Paper ID: 86557
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IAF ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimization (2) (7)

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PRACTICAL RENDEZVOUS SCENARIO FOR LOGISTICS RESUPPLY MISSION TO THE LUNAR GATEWAY AFTER NRHO INSERTION AT THE PERILUNE.

Abstract

JAXA is presently investigating a logistics resupply vehicle to the Gateway, HTV-XG, as an enhancement to the HTV-X, the new cargo transportation vehicle to ISS. The Perilune Rendezvous Method (PRM) is the newly proposed option for the transfer trajectory from the Earth to the NRHO, in which the spacecraft is first transferred into a long elliptical lunar orbit and then inserted at the perilune of the NRHO when the orbital planes coincide. Although the PRM requires a relatively long transition period of 20-30 days, it has the advantage of significantly low propellant consumption, which is attractive for unmanned spacecrafts as HTV-XG.

However, in the PRM, the rendezvous scenario planning after the NRHO insertion (NRHOI) becomes complicated: To ensure the visibility of the onboard optical sensors, the vehicle should approach the Gateway from the sun direction. On the other hand, since the steep gravity gradient near the perilune rapidly expands small differences in position and velocity, the initial relative state at NRHOI should be determined according to the instantaneous orbit plane, not the sun direction. Therefore, after NRHOI, the vehicle should first be efficiently guided to a region where the sun is located behind it. However, since the sun direction in the NRHO rotates with the revolution of the moon, the region with good sun conditions varies depending on the operation date.

The purpose of this study is to propose rendezvous trajectory design and practical operation scenario that are valid for any operation date. It is found that by selecting whether to insert the vehicle in front of or behind the Gateway depending on the initial sun direction, the vehicle could always be guided to a region with good optical conditions with a small burn after NRHOI. In addition, the aimed point of the first small burn could be set the same in any case, which means the common operation scenario could be applied regardless of the operation date.

In this paper, the sun-referenced relative trajectory after NRHOI at the perilune is first investigated and categorized in 9 pattens. For each pattern, it is shown that either the trajectory in front of or behind the Gateway could be guided to the common target point with good optical conditions. Then, the subsequent trajectory design and rendezvous scenario accounting for the practical navigation and control operation are described. Finally, the fuel consumption, safety, and operational feasibility are evaluated via Monte Carlo simulation.