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SOLAR SAIL PROPELLANT–FREE TRANSFER MANEUVERS BETWEEN LIBRATION POINT ORBITS AROUND THE COLLINEAR EQUILIBRIUM POINTS

Abstract

This paper investigates propellant-free transfers between libration point orbits using solar sailing. The dynamical model used is the 3-dimensional Sun–Earth restricted three-body problem, including solar radiation pressure (SRP). The model of the SRP acceleration is the cannonball model, which depends on three parameters: the lightness parameter, which is a function of the spacecraft's reflectivity and area-to-mass ratio, and the normal unitary vector to the sail, which is represented as a function of the so called cone and clock angles. The maneuver under consideration are controlled by the change in the spacecraft reflectivity or by re-orienting the spacecraft, such that the angle of incidence of the Sun-line direction with respect to the sail is varied.

We have mainly considered Lissajous orbits around the collinear libration points, which are useful for spacecraft missions due to their different variety of sizes and shapes. Transfers between Lissajous orbits are advantageous for reaching higher or lower amplitude sizes, for avoiding escape from the nominal orbit (due to their inherent instability), or for avoiding forbiden zones, such as the ones related to eclipse avoidance that lower constrains the spacecraft-Sun angle for missions around L_1 or for avoiding the Earth shadow cone for missions around L_2.

The study is based on a careful analysis of the geometry of the phase space of the linearized equations around the equilibrium points, the dynamical identification of the parameters that appear in them, and the representation of the solutions in the effective phases plane. As a matter of fact, and contrary to the classical impulsive maneuvers, in the geometrical approach, solar sail maneuvers in the libration zone can be seen as "jumps" in position instead of in velocity. This is due to the fact that with a re-orientation of the sail the position of the (artificial) libration point changes. Then, keeping a reference frame centered on the equilibrium, the relative position of the spacecraft with respect to the origin changes with the solar sail maneuver. The paper uses this fact to systematically analyze the impact of a maneuver on a satellite in a libration point trajectory. Considering maneuvers that do not introduce unstable components in the modes of motion (that would produce divergence from the libration zone) one obtains the solar sail propellant-free transfers between Lissajous orbits.