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EXTENDED MISSION OPTIONS FOR THE LUNAR ICECUBE LOW-THRUST SPACECRAFT BY LEVERAGING THE DYNAMICAL ENVIRONMENT

Abstract

The recent renewed interest in developing cislunar space has enabled numerous proposals supporting small spacecraft destined for lunar orbit. Most of these small vehicles utilize low-thrust propulsion technology, for example, the Lunar IceCube (LIC) spacecraft, a 6U CubeSat equipped with a 1.24mN maximum thrust engine. Upon deployment as a secondary payload from the Artemis-1 spacecraft, LIC will transfer to an orbit in the lunar vicinity from which it will complete its primary science and technology demonstration objectives. The efficiency of LIC's low-thrust engine enables the spacecraft to pursue extended mission objectives; however, the low acceleration level available to LIC offers significant challenges for the design of orbits and transfers. This investigation presents a framework for the construction of low-thrust transfers between multi-body orbits in the lunar vicinity for applications with the LIC acceleration level.

The main challenges encountered by LIC are the large energy and plane changes required to transfer between multi-body orbits in the lunar vicinity given the limited low-thrust acceleration levels available. A design methodology is developed that exploits an orbit chaining strategy via two approaches: (i) The spacecraft leverages the continuous evolution in amplitude and Jacobi constant value for families of multi-body periodic orbits to gradually modify its energy and inclination. Since the orbits of interest and their Jacobi constant values are native to the Circular Restricted Three Body Problem (CRTBP), this force model—augmented by the influence of the thrust force—is employed by the algorithm to generate informed initial guesses that are converged to continuous solutions. (ii) The second approach utilizes long transits around the Earth-Moon system to achieve the required large plane changes. Results from both types of approaches are ultimately validated in a high-fidelity ephemeris model that incorporates the gravitational influence of the Sun, the Earth and the Moon.

Low-thrust transfers are computed to and from a variety of multi-body orbits that exist in the vicinity of the Moon, e.g., Lyapunov, distant retrograde, and halo orbits. The proposed methodology offers a strategy applicable not only to the LIC mission but extendable to other low-thrust missions in the lunar vicinity, whether the acceleration capabilities are greater or less than LIC, particularly when science objectives, line of sight constraints, or orbital determination requirements, necessitate the use of multi-body orbits. Cost-time efficiency transfer performance is assessed that demonstrates the flexibility of the framework and delivers a new variety of mission options for the LIC spacecraft.