Nonlinear control and aerospace applications - Lab session 9

In the following exercises, you can use the Matlab libraries "lib_aerospace" and and "lib_nmpc". In particular, you can use the functions/blocks "spacecraft_dynamics.m" (spacecraft model), "nmpc_design_st.p" (NMPC design), "rv2oe.m" (conversion to orbital parameters) and "nmpc_block.slx" (NMPC controller Simulink block).
A template for a possible main script is the file "nmpc_design_template.m".

Exercise 1
Design a NMPC controller, finalized to launch a spacecraft and place it in a low Earth orbit (LEO), according to the following data.

- Spacecraft:
  - spacecraft body mass: 4000 kg;
  - total initial mass (body + fuel): 30000 kg;
  - engine exhaust velocity is $v_e = 30\,\text{km/s}$;
  - no input saturation;
  - the spacecraft model is implemented in the Matlab function "spacecraft_dynamics.m".
- Launch point on the Earth: $\mathbf{r}(0) = (r_E, 0, 0)$, $\mathbf{v}(0) = (0, v_E, 0)$, where $r_E = 6371\,\text{km}$ is the mean Earth radius and $v_E = 0.465\,\text{km/s}$ is the mean Earth rotation speed at the Equator.
- Target orbit:
  - circular orbit: $\mathbf{e}_r = (0, 0, 0)$ (eccentricity vector);
  - altitude: $h_r = 500\,\text{km}$, corresponding to a semi-major axis $a_r = r_E + h_r = 6871\,\text{km}$, where $r_E = 6371\,\text{km}$ is the mean Earth radius;
  - equatorial plane: $ci_r = 1$ (inclination).

Exercise 2
Design a NMPC controller, finalized to change the shape of a spacecraft orbit from circular to ellipsoidal, according to the following data.

- Spacecraft:
  - spacecraft body mass: 4000 kg;
  - total initial mass (body + fuel): 10000 kg;
  - engine exhaust velocity is $v_e = 4.4\,\text{km/s}$;
  - input saturation: $u_i \in [-132, 132]\ \text{kg} \cdot \text{km/s}^2,\ i = 1, 2, 3$;
  - the spacecraft model is implemented in the Matlab function "spacecraft_dynamics.m".
- Initial orbit:
  - semi-major axis: $a_0 = 6871\,\text{km}$;
  - eccentricity vector: $\mathbf{e}_0 = (0, 0, 0)$;
  - inclination: $ci_0 = 1$.
- Target orbit:
  - semi-major axis: $a_r = 8932\,\text{km}$;
  - eccentricity vector: $\mathbf{e}_r = (0.25, 0, 0)$;
  - inclination: $ci_r = 1$.