ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations and Optimization (2) (9)

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OPTIMIZATION OF THE SPACECRAFT INSERTION INTO THE SYSTEM OF HELIOCENTRIC ORBITS FOR SUN EXPLORATION

Abstract

Spacecraft insertion into the system of heliocentric working orbits, providing good conditions for observing the Sun, is considered. The possibility of space transportation system based on the launcher "Soyuz-2", chemical upper stage (ChUS) "Fregat" and solar electric propulsion (SEP) is analyzed. Studying the Sun using the SC at heliocentric orbits is interested. These SC allow monitoring the region of the Sun including the polar regions that are not visible from the vicinity of the Earth. We propose to use the system of working heliocentric orbits. The spacecraft makes one or more revolutions around the Sun on each orbit. These orbits are characterized by small perihelion radius (60...110 solar radii) and relatively large inclination. SC transfers form one orbit to another by using passive Venus gravity assist. All working orbits (except the last) are in resonance with Venus' orbit and different orders of resonances are used. Launcher "Soyuz-2" delivers the SC with ChUS into the near Earth orbit. The ChUS provides the hyperbolic excess velocity and is separated from SC. SEP provides Earth - Earth flight and encounter Earth with sufficiently large hyperbolic excess velocity. Earth gravity assist provides passive flight to Venus. Then a series of gravitational maneuvers at Venus are implemented. Each maneuver delivers the spacecraft into sequence of heliocentric orbits. The purpose of this study is to evaluate the possibility of the transport system in terms of the SC mass, which can be delivered to the working orbits. Optimization of the transport system parameters and motion control in insertion the spacecraft into the working orbits is carried out by using the maximum principle. Much attention is paid to optimal conditions; note the optimization in multi-point boundary value problem. The developed algorithm to solve this problem is based on the continuation method. The considered transport system can provide sufficiently large mass of spacecraft (1400 kg) into the system of working heliocentric orbits. This SC mass depends on required inclination of the working orbits (at 25 degrees of inclination, SC mass may be more than 1600 kg). The possibility of using SEP based radio frequency ion thrusters type RIT22 is analysed. The use of RIT22 allowing reduces the required propellant mass. The study shows that the considered space transportation system can deliver the large spacecraft into the system of working orbits, providing good conditions for the observation and study the Sun.