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RENDEZVOUS TRAJECTORY DESIGN FOR LOGISTICS RESUPPLY MISSIONS TO THE LUNAR GATEWAY IN NEAR-RECTILINEAR HALO ORBIT

Abstract

Logistics resupply to the lunar Gateway is one of the candidates for Japan's contributions to the Artemis program. JAXA is presently developing the HTV-X transfer vehicle to transport supplies to the International Space Station, and investigating enhancements to the HTV-X to enable logistics resupply to the lunar Gateway. As the Gateway Operational orbit, a Near-Rectilinear Halo Orbit (NRHO) of the L2 southern family was selected. In this study, we suggest a trajectory design for logistics resupply missions to the Gateway in NRHO and clarify the requirements regarding guidance, navigation, and control (GNC) for rendezvous in NRHO. The rendezvous scenario consists of transfer phase from the Earth to NRHO and rendezvous and proximity operation phase in NRHO. The baseline trajectory design for the transfer phase is composed of insertion into the lunar transfer orbit, powered lunar flyby, and arrival maneuver to insert into the NRHO (NRHO insertion maneuver), which is same with basic mission design methodology used by NASA's Orion. From the viewpoint of minimum delta V, NRHOI is performed at a point away from the apoloon for a flight period of about two days. The rendezvous phase starts at a point away from the gateway by a distance determined based on the position control accuracy just before the NRHOI. The rendezvous trajectory is designed so that the 24-hour free drift trajectory after any planned maneuver does not enter the safety regions until the final approach based on navigation by proximity sensors starts at 500m away from the Gateway. Rendezvous in Cis-Lunar orbit differs from rendezvous in Low Earth orbit in that the dynamics of relative motion is based on the three-body problem and GPS navigation is unavailable. The former is solved by using maneuvering planning based on a linearized equation of motion that includes the gravity of the moon and the earth. The latter is solved by using navigation by optical LOS angle observation and relative ranging observation. At the 500m distance from the Gateway, the final approach starts when the navigation switches to LiDAR based navigation and Closed-loop PD

trajectory control is applied. Monte Carlo simulations were carried out for all phases in consideration of navigation error and control error. We evaluated the designed trajectory through the simulations in terms of fuel consumption, safety, and operational feasibility, and clarify the requirements regarding GNC for rendezvous in NRHO.