Spaceflight Mechanics

Exercise set 5

1. The international space station (ISS) orbits the Earth, flying on a circular orbit at altitude of 450 km. A spacecraft of mass 5000 kg and effective exhaust velocity 3 km/sec is placed on a coplanar circular orbit at altitude of 500 km. At the initial time t_0 the spacecraft has an angular displacement of 30 deg (i.e. the spacecraft is 30 deg ahead of the space station). Calculate

a. the components and magnitude of the velocity change that leads the spacecraft to intercept the ISS 60 minutes after t_0.

b. the components and magnitude of the second velocity change that leads the spacecraft to rendezvous with the ISS.

c. the propellant mass needed for the two impulsive maneuvers.

In order to reduce the overall propellant for rendezvous, a Hohmann transfer is considered. Using the HCW equations of relative motion,

d. calculate the initial displacement for a Hohmann-like rendezvous trajectory;

e. calculate the directions and magnitudes of the two velocity changes;

f. portray the relative trajectory ending with rendezvous in the HCW frame;

g. calculate the propellant mass for the two impulsive maneuvers.

2. A space debris is in circular orbit at altitude of 700 km. A spacecraft orbits a coplanar circular orbit at the same altitude, and is placed 10 km ahead of the space debris. Calculate the velocity change in radial direction needed to inject the spacecraft into a relative elliptic orbit about the debris, such that the spacecraft distance from the debris is 30 m at closest approach.

3. A space debris is in circular orbit at altitude of 700 km. A spacecraft orbits a coplanar circular orbit at the same altitude, and is placed 10 km ahead of the space debris.

a. Calculate the components and magnitude of the two tangential velocity changes that lead the spacecraft to rendezvous with the debris after one orbital period.

b. Portray the rendezvous trajectory in the HCW frame.

4. A spacecraft is placed in an Earth sunsynchronous, circular orbit, at altitude of 650 km. Its ballistic coefficient equals $0.02\ \mathrm{m^2/Kg}$, whereas the atmospheric density is $1.454\cdot 10^{-13}\ \mathrm{Kg/m^3}$ and $3.614\cdot 10^{-14}\ \mathrm{Kg/m^3}$ at 600 and 700 km of altitude, respectively.

a. Calculate the orbit inclination.

b. Evaluate the altitude decrease in 30 sidereal days, using the approximate formula for circular orbits.

5. A spacecraft is placed in an Earth geostationary orbit.

a. Evaluate the orbit precession period due only to the Sun.

b. Evaluate the orbit precession period due only to the Moon, under the approximating assumption that the angular momentum of the Moon orbit is aligned with the ecliptic pole.