OPTIMUM GUIDANCE STRATEGY FOR RENDEZVOUS MISSION IN EARTH-MOON L2 HALO ORBIT

Satoshi Ueda[1], **and Naomi Murakami**[2]
[1][2] *Japan Aerospace Exploration Agency, Tsukuba Space Center,*
2-1-1 Sengen, Tsukuba, Ibaraki, Japan
[1] *+81-50-3362-7403, ueda.satoshi@jaxa.jp*
[2] *+81-50-3362-3725, murakami.naomi@jaxa.jp*

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Abstract

Based on experience of the International Space Station (ISS), the Global Exploration Roadmap is being discussed focusing on exploration mission to the Moon, near-Earth asteroids, and Mars. A concept of new space station in the lunar vicinity is proposed in the roadmap as the intermediate step to expand the capabilities needed for future Mars missions. An Earth-Moon L2 halo orbit is one of the candidates in which the lunar vicinity station will be located.

Rendezvous flight capability is a key technology to maintain the ISS in terms of human transfer and resupply. Especially, safety requirements for avoiding collision of two spacecrafts are the main factors which decide the relative approach trajectory design. On the other hand, each rendezvous flight must meet requirements of punctuality from resupply and storage planning side. We think similar requirements will be imposed on rendezvous missions to the lunar vicinity station. Therefore it is important to proceed a research on establishing the optimum rendezvous guidance strategy by considering requirements of safety and punctuality. A guidance law must be developed by considering relative orbital motion which is unique because the orbit is located in the weak stability boundary.

As a basic study, simulations in the circular restricted three-body problem (CRTBP) have been performed (see Fig.1 for an example). According to the result, major factors which affect trajectory dispersions are relative navigation accuracy and maneuver performance. According to the specification of current visiting vehicle to the ISS, a safety requirement is defined such that "a visiting vehicle's nominal and free drift trajectories including 3−sigma dispersions shall stay outside of the safety zone around the ISS for a minimum of 24 hours". Therefore an analysis to show trajectory dispersions is important to ensure that the rendezvous trajectory is safe. Based on the result of simulations in the CRTBP, we may define basic requirements regarding the Guidance, Navigation and Control (GN&C) system for a rendezvous vehicle to the lunar vicinity station, e.g., performance of relative navigation, attitude control performance during maneuver, and alignment accuracy for attitude determination sensors.

In this study, we investigate dynamics related effects which may affect relative motion and trajectory safety in an Earth-Moon L2 halo orbit:

- Is the CRTBP sufficient for analyzing relative trajectory dispersions and defining vehicle's GN&C requirements?
- How strictly accurate we need to calculate state transition matrices for guidance?

- Can a visiting vehicle accept potential attitude constraints of the lunar vicinity station? Attitude constraints may be imposed by sun-oriented attitude requirements.
- Can a visiting vehicle perform loitering around the lunar vicinity station or perform approach flight in any place in an Earth-Moon L2 halo orbit?

By considering the factors listed above, we present optimum relative trajectories and guidance strategies which are suitable for a rendezvous mission in an Earth-Moon L2 halo orbit:

- Total delta-V for approach is minimal
- Time of flight is sufficiently short
- Trajectory safety must be ensured by considering 3-sigma dispersions
- Trajectories must keep inside the region in which relative navigation sensors work

The study focuses on the mission phase after a visiting vehicle has been injected into an Earth-Moon L2 halo orbit. We consider an assumption that a visiting vehicle's injection point is sufficiently close to the lunar vicinity station, e.g. 1000km away from the station.

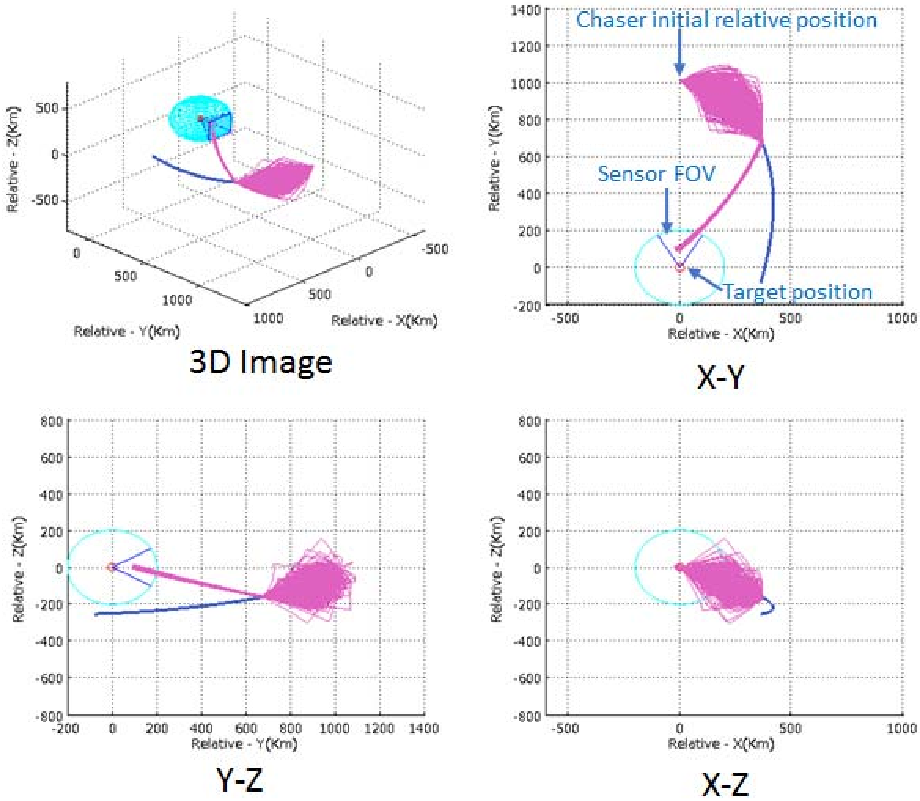

Figure 1. An example of relative approach trajectory analysis in the CRTBP
A visiting vehicle starts approach flight after it is injected into an Earth-Moon L2 halo orbit. The plot (red) shows relative position of a visiting vehicle with respect to the lunar vicinity station. Initial relative position is 1000km away from the station. Trajectory safety is analyzed by considering 3-sigma navigation errors and 3-sigma maneuver delta-V errors.