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ORBITAL DYNAMICS OF SYNCHRONISED ORBIT-ATTITUDE OSCILLATIONS UNDER SOLAR RADIATION PRESSURE

Abstract

Interest in high area-to-mass spacecraft has increased in recent times because of their interesting orbital dynamics, in which the gravitational acceleration is highly perturbed by solar radiation pressure (SRP). SRP has been successfully exploited for small attitude manoeuvres through deployable vanes, but as the area-to-mass ratio increases, the effect of the SRP on the orbit becomes more significant. This is particularly true for both very small spacecraft (e.g. “spacecraft-on-a-chip”), and for conventional spacecraft deploying a large, reflective membrane, or solar sail. When the SRP exerts a non-negligible net force on the spacecraft, a function of the effective exposed area to the sun, it can effectively be used for orbital control and transfers, without traditional reaction-mass propulsion. This is appealing, as it enables orbit control on pico-satellites, which do not have propulsion systems due to size and mass limitations, but it also has the potential to reduce the propellant requirements of traditional spacecraft. It was shown by the authors that if the centre of solar pressure is displaced in the direction away from the sun with respect to the centre of mass of the spacecraft, then a “heliostable” configuration is achieved where an unlimited attitude oscillatory motion can be induced that is centred in the sun direction. The period of the oscillations can be controlled by changing the static margin. These oscillations have the effect of periodically varying the effective area exposed to the sun and the pitch angle of the reflective membrane. If the oscillations are synchronised with the orbital motion, then it becomes possible to have a periodic variation of the SRP acceleration over the orbit; as well-known from the Gauss’ variational equations, this can be exploited to achieve a change in orbital parameters. By varying the period, together with the orientation of the orbital plane and the oscillation plane with respect to the sun, different changes on the orbital parameters can be obtained. Focusing on the study of the orbital dynamics of such oscillating spacecraft, this paper proposes this new concept to control the orbit in various ways. A range of orbits are considered, as well as different oscillation-plane directions with respect to the sun and the orbital plane. Configurations for selectively changing the orbital parameters will be studied. In each scenario, the rate of change of the orbital parameters is presented as a function of the area-to-mass ratio of the spacecraft.