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CYCLER ORBIT DESIGN USING LOW-THRUST IN THE SUN-EARTH-MOON SYSTEM

Abstract

Recently, a lot of studies and space agencies have been focusing on the transfer to the Moon. Cycler orbits which can periodically encounter the Earth and the Moon using swingbys can provide a low-cost transportation system to the Moon.

In previous research, a method to design cycler orbits was mainly developed based on the two-body problem or the Earth-Moon three-body problem. Even though the three-body model is used, the cycler orbit should be further improved since the gravity of the Sun is effective in the Earth region. However, the degree of freedom would be largely reduced in the four-body problem because there is a strong constraint that the phase period of the Sun, the orbital period Earth and Moon cycles must be considered. This constraint is one of the main difficulties to design the cycler orbit.

This paper considers cycler orbits in the Sun-perturbed Earth-Moon system with the aid of low-thrust acceleration. The motion of the spacecraft is modeled by the Sun-Earth three-body problem, considering the lunar gravity in the vicinity of the Moon. A linearized dynamics with respect to a reference orbit generated in the two-body problem with the Earth is used to design low-thrust acceleration which continuously eliminates the perturbation from the Sun. Thus the controlled orbit realizes a cycler orbit between the Earth and the Moon without the constraint of the synodic of the Sun. The low-thrust acceleration is designed based on the minimum energy solution described by the two-point boundary value problem and used to find the optimal swing-by conditions. Then, the phase of the Sun is also included in the optimization variables to find the minimum energy solution by changing the initial phase of the Sun. This two-layered optimization problem significantly reduces the calculation cost, therefore it expands search regions of the solution with lower calculation cost and enables to find a global minimum solution. Moreover, the feasibility of the mission is considered to evaluate fuel consumption from the optimal solutions.