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Luni-solar perturbations for missions design in highly elliptical orbits

Highly Elliptical Orbits (HEOs) about the Earth are often selected for astronomy missions, such as INTEGRAL and XMM-Newton, as well as for Earth missions, such as Molniya or Tundra orbits, as they offer vantage point for the observation of the Earth or are used for injection into Geostationary orbit through Geostationary Transfer Orbits. In 2018 the Proba-3 satellites will be injected into a HEO to demonstrate formation flying in the context of a large-scale science mission. HEOs guarantees spending most of the time at an altitude outside the Earths radiation belt; therefore, long periods of uninterrupted scientific observation are possible. Geo-synchronicity is often opted to meet coverage requirements, enhanced at the apogee, and optimise the ground station down-link. If the inclination is properly selected, HEO can minimise the duration of the motion inside the eclipses. This talk analyses the long-term evolution of spacecraft in HEOs. The dynamics of HEOs with high apogee altitude is mainly influenced by the effect of third body perturbations due to the Moon and the Sun, which induces long-term variations in the eccentricity and the inclination, corresponding to large fluctuations of the orbit perigee. A method is proposed to compute the optimal man oeuvre to perform end-of-life re-entry or transfer into a stable elliptical orbit. The Δ-v manoeuvre is computed in the eccentricity-inclination-anomaly-of-perigee map, first introduced by Kozai. Through these maps, conditions for quasi-frozen, or long-lived libration orbits are identified. In addition, to allow meeting specific mission constraints, stable conditions for quasi-frozen orbits can be selected as graveyard orbits for the end-of-life of HEO missions, such as the XMM-Newton mission. On the opposite side, unstable conditions can be exploited to target an Earth re-entry at the end-of-mission, such as the INTEGRAL mission.