Satellite conception

Aéro 5 ELS

Satellite preliminary design

A customer mandated your agency for the preliminary design of a 6-ton telecommunication satellite as maximum weight, after separation.

Propellant budget

Following an Hohmann transfer scheme, the satellite is first put on a circular orbit at 190 km altitude. The satellite uses its liquid bi-propellant periapsis engine (MON/MMH, with a specific impulse of 280 seconds to pass on GTO.

1°/ From LEO to GTO: what is the increment of velocity, and what mass M_1 of propellant is especially used ? Confirm with a GMAT simulation.

To circularize the orbit at GTO apoapsis, the satellite uses its liquid bi-propellant apoapsis engine (MON/MMH), with a specific impulse of 300 seconds.

2°/ From GTO to GEO: what is the increment of velocity, and what mass M_2 of propellant is especially used ? Confirm with a GMAT simulation.

During its 17-years life, the satellite maintains its orbit using one of the following two propulsion systems:

a) A bi-propellant MON/MMH engine with 290 seconds of specific impulse, 20 N of thrust, and an efficiency of 100%.
b) An electric propulsion at 1700 seconds of specific impulse, 90 mN of thrust, and an efficiency of 70%.

The increment of speed per year required to maintain this orbit is 50 m/s north/south and 5 m/s east/west. And at its end of life, the satellite is put into a parking orbit 300 km above the GEO, using a 6 m/s increment of speed.

3°/ Maintain on orbit:

- Using only the chemical thruster, what is the mass M_C of propellant necessary to maintain the satellite on orbit and for deorbiting ?
- Using only the electrical thruster, what is the mass M_E of propellant necessary to maintain the satellite on orbit and for deorbiting ?

4°/ Depending of the thruster used, what is the mass remaining for payload, platform and solar generator ?

5°/ Discuss the mass budget as you should do for the customer.

Electrical budget

Considering that the satellite has he following characteristics:

- Satellite power consumption in operational mode $P_{sl} = 2\ kW$
- Satellite power consumption in transition phases $P_{slt} = 1\ kW$
- Maximum duration of a transition phase $T_t = 24\ h$
- Power regulator efficiency $\eta_{reg} = 93\%$
- Battery efficiency $\eta_{bat} = 91\%$
- Typical eclipse duration is 5% of orbit

6°/ Determine the average P_{gs} power that the solar generator must provide during the day period of the orbit.

7°/ Determine the average P_{gsm} power that the solar generator must provide during the orbital period.

8°/ Determine the nominal P_{gsn} power that the solar generator must provide.

Considering the following battery characteristics:

- Maximum DOD during transition phases is $DOD1 = 80\%$
- Worst case of initial DOD before transition is $DOD_{init} = 30\%$
- Maximum DOD in operational phase is $DOD2 = 70\%$

9°/ Determine the battery energy W_{bat1} needed for transition phases.

10°/ Determine the battery energy W_{bat2} needed for eclipses in operational mode.

11°/ Determine the total energy W_{bat} that the battery should be able to deliver.

12°/ Give an estimation of the battery mass M_{bat}.

Solar generator budget

We use AsGa triple junction solar cells with efficiency $\eta_{cell} = 31\%$.
Relative illumination K_r and relative power K_m over the year are given in appendix.

13°/ Determine the Asg solar cell surface needed for worst case orbit.

14°/ Give an estimation of the solar generator mass M_{GS}.

15°/ What is the mass remaining for payload and platform without batteries and solar panels depending on the thruster used ?

Warming budget

We there assume that the solar panel surfaces are not taken into account for the external warming budget.

16°/ Considering that the average volumic mass of the satellite is about of 3000 kg/m^3, provide both an estimation of the satellite dimensions, and the diameter of the virtual sphere in which it could be contained.

The thermal fluxes received by the sphere are as follows:

- 1353 W/m^2 for the solar flux.
- Albedo flux is 0.35 times the solar flux.
- The terrestrial flux is equal to a quarter of the difference between the solar flux and the albedo flux.

17°/ Calculate the equilibrium total energy and temperature of 3 spheres defined above:

- a black with $\alpha_S = 0.95$ and $\epsilon_{IR} = 0.90$
- a white with $\alpha_S = 0.15$ and $\epsilon_{IR} = 0.85$
- a golden with $\alpha_S = 0.30$ and $\epsilon_{IR} = 0.03$

