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EVALUATION OF OPTIMAL LOW-THRUST INTERPLANETARY TRAJECTORIES WITH COLLINEAR LIBRATION POINTS TRANSITIONS

Abstract

Traditionally, a zero-radius sphere of influence (ZSOI) model has been utilized at the preliminary stage of designing the interplanetary spacecraft trajectories. The results of optimizing low-thrust interplanetary trajectory within the framework of ZSOI model can lead to significant methodological errors. Therefore, the problem of developing an approach to optimize low-thrust interplanetary trajectories, which would allow, on the one hand, to obtain more realistic results, and on the other hand, would be simple enough and ensure the possibility of its application at the earliest stages of space mission design, is an urgent issue. As one of the possible approaches to solve this problem, we consider the problem of optimizing low-thrust interplanetary trajectory, which passes through the collinear libration points near the planets of departure and arrival. The considered scheme of interplanetary flight of a spacecraft equipped with an electric propulsion system, in the case of transfer to an outer planet, includes the following sequence of segments: 1) geocentric escape spiral from an intermediate Earth orbit to the $L2$ point of the Sun-Earth system; 2) heliocentric transfer between libration points $L2$ of the Sun-Earth system and $L1$ of the Sun-planet system; 3) planetocentric capture spiral around the planet from the $L1$ point of the Sun-planet system to the final target orbit. At all segments of trajectory, the gravity of the Sun, the planet of departure, the planet of arrival, and, if necessary, the gravity of other celestial bodies are taken into account. The minimum fuel consumption problem is considered. An indirect approach, based on the maximum principle and the continuation method with respect to gravity parameter, is applied to optimize trajectories. Numerical examples of trajectories from the Earth orbit to the orbit around the destination planet (Mars and Jupiter) are given. The possibility of a significant reduction in the required value of characteristic velocity is shown in comparison with the estimates obtained by using the ZSOI model. The obtained results can be used as an initial guess to solve the end-to-end optimization problem, i.e., to calculate interplanetary low-thrust trajectories that satisfy the necessary optimality conditions at the junction points of the heliocentric and planetocentric segments of trajectory.