IAF SPACE EXPLORATION SYMPOSIUM (A3)
Solar System Exploration including Ocean Worlds (5)

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ADVANCED METHODS OF LOW-ENERGY MISSION DESIGN FOR ICY MOONS EXPLORATION

Abstract

Mission design of low-cost DeltaV gravity assists tours for the Icy Moons exploration (orbiters around Io, Europa, Ganymede and probes for the detection of liquid water beneath their surfaces) is considered, taking radiation hazard into account. Limited dynamic opportunities of fly-bys require multiple gravity assists implementation. Relevance of regular creation of the working optimum scenarios – sequences of passing of celestial bodies with definition of conditions of their execution is obvious. Withal low-cost reduction of the spacecraft (SC) asymptotic velocity for the capture of the moon is required. One of main problems of the Jovian system mission design (JIMO, JUICE, Laplas-P) is that the reduction of the asymptotic velocity of the spacecraft with respect to the individual Icy moon is impossible. A valid reason covered in the Jacobi integral invariance in the restricted three body problem (RTBP). Besides the solo-body gravity assists tour falls into the hazard radiation zone according the Tisserand-Poincaré graph. Formalized beam's algorithm to overcome this "problem of the ballistic predestination" with using full ephemeris model using bang-bang multibody gravity assists has been implemented. The corresponding numerical scheme was developed with using Tisserand-Poincaré graph and the simulation of tens of millions of options. The Delta V-low cost searching was utilized also with help of the modeling of the multiple rebounds (bang-bang gravity assists) of the beam of trajectories. The techniques are developed by the authors specifically to the needs of the Jovian missions. The region of exceeding of the total received radiation dose (TID) can be bypassed along the upper section of the Tisserand-Poincare graph. Advanced Multi-Tisserand coordinates for this purpose are introduced for the best study of features for the radiation hazard decrease and the spacecraft asymptotic velocity reduction. They are Tisserand parameters of SC relative some small bodies in several local RTBP. The Multi-Tisserand graph built based on them. It is shown that the "bang-bang" gravity assists at the early stage of SC orbital energy reduction for TID-comfortable tour are required. As a result, a reasonable increase in the duration of the missions of the Icy Moons exploration can be exchanged on a sharp decline TID and "comfortable" (in TID) tours scenario can be found in the Jovian system (less than 70 Krad for standard SC protection 8-10 mm Al, or less than 200-300 Krad for the "light" SC with the 4-5 mm Al shield).