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PHASE SPACE AND ORBIT RELATIVE MOTION BETWEEN HIGH AREA-TO-MASS RATIO SPACECRAFT

Abstract

Enhanced mission goals can be achieved by multiple spacecraft cooperating as distributed nodes of a sensor network. Relative displacement at different mean anomalies or on different orbits allows fine measurements and triangulation for positioning, Earth observation and telecommunications. On the other side, solar sailing established as low-cost propulsion. The effect of solar radiation pressure (SRP) on high area-to-mass spacecraft can be exploited for maintaining families of non-Keplerian orbits. Stable anti-heliotropic elliptical orbits were designed for the GeoSail mission, whereas at lower semi-major axis, a family of heliotropic elliptical orbits was studied for a swarm of small sail spacecraft for enhanced day-side Earth observation. Previous work described the long term evolution of orbits under the influence of SRP and Earth's oblateness in the phase space of eccentricity and Sun-perigee angle. Level lines of the Hamiltonian identify the stationary points corresponding, respectively, to stable and unstable anti-heliotropic orbits and stable heliotropic orbits. For other initial conditions in the neighbourhood of the equilibria, the orbital elements librate or rotate in the phase pace. This paper studies the relative orbital dynamics between high area-to-mass ratio spacecraft in Earth's orbit. Conventional formation flying usually considers a two-body problem as orbit perturbations are counteracted by the engine. In this study a Hamiltonian approach is used to study the relative orbit evolution in vicinity of an equilibrium point. The attention is firstly focused on high altitude orbits, where SRP is the main perturbing effect. In this case the relative evolution of two or more orbits evolving on different phase space lines can be described analytically through a differential Hamiltonian. The relative orbit evolution in the phase space is then translated onto the relative motion of the pair spacecraft on their respective orbit through relative motion equations for elliptical orbits. In this way, the displacement of each deputy satellite with respect to the chief can be fully characterised. The analysis is then extended to include the influence of eclipses, which causes long term oscillation in the semi-major axis, and the Earth's oblateness, which include non-linarites in the Hamiltonian system. In the mission scenario studied the chief spacecraft is placed on a highly eccentric anti-heliotropic orbit and the deputy spacecraft liberates on non-equilibrium orbits to perform a distributed measurement of the Earth magnetosphere. The change in the relative dynamics, when the orbit altitude decreases, will be also analysed.