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EXTENDED PERILUNE RENDEZVOUS METHOD FOR LOW DELTA-V TRANSITION TO NRHO

Abstract

As a post-ISS mission, the construction of Gateway in lunar orbit is planned, and a cargo supply mission to Gateway is also being considered by JAXA. Near-Rectilinear Halo Orbit (NRHO) is a candidate orbit for Gateway, and several methods for the transfer trajectory from Earth are being researched. However, an intermediate trajectory between the Lunar Fly-by Method (LFM), adopted by NASA for manned missions, and the Weak Stability Boundary (WSB) trajectory have not been actively studied yet.

In 2022, the Perilune Rendezvous Method (PRM) of NRHO transfer for future supplies to Gateway was discovered.[1] In this method, a deceleration maneuver during a lunar swing-by inserts a spacecraft into an elliptical lunar orbit. The spacecraft can then enter the NRHO with a small velocity increment by waiting for when the orbital plane coincides with the NRHO. One useful feature of this method is that most of the velocity increment is in the direction of the velocity vector, so the transition to NRHO is highly V efficient.

This paper proposes the Extended Perilune Rendezvous Method (EPRM) as the improvement of the PRM. This method reduces V by remaining in an elliptical lunar orbit for longer than the PRM, taking advantage of the effects of Earth perturbations. Moreover, since the transition to Gateway takes longer, it can be rendezvoused more precisely by several Trajectory Correction Maneuvers (TCM).

The EPRM requires a lower V than the LFM and the PRM, so more cargo can be delivered. However, the disadvantage is that the transfer period is longer than for the LFM and the PRM, but this is not major problem for a cargo supply mission. Moreover, the transfer period is much shorter than for the WSB trajectory, and there is no restriction on the launch window when using the EPRM. Therefore, the EPRM significantly expands the transfer options for future missions, such as cargo transport.

This paper explains using the EPRM for the transfer trajectory from Earth to NRHO. Then, the V and the transition period of the EPRM and LFM are compared. Moreover, the estimation of the TCM considered the launch rocket guidance, attitude control, and thrust errors during trajectory control maneuvers is explained. Finally, the rendezvous accuracy with Gateway is discussed considering the maneuver plan.

[1]Kikuchi J, et al.: Perilune Rendezvous Method of Earth-NRHO Transfer Orbit for Cargo Transportation Mission to Gateway, JSASS Aerospace Technology Japan, Volume 20, p.26-33, 2022