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TRANSPORTATION ARCHITECTURE FOR ROUND-TRIP EXPLORATION TO MARS UTILIZING DEEP SPACE PORT AT SUN-EARTH LIBERATION POINT

Abstract

Currently, investigations of human exploration mission to Mars are debated around the world. In particular, the transportation strategy between Earth and Mars holds the key to the implementation of this kind of manned missions. One of the approaches to this problem beyond EarthMars direct transfer is a utilization of so-called "Deep Space Port (DSP)". The DSP, a concept of utilizing the Sun-Earth liberation points for stopover, has been recently investigated by several researchers and space organizations, revealing that it offers a strategic waypoint for refueling and cargo hand-over for interplanetary transportation. In general, a high thrust propulsion system, (which generally results in relatively low specific impulse) is necessary for the escape from a gravitational sphere of influence of the Earth. On the other hand, the interplanetary transfer requires high specific impulse (with low thrust practically) to transport as much payload as possible. Thus, those of near-Earth and interplanetary transportation differ in the requirement for the propulsion system, and hence changing spacecraft at an appropriate midpoint may become an optimum scenario. As the Sun-Earth liberation points maintain geometric relationship with the Sun and the Earth at the same time, the DSP on a liberation point is a promising candidate for the stopover for the interplanetary transportation. This paper discusses the transportation architecture for the round-trip exploration to Mars taking advantage of the combination of the "DSP" and "low-thrust propulsion." One of the merits of utilizing the DSP is the reusability of the interplanetary portion of the architecture. Past studies mostly discusses fuel- or time-optimum one-way trip between the Earth and Mars. On the other hand, this paper focuses on multiple round-trip transportation with reusable spacecraft. The paper divides the scenario into three segments; near Earth phase, interplanetary phase and near Mars phase. Both ballistic trajectories and low-thrust trajectories are assessed. The low-thrust optimization is performed by DCNLP (Direct Collocation with Nonlinear Programming) which approximates the continuous problem with parameter optimization problem and provides precise results by simple formulation. The paper shows the results of analysis and numerical computation of the multiple round-trip trajectory design with chemical and low-thrust propulsion system. The Earth and Mars swing-by and the utilization of EDVEGA (Electric Delta-V Earth Gravity Assist) technique are also considered. In addition to these, we also investigate the aerobraking options at Earth and Martian atmosphere. Then based these results, the architecture suitable for reusable multiple round-trip Mars exploration is discussed.