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DESIGN OF TRANSFER TRAJECTORIES FROM CISLUNAR ORBITS TO THE RETROGRADE GEO-SYNCHRONOUS ORBIT

Abstract

The Retrograde Geo-Synchronous Orbit (RGSO), is an Earth orbit with the same period of Earth rotation and the inclination of 180 degrees. Since it can implement rapid coverage of the GSO region per 12 hours, the RGSO shows great potential in satellite surveillance and space debris observation. However, direct insertion into RGSO from the Earth is uneconomical due to the high fuel consumption. To overcome this difficulty, several transfers toward RGSO from low Earth orbit (LEO) and GSO have been investigated, which may take advantage of lunar gravity assist and save fuel-cost.

In this study, a novel transfer pathway from cislunar orbits to RGSO is proposed. Nowadays, cislunar orbits, such as the near rectilinear halo orbit (NRHO) and the distant retrograde orbit (DRO), have played an important role in human lunar exploration and space infrastructure construction. With the specific dynamical mechanism in the Earth-Moon system, these orbits could also perform as a good option of transfer to RGSO.

A two-step transfer design method is adopted to design the trajectory between cislunar orbits and RGSO in the bicircular restricted four-body problem (BR4BP). Firstly, large numbers of trajectories departing from cislunar orbits that could approach the RGSO region are found and selected as initial guesses. Then, the transfer problem is converted into an NLP problem which minimizes the fuel consumption under certain orbital constraints. From above, the initial guesses are optimized through the NLP problem and the solution distribution of the transfer is obtained.

The transfers from both DRO and NRHO to RGSO are calculated. The transfer trajectories from DROs with different amplitudes and L1/L2 NRHOs with different perilune altitudes are analyzed in aspect of departure and insertion points, time-of-flight, total impulse cost and orbital energy, which reveals the key factors of the RGSO insertion. Besides, some transfers utilizing lunar gravity assist and the weak stability boundary theory can significantly reduce the fuel consumption. Finally, some representative orbits are transitioned into the high-fidelity ephemeris model.

The results prove that the transfer from cislunar orbits to RGSO is an efficient way to deploy RGSO satellites. Compared with the transfers from LEO and GSO, this new pathway possesses diverse transfer forms and has an advantage in the transfer cost. Predictably, it would become more convenient to get insertion into RGSO in the future as cislunar orbits are extensively explored and employed.