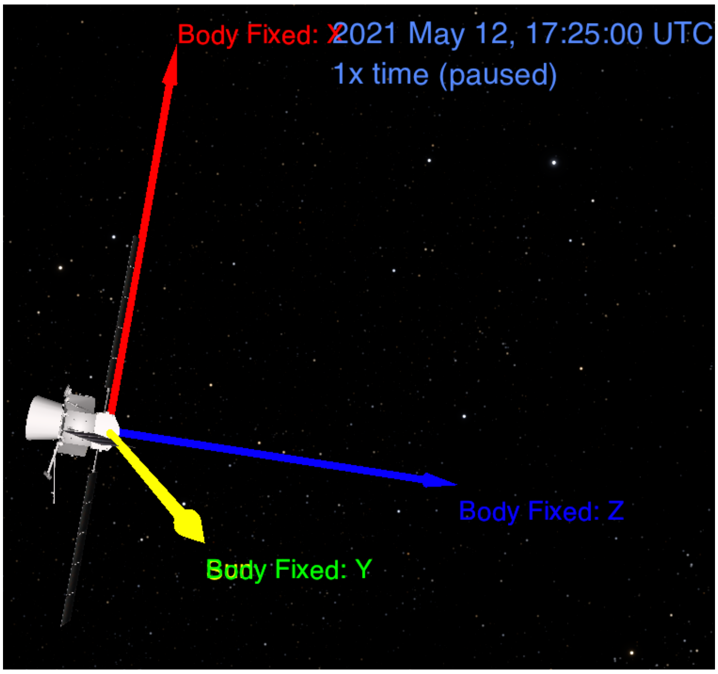
Space Missions and Systems 2021: Homework #2

BepiColombo is currently in cruise towards Mercury. For the period of interest, the orbit can be approximated by a circular orbit with a radius of 0.5 AU. The geometry is reported in the figure below. The two large solar panels mounted on the spacecraft have an area of 21 m^2 each. (The small solar panel of the MPO is not exposed to the Sun.)



The asymmetrical spacecraft is subject to a torque produced by the solar radiation pressure. The flight rules impose that the body-fixed Y-axis must be at maximum 1 arcsec from the spacecraft-Sun direction. At the beginning the spacecraft has an offset angle of +3 arcsec along the body-fixed X-axis and is not rotating. The new control law must bring the attitude back inside the 1 arcsec threshold in no more than 30 s.

Consider the center of mass of the spacecraft at the center of the spacecraft bus, and at the center of the body-fixed reference frame. The center of pressure is 2 m on the positive direction of the Z-axis, the other components are null. The solar panels sun-aspect-angle, i.e. the angle between the direction of the Sun and the orthogonal to the solar panels, is 75 deg. Consider this angle fixed, i.e. the disturbance torque is constant.

The attitude control system of the spacecraft uses a set of momentum wheels and thrusters.

Suppose that one reaction wheel has its axis along the X-axis of the spacecraft and is used to control the attitude. Four 10N thrusters can be used to produce a balanced torque along the X-axis. They are located 1 m from the center of mass the spacecraft. The thrusters provide pulses for a minimum of 0.01 s.

1. For how long can the spacecraft be controlled by the wheel under the presence of the solar pressure induced torque?
2. Design an attitude control system compliant with the flight rules. Provide the constants describing the control algorithm. Comment your choice and plot all the relevant quantities (wheel angular speed, torque, currents and power). Provide a zoom on the first 100 s of the plots.
3. Compute the time necessary to execute the first desaturation maneuver. Such maneuver

must be carried out so that the interval between two subsequent maneuvers is maximum. Only for this point consider a maximum pointing error of 0.5 deg, instead of 1 arcsec. Plot and comment the results.

4. After the desaturation maneuver the solar panels sun-aspect-angle is set to 0 deg (i.e. all surface is exposed to the Sun), for how long can the spacecraft attitude be controlled by the wheel? Plot all the relevant quantities up to the next desaturation maneuver.

Read carefully the following information:

- Solar flux at 1 AU (ϕ): 1371 W/m^2
- Solar panels total area (A): 42 m^2
- Solar panel reflectivity coefficients: Cs specular 0.3, Cd diffuse = 0
- Spacecraft moment of inertia: 6500 kg m^2
- Wheel moment of inertia: 0.054 kg m^2
- Wheel maximum angular speed: $\pm$4000 rpm (revolutions per minute)
- Wheel maximum torque: $\pm$0.211 Nm
- Wheel initial angular velocity: 1751 rpm
- The electric equations of the reaction wheel are:

$$i_{W=}\frac{T_C}{K_M}$$

$$P_W = V_M i_W = (K_W \omega_W + R i_W) i_W$$

K_M = 0.118 Nm/A, K_W = 0.003 V/rpm, R = 1.2 Ω; Pmax = 29 W.

The solar radiation pressure can be modelled as follows:

$$\vec{F}_{SRP} = -\frac{\phi}{c}\left(\frac{1AU}{R_{BEPI}}\right)^2 A\hat{n}\cdot\hat{s}\big((1-C_s)\hat{s} + 2C_s(\hat{n}\cdot\hat{s})\hat{n}\big)$$

$\hat{s}$ is the Sun direction, $\hat{n}$ is the normal to the solar panels.

Upload on Google Classroom a working computer code (Matlab is recommended) in a zip folder and a concise but comprehensive note (a pdf file, outside the zip folder) reporting clearly the **mathematical procedure, results, comments, and figures** by Sunday 16 May 23:59. The code must print the relevant results. ALWAYS put labels and units on the plot axes.