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MULTIPLE GRAVITY ASSISTS LOW THRUST TRAJECTORY DESIGN FOR HELIOSPHERIC BOUNDARY MISSION

Abstract

Heliospheric boundary mission is currently one of the China's most important future deep space plans. Sending a probe to the heliospheric boundary (100 AU) can enlarge human's acknowledgment of the composition of matter outside the solar system, as well as the origin and evolution of the solar system. In the heliospheric boundary the nose-tail region is of high scientific value. Through our mission analysis, if the probe to the nose-tail region is launched between 2025-2030, then there will be a chance to fly by Neptune. Neptune flyby can boost the science return of the mission in a great way. Therefore, the electric propulsion trajectory to the nose-tail of the heliospheric boundary with a Neptune flyby is optimized in this paper. The difficulty of the heliospheric boundary mission trajectory design is that the heliospheric boundary is too far, and the probe must accelerate to a very high speed to reach 100 AU in an acceptable flight time. Limited by the launch vehicle's C3 capability, multiple gravity assist is necessary. Therefore, the trajectory optimization problem addressed in this paper is a multiple gravity assists low thrust problem with a flight time constraint. The gravity assist sequence after launch is Earth-Earth-Jupiter-Neptune and is fixed in this paper. The maximum flight time is 22 years. In this paper, the impulse model is used at first to search for the preliminary launch C3, launch epoch, and gravity assist epoch. To better describe the low thrust arc using impulse, a novel technique that constrains the impulse magnitude is proposed, and a dual-impulse powered gravity assist model is used. These treatments make the impulse model represent the low thrust model better. Then, indirect low thrust optimization is applied using fixed launch C3, launch epoch and gravity assist epoch given by the impulse search. Gravity assist is taken as an inner point constraint. At last, an iterative procedure is applied to optimize launch C3, launch epoch, and gravity assist epoch using indirect optimization step by step. Simulation results show that using the proposed method, the multiple gravity assists low thrust can be optimized fast, and the heliospheric boundary can be reached in 2049 (100th anniversary of the founding of PRC) if the probe is launched in 2027.