RENDEZVOUS OPTIMIZATION WITH AN INHABITED SPACE STATION AT EML2

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ABSTRACT

In the context of future human space exploration missions in solar system and according to the roadmap proposed by ISECG (International Space Exploration Coordination Group), a new step could be to maintain as an outpost, at one of the libration points of the Earth-Moon system, a space station that would ease access to far destinations as Moon, Mars and asteroids and would allow to test some innovative technologies, before employing them for far distant human missions. One of the main challenges will be to maintain permanently and ensure on board crew survival. Then the main problem to solve is to manage the station servitude, during deployment (modules integration) and operational phase.

The Space Station, as a test bed for human exploration of the solar systems, may be located in the vicinity of the Earth so as to ease its deployment and maintenance and ensure continuous communications. Trade-off analysis led to recommend locating it around EML2 (Earth-Moon Lagrangian point n°2), on a Halo orbit and the space station is then called THOR (for Trans-Lunar Human explORation).

The main challenges of this project lie in the design of the operational scenarios and, particularly, in trajectories selection, so as to minimize velocity increments (energy consumption) and transportation duration (crew safety). Transfer trajectories have already been deeply studied, since the 1950s. The work presented in this paper focuses on the feasibility of rendezvous in the vicinity of EML2 by comparing several rendezvous strategies and by providing quantitative results so as to select the optimal rendezvous scenario for a cargo or a human spacecraft (chaser) with the THOR station (target). It is assumed that the THOR space station is already rotating on a Halo orbit around EML2 while, the chaser tries to reach it. In THOR resupply context, the main rendezvous phases have to be modified and adapted to non-keplerian orbits around unstable Lagrangian points (here, EML2). The main goal of the rendezvous is to conduct the chaser relatively close to the target in order to linearize the equations of motions of both vehicles until the contact.

The rendezvous operations that are considered in this study will start from the departure of the chaser from its parking orbit to the injection maneuver onto the target orbit in the vicinity of the Earth-Moon Lagrangian point EML2. Final maneuvers to phase the target and the chaser on the target final orbit are considered out of the scope of this project.

The selected strategy to perform the rendezvous between a chaser and the THOR station corresponds to a heteroclinic connection between two Halo orbits, by finding the intersection

between their manifolds (the unstable manifold for the chaser and the stable manifold for the station). The intersection is planned to occur on Poincaré section. An example of this process is presented on Figure 1.

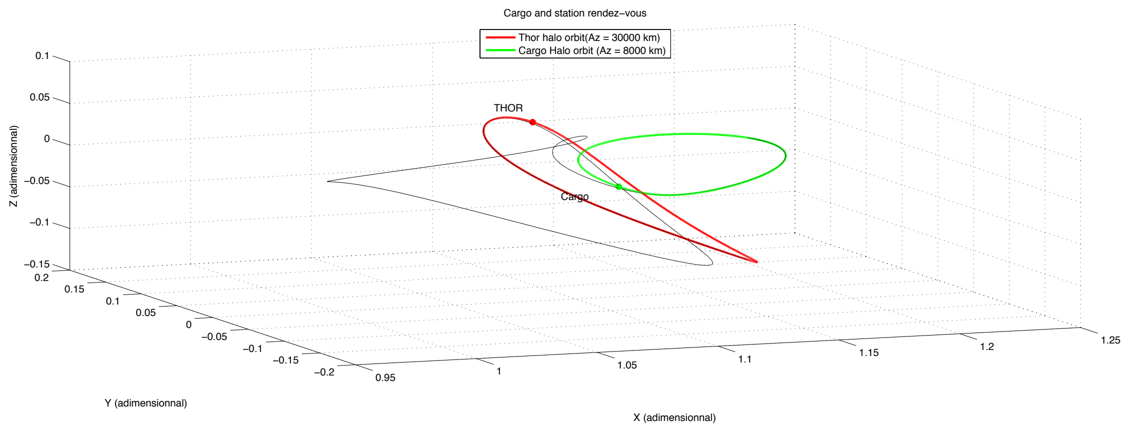

Figure 2: Example of rendezvous strategy between a chaser and the THOR space station

Three maneuvers would be necessary to perform the rendezvous. Main design parameters are primary, the class of both Halo orbit, their elongation along the out-of-plane axis and the angular position of the Poincaré section and secondary, the initial angular position of the chaser and the THOR space station when the rendezvous operations would start. First guess reaches a rendezvous trajectory within a tree days and a half, for a total delta-v 0.002 km/s. Then, the influence of the secondary design parameters are evaluated. Optimization process aims to minimize not only the total delta-v (for the three maneuvers) and the duration, but also the feasibility conditions (realistic intersection at Poincaