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COMPACT FINITE-DIFFERENCE METHOD FOR PLANETARY FLYBY ORBIT DESIGN

Abstract

The two-point boundary-value problem of the orbit equations are discretized as fourth-order compact finite-difference equations, which are solved by iteration with the acceleration terms expressed as a block tri-diagonal matrix of positions and the gravitational force terms treated as known. The grid for the spacecraft escaping Earth or approaching Venus can be refined by any times of powers of 2, to keep tri-diagonal form and 4th-order accuracy. The force terms can be further linearized to increase the diagonal domination and hence the convergence stability. With the stability and accuracy, it is very useful for the orbit design of Earth escape and planetary flyby.

Consider the orbit design of ASTROD-I mission, which is a planned interplanetary space mission to test general relativity and to measure key solar system parameters. The spacecraft is required to reach the far side of Sun to measure the Shapiro effect to high precision. The orbit design is to find the initial state of the spacecraft to escape from Earth, to fly by Venus, and to enter a near half-year orbit. DE431 solar ephemerides are utilized for the initial states of the solar system, and post-Newtonian formulation for the equations of motion of the celestial bodies and the spacecraft. Computed results show that the spacecraft escapes from low-Earth orbit with delta-V of 1.421 km/s and propellant mass ratio of 0.364 assuming the specific impulse of 320 sec. As launched on Dec. 19, 2024, the spacecraft will fly by Venus after 140 days, and enter a near half-year orbit. During its three-year mission, the spacecraft will locate at the opposite side with respect to Earth three times.