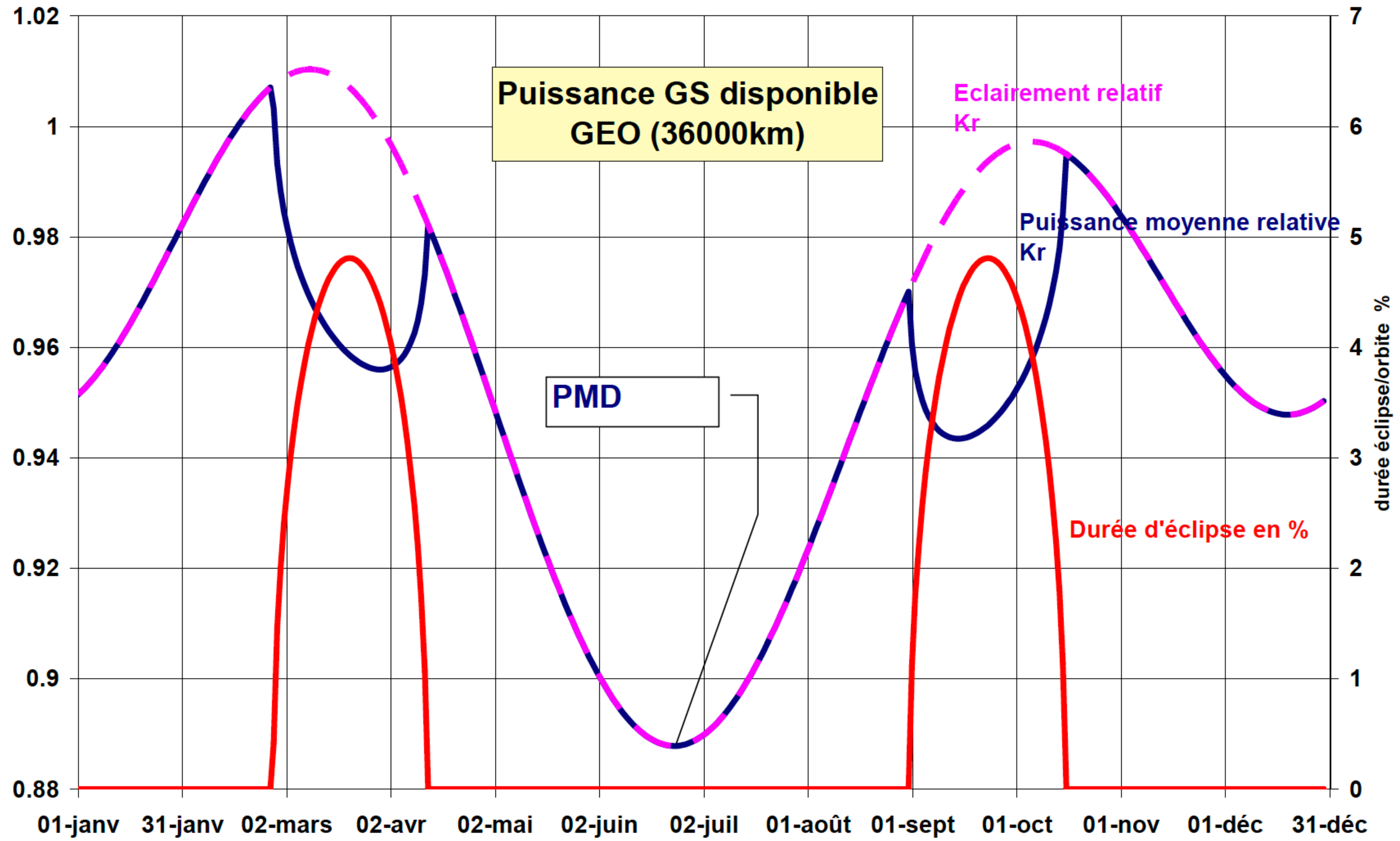
Cooling budget

Considering that the complete satellite has an external thermal insulation with efficiency $\eta_{ins} = 40\%$, we want to size the radiators to dissipate the total calorific energy received by the satellite and that of 700 W produced by all equipments and S/S, with a limit temperature of 40°C for each radiator. We assume that the radiators are on North and South faces, and that they dissipated half the total energy, respectively. As a first sizing, we will use the worst case of previous question for external flux.

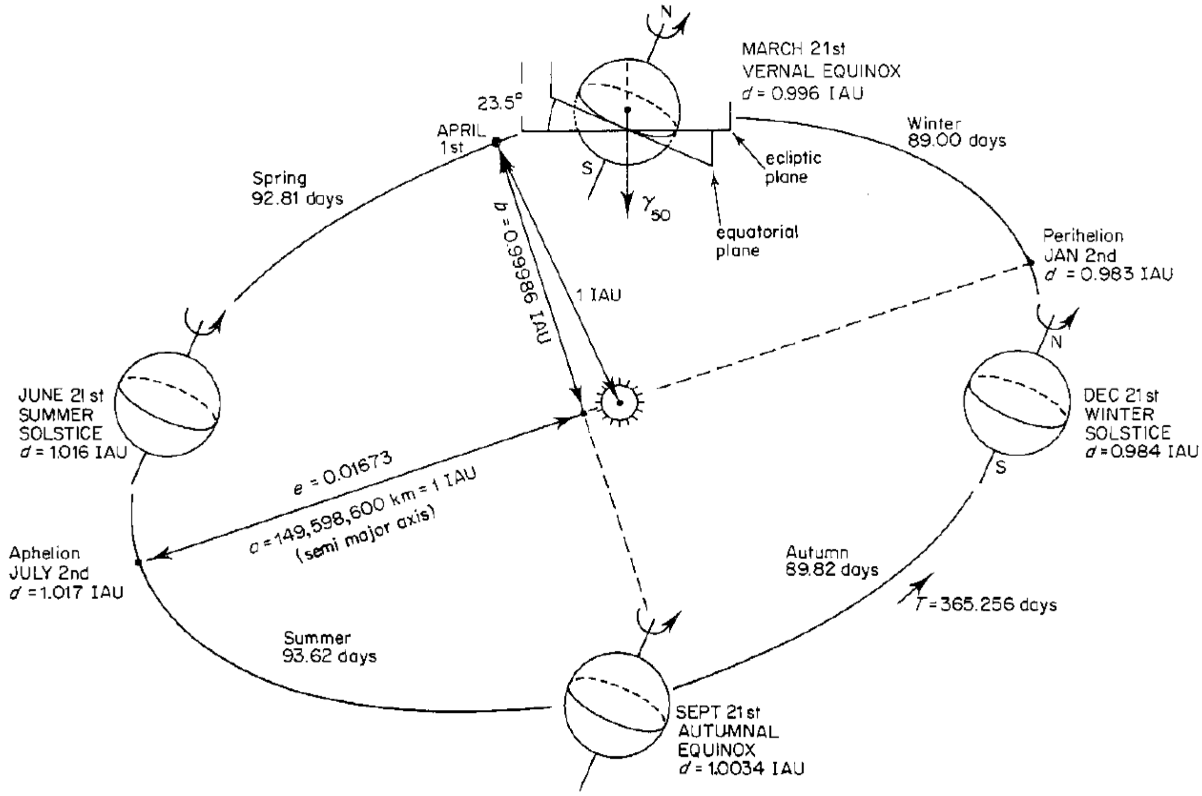
18°/ At equilibrium, what is the emitted power ?

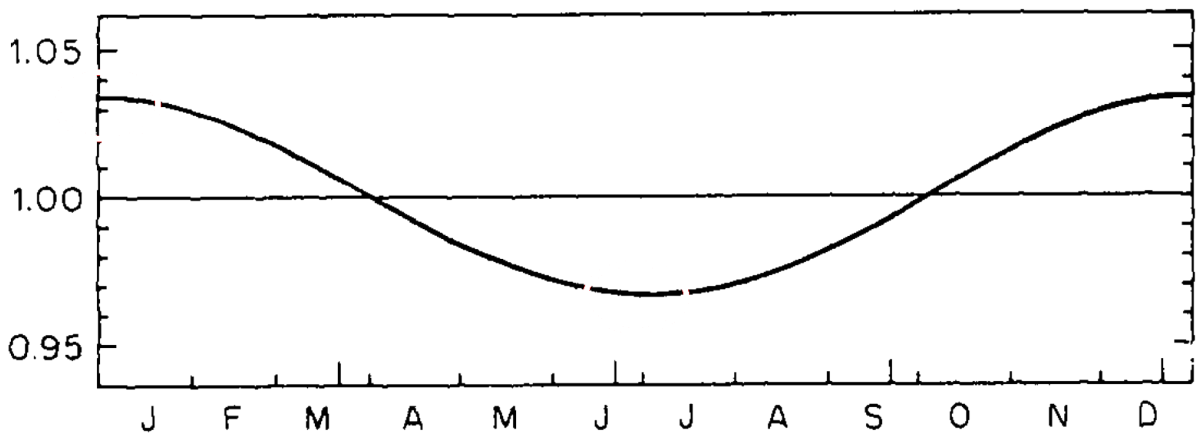
19°/ Determine the needed radiator surfaces.

20°/ Is it in accordance with the estimated size you determined in question 16 ? Why is it oversized and what should be the best estimation of the radiator surfaces if their thermo-optical parameters of the radiators were $\alpha_S = 0.15$ and $\epsilon_{IR} = 0.75$?



Puissance GS disponible
GEO (36000km)
Eclairement relatif
Kr
Puissance moyenne relative
Kr
PMD
Durée d'éclipse en %
durée éclipse/orbite %
1.02
1
0.98
0.96
0.94
0.92
0.9
0.88
7
6
5
4
3
2
1
0
01-janv
31-janv
02-mars
02-avr
02-mai
02-juin
02-juil
01-août
01-sept
01-oct
01-nov
01-déc
31-déc





Solar radiation flux relative variation due to variation of the distance from the sun only 1.00 = 1353 W/m^2