal phases analysis

Different thermal conditions have been encountered by Juno during its cruise. In previous chapters, the mission was divided into phases by different attitude and communication constraints. These phases will be now grouped by the means of thermal constraints to better analyze their evolution during the mission time.

- **TP-1**: in this first phase, which comprehends both LEOP and IC-1, the S/C is in SPM due to thermal and power requirements. In particular, since the trajectory is relatively close to the Sun, Juno has to protect the vault with the HGA (as already explained in the previous chapters). Even if TP-1 is considered a hot phase, it is not the most critical as other phases have more stringent requirements, facing longer periods closer to external heat sources (i.e. Sun and Earth).
- **TP-2**: this second phase corresponds to IC-2. Among the ICs it is the longest and the only one featuring EPM. It does not call for any particular thermal requirement, being Juno farther from both Sun and Earth. No specific attitude is required to thermally control the S/C during the different manoeuvres performed during IC-2. Neither hot nor cold phase is considered along TP-2.
- **TP-3**: the third thermal phase consists mainly of IC-3 till the EGA, performed in SPM to protect the electronics inside the vault as the S/C passes through the perihelion of its orbit at 0.88 AU. During TP-3, Juno was found to face the most relevant hot environment, occurring at the closest approach to the Sun.
- **TP-4**: the fourth phase analyzed consists only of the EGA, from the entrance till the exit of Juno from Earth's SOI. This phase contains both a possible hot case and cold case, the first due to the proximity to the planet, the latter due to the eclipse. It was found that neither of the two conditions are the most extreme in terms of heat flux. However, during TP-4 Juno faces the highest flux excursion of the entire mission.
- **TP-5**: this phase is the continuation of the TP-3, except that the S/C does not encounter such high flux environment as at perihelion. It goes from the end of EGA till the end of IC-3.
- **TP-6**: this phase only includes the OC up to JOI. The S/C encounters progressively colder environment as it is going away from the Sun. In particular, towards the end of TP-6, Juno experiences the lowest flux from the Sun and the radiation coming from Jupiter is still negligible. This condition was found to be the coldest case along the mission.
- **TP-7**: the last phase goes from the JOI till the end of the mission, including all the science orbits around Jupiter. During this period of time, the spacecraft is subject to the harsh environment of Jupiter, where it faces oscillating flux from the planet: higher nearby the perijoves and lower at apojoves. Overall, the environment stays cold during the whole phase but it is always higher with respect to the cold case found in TP-6.

2.2 External heat flux analysis

In order to find the hot and the cold cases, a simplified model of the main external heat fluxes has been carried out. To facilitate the computation, some assumptions have been adopted:

- as previously mentioned, only the external heat fluxes have been modeled, discarding the internal contribution which is better treated in section 4;
- the only contribution considered during the interplanetary phases is the Sun flux, while in proximity of the planets also albedo and IR emissions are added;

- for the hot case only TP-3 and TP-4 have been analyzed, since the other phases do not have critical condition in this sense;
- for the cold case TP-4 and TP-6 have been analyzed, which present the criticalities on the eclipse and on the farther position of the S/C with respect to the Sun;
- the analysis has been carried out from the ephemeris of the real mission instead of taking the nominal cruise;
- the $\cos\theta$ factor in the albedo calculation is assumed to be always at maximum value as a conservative simplification.

3 Architecture and rationale of TCS

4 Reverse sizing of TCS

Bibliography

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