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# DESIGN OF LOW-ENERGY CAPTURE TRAJECTORIES IN THE ELLIPTIC RESTRICTED FOUR-BODY PROBLEM

**Abstract**

The fast development of microsatellites and their use for deep space exploration pushed the interest toward the design of low-energy trajectories. These trajectories take advantage of the mutual action of multiple celestial bodies on the spacecraft, allowing missions with consistent savings of propellant mass, with respect to traditional ones. Because of the inherent high complexity of chaotic dynamics of n-body environments, the design is typically obtained from the combination of some circular restricted 3-body problem (CR3BP). The accuracy of the nominal paths is then verified by numerical analyses in the n-body environment (i.e. ephemerides model) and, as proved by many authors, the presence of other bodies can strongly affect the result. It follows that the process can be significantly improved if the design is based on a more accurate model. In the present work we propose a method to design internal capture trajectories between the Earth and the Moon in the dynamical framework of the elliptic restricted 4 body problem (ER4BP). The method is based on a Hamiltonian approach and takes advantage of normal forms to obtain a set of the dynamic equations of motion whose form is equivalent to that of the CR3BP. The process starts by expanding the Hamiltonian function for the ER4BP in power series, isolating the terms depending on the eccentricity of the Earth-Moon system (e) and the mass of the Sun (m1). These terms are then absorbed by a canonical transformation and the resulting function is linearized about the Earth-Moon L1 (or L2) equilibrium point for the CR3BP. This process produces a Hamiltonian function H2 whose form is equivalent to that of the CR3BP. Finally a second canonical transformation is performed setting H2 as a sum of three local integrals of motion. The value of each integral is defined by a set of two parameters ($\alpha_1$,$\alpha_1$), ($\beta_1$,$\beta_2$) and ($\gamma_1$,$\gamma_2$), depending only on the energy level of the system and the masses of the primaries. Based on this representation, ballistic captures can be designed taking advantage of Conley's theorem, which defines their topological location in the close proximity of orbits asymptotic to (or departing from) Lissajous quasiperiodic orbits. Furthermore, for a spacecraft moving close to L1 or L2, some parameters can be modified by applying low-thrust accelerations and powered permanent captures can be obtained as a result. The proposed method is validated by means of numerical analyses using the full nonlinear equations of motion.