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Reverse Engineering of Juno Mission

Homework 6

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Group 5

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Notation

EPS	Electric Power System
SYM	Remove this line[1]

1 Introduction of EPS

2 Analysis of power requirements along the mission

3 Architecture and rationale of EPS

3.1 Available alternatives

The endeavour that Juno faces to generate enough electricity to sustain science operations at 5.44 AU required particular attention in designing an efficient and reliable electric control system. Particularly, different options were present to generate the amount of power required, each of them with advantages and disadvantages:

- **RTG:** the choice of a radioisotope to generate electricity could be considered. In order to generate the amount of power required around Jupiter, during the planetary phase (**REFERENCE**), one RTG of the same size of the one present on board New Horizons spacecraft would have been sufficient (≈ 250 We of production at BOL)[2]. Electric power requirement would also be lower as some heat could have been routed to the propulsion section to heat up the tanks and fuel lines. This choice however had some problems, mainly with respect to the safety during Earth EGA, radiation contamination, heat dissipation at distances lower than 2 AU from the Sun and weight distribution. Particular problems could have rose as the said RTG generates around 4.4 kW of heat, requiring a very efficient dissipation system for the first years of the mission, oversizing it with respect to the nominal orbit around Jupiter. Availability of Plutonium-238 was also critical as suppliers could not guarantee the needed amount of fuel, given the stop in the production of the said isotope during the 80s. **REFERENCE**
- **Solar panels:** no spacecraft equipped with solar panels has ever been tested at 5.44 AU from the Sun. This choice would have required a very large surface area, and thus precautions had to be taken into account inside the fairing during launch operations, to provide enough power for safe operations at Jupiter. A complex management system is also required in order to not discharge too much current inside the electronics during the ICs and the OC as the amount of solar flux hitting the S/C during different parts of the mission dramatically reduces. More stringent pointing requirements are also present as not having a clear view of the Sun could have led to the need of bigger and heavier batteries.

Considering also the driving requirement of utilizing as much as possible off the shelf components, budget constraints, the limited supply of plutonium and the different possible configurations offered, solar panels were chosen. This choice led to a particular design of the satellite, where mass distribution was exploited to grant more stability throughout the different phases of the mission.

3.2 Components and distribution

The flown spacecraft is fitted with 3 solar arrays and 2 Li-On batteries.

- The arrays are mounted on the side of the main body, spaced 120° apart, and are composed by a different number of panels, as can be seen in Table 1: solar wing 1 presents only 3 panels while solar wing 2 and 3 present 4 panels each. Solar panels are linked one to the other and to the main body with electro-actuated hinges and the first panel of each array is supported by struts. All these elements are needed to both extend the panels soon after separation from the Centaur and to control the position of the arrays during all the operations. This is necessary to take into account the bending of the arrays during large manuevers and their thermal expansion. Moreover it is necessary to align the main inertia axis (Z-axis) with the spin axis as the three solar arrays do not feature an exactly symmetrical mass distribution due to the presence of the MAG boom. However, using different dimensions for each set of panels allowed to minimize the effect of the said asymmetry. From Table 1 the area of each panel can be observed: A2 and A3 feature identical panels distribution while A1 presents only 3 panels. Once the power requirement is fixed, each panel's area was defined to optimize the inertia matrix. As a result, A2P1, A2P2 and A2P3, and the same in A3, are slightly smaller than the A1 correspondents, because of the presence of a fourth panel, P4, on both A2 and A3's extremities.
  Each cell, produced by Spectrolab, is in an ultra triple junction (UTJ) configuration, to obtain optimum packing and high performances in LILT environments like the one around Jupiter. The three layers, Ge for the bottom cell, GaAs for the middle cell and $GaInP_2$ for the top cell, are placed on top of a Germanium Kapton substrate and connected with tunnel junctions. An anti-reflective Si coating protects the cell. Solar cells are connected into circuits and each panel is composed by strings of three possible lengths, defined to satisfy the instrumentation's needs during the whole mission. In fact the strings can be connected or disconnected, either in series or in parallel, according to the required voltage and power.

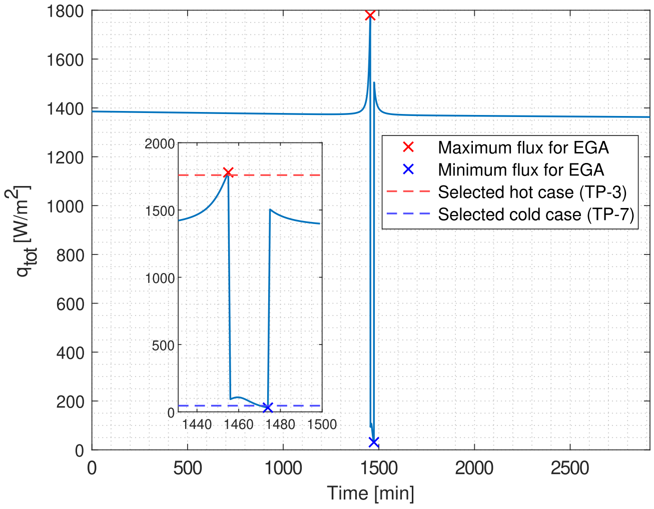

Figure 1: Juno's panel configuration

	P1	P2	P3	P4
A1	4.92	5.60	5.60	-
A2	4.81	5.46	5.46	6.29
A3	4.81	5.46	5.46	6.29

Table 1: Panels areas [m^2]

4 Reverse sizing of EPS

Bibliography

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

[2] Gary L. Bennett. "Space Nuclear Power: Opening the Final Frontier". In: (2006).