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DYNAMICS OF CAPTURE ORBITS FROM LIBRATION REGION ANALYSIS

Abstract

Investigations on low-energy trajectories have strongly influenced space mission analysis and design during the last decades, with several missions planned for the upcoming years, other than those successfully performed in the past. These trajectories take advantage of the mutual action of multiple celestial bodies on the spacecraft, and can conclude with ballistic capture about the arrival body, thus allowing significant savings in terms of propellant consumption, if compared to more traditional transfers. As a main drawback, these missions often require longer transfer times, which affect the design of the spacecraft systems and devices. Because of the chaotic nature of multibody environments, the design of low-energy trajectories with given constraints can be complex and it is often obtained after a long, iterative, and eventually computationally expensive process. This work is aimed at identifying a limited set of characteristic parameters related both to the time behavior of three-dimensional ballistic capture orbits and to some osculating orbit elements (i.e., inclination, semimajor axis, and eccentricity), relative either to the departure or to the arrival body. The analysis is performed using the linear expansion of the Hamiltonian equations of motion about the collinear libration point L1 (or L2), in the dynamical framework of the circular restricted 3-body problem. By means of a canonical transformation, the system variables related to the aperiodic flow can be separated from those associated with quasiperiodic motion. This leads to defining 6 characteristic parameters, corresponding to the dynamical state in the libration region and depending only on the eigenvalues of the related linear system. The (local) Hamiltonian equations also provide a clear graphic representation of the system variables, thus allowing a simple preliminary selection of the characteristic parameters. Based on the results of this analysis, the design of long-term ballistic capture orbits can be performed. Moreover, for a spacecraft that crosses the libration region, the characteristic parameters can be adjusted by means of modest velocity changes, with the final aim of modifying the orbit elements about the primary of interest.