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AN OPTION FOR CHANG'E-2'S EXTENDED FLIGHT: NEAR-EARTH ASTEROID FLYBY TRAJECTORIES FROM THE SUN-EARTH L2 VIA LUNAR GRAVITY ASSIST

Abstract

There are several flight options for Chang'e-2 spacecraft to depart from the Sun-Earth L2 point, for example, impacting the moon or re-capture into lunar orbit, returning to Earth orbit, heading for halo orbits of the Earth-Moon L1 or L2 or the Sun-Earth L1 point, and flying by near-Earth asteroids (Finally, Chang'e-2 successfully conducted a close flyby of Toutatis, a potentially hazardous near-Earth asteroid, on Dec. 13, 2012). The analyses of these flight options require designing preliminary transfer trajectories with total velocity impulses no more than 100m/s in four-body dynamics, in which the motion of the spacecraft is influenced by the gravities of the Sun, Earth, and Moon. In this study, we shall present low-energy Toutatis flyby trajectories from a Sun-Earth L2 quasi-periodic orbit, specifically, via a single lunar gravity assist that is intentionally utilized for exploring potential benefits, compared with the direct transfer manner adopted in the practical mission operation. We first propose two fundamental models of trajectory bundle computed in four-body dynamics: 1) perturbed unstable manifolds of libration point quasi-periodic orbits and 2) trajectory bundle with lunar gravity assist. The former is characterized by a small velocity impulse to depart the quasi-periodic orbit and the latter is computed with the orbital states at lunar close approaches that are approximately modeled by lunar B-plane parameters. Subsequently, a three-step shooting strategy is employed to facilitate the trajectory design process: 1) shoot the perturbed unstable manifolds to the moon, 2) shoot the trajectory bundle with lunar gravity assist to the asteroid, and 3) shoot the trajectory bundle with lunar gravity assist backward in time to Poincare sections to connect with the perturbed unstable manifolds. In order to reduce the targeting errors, an intermediate impulse is allocated to each trajectory bundle and its initial value and the time instant for exertion are estimated using state transition matrices. Coarse trajectory solutions are then obtained by the three-step shooting strategy and impulse allocation. Finally, the trajectory optimization problem is transformed into the parameter optimization problem that is solved by sequential quadratic programming to obtain accurate solutions in four-body dynamics using the coarse trajectory solutions as initial guess. Compared with the direct transfer to the asteroid, the designed results show that lunar gravity assist is capable of saving propellant and enlarging the time window for departing the quasi-periodic orbit. Potential benefits of lunar gravity assist for future near-Earth asteroid missions are also discussed.