



# POLITECNICO

## MILANO 1863

### Reverse Engineering of Juno Mission

#### Homework 3

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#### Group 5

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Notation

<b>TMTC</b>	Telemetry and Telecommand	<b>TLGA</b>	Toroidal Low Gain Antenna
<b>HGA</b>	High Gain Antenna	<b>ALGA</b>	Aft Low Gain Antenna
<b>MGA</b>	Medium Gain Antenna	<b>FLGA</b>	Forward Low Gain Antenna
<b>LGA</b>	Low Gain Antenna	<b>SYM</b>	Symbol description <sup>[1]</sup>

## 1 TMTC architecture

## 2 Rationale of TMTC system

## 3 Reverse sizing of TMTC system

The reverse sizing of the TMTC system is based on the link budget equation that represents a power balance between the transmitted signal and the receiver noise. The same equation can be applied on both uplink and downlink. It is valid for all the architectures, both that transmit data or tones

$$\frac{P_{rx}}{N_0} = \frac{P_{tx} G_{tx} G_{rx} L_{tot}}{k T_{eq}} > \left( \frac{P_{rx}}{N_0} \right)_{min} \quad (1)$$

For antennas that broadcast data, an additional equation is used to constrain the sizing.

$$\frac{E_b}{N_0} = \frac{P_{tx} G_{tx} G_{rx} L_{tot}}{k T_{eq} R} > \left( \frac{E_b}{N_0} \right)_{min} \quad (2)$$

$L_{tot}$  considers the following losses:

$$L_{tot} = L_{cable} \cdot L_{space} \cdot L_{point,tx} \cdot L_{point,rx} \cdot L_{atm} \cdot L_{cover} \quad (3)$$

For each communication link, different minimum required ratios are defined. In particular,  $\frac{E_b}{N_0}$  must also satisfy the Shannon theorem by ensuring a value higher than  $-1.59$  dB.

### 3.1 HGA links sizing

The HGA as described in (sec) is used for the downlink of telemetry and scientific data during the science orbits around Jupiter. It has been sized in the following scenario:

- the maximum distance from Earth  $r_{JE} = 6.5$  AU;
- the minimum datarate  $R = 18$  kbps has to be ensured regarding the distance.

From the literature, some other parameters were recovered:

The link budget equation can be expressed in a dB form, each term is then calculated as follows:

$$\begin{aligned} G &= 10 \cdot \log_{10} \left( \frac{\pi d \mu}{\lambda} \right) & \theta_{bw} &= 65.3 \cdot \frac{\lambda}{d} \\ L_s &= 20 \cdot \log_{10} \left( \frac{\lambda}{4\pi d_{JE}} \right) & L_p &= -12 \cdot \left( \frac{\eta}{\theta_{bw}} \right) \\ EIRP_{dw} &= P_{tx} + G_J + L_{cb} + L_{cv} & EIRP_{up} &= P_{tx} + G_g \\ P_{rx,dw} &= EIRP_{dw} + G_g + L_s + L_a + L_p & P_{rx,up} &= EIRP_{up} + G_J + L_a + L_s + L_p + L_{cv} \\ \frac{P}{N_0} &= P_{rx} - N_0 & \frac{E_b}{N_0} &= \frac{P}{N_0} - 10 \log_{10} \end{aligned}$$

## Bibliography

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