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PHASING PROBLEM FOR SUN-EARTH HALO ORBIT TO LUNAR ENCOUNTER TRANSFERS

Abstract

Halo orbits are advantageous for various space applications. There will be more utilization of halo orbits in the future. Inspired by the ISEE-3 Sun-Earth halo orbit mission, which applied low-energy transfers to achieve more goals than planned, our work concerns about the extended mission following the completion of a halo orbit mission.

It is interesting to link halo orbits with interplanetary exploration. There have been several studies on this. In a previous study, we proposed the strategy of using the unstable manifolds associated with the Sun-Earth L_1/L_2 halo orbit along with lunar gravity assists to achieve Earth escape, and compared this scenario with the escape along manifolds only. Some remarks are: 1) the manifold-guided lunar gravity assists can achieve much higher characteristic energy (C_3) with respect to the Earth than the direct escape along manifolds; 2) if the V_∞ with respect to the Moon at the lunar encounter is not great enough for high energy escape, a second lunar gravity assist can efficiently increase the C_3 to the theoretical maximum level at the expense of another 90 day flight time. For these advantages, the present work investigates the minimum required phasing ΔV for the transfer from the halo orbit to a lunar encounter.

The transfer consists of a departure to the unstable manifold at infinitesimal cost, followed by a coast along the manifold, and a corrected trajectory to the Moon led by a phasing ΔV paid along the coast manifold trajectory. The lunar phase with respect to the halo orbit (by defining an initial lunar phase θ_0 when the spacecraft passes a reference point $\mathbf{x}_0$ in the halo orbit) and the halo orbit size (z-amplitude A_z) would be known in practical missions. The paper presents the routine of calculating the minimum phasing ΔV for given θ_0 and A_z. A concern arises as there are multiple solutions (e.g. the short-way and long-way motions) for the two-point boundary value problem as well as multiple optimization directions. Based on the knowledge and partial derivatives of the two-body Lambert problem, the differential correction sequence we developed can identify the two solutions in the three-body problem. The ΔV budget to cover full lunar phases will be revealed. In addition, the paper discusses referencing the lunar phase to consecutive halo revolutions to decide a minimum-ΔV phasing plan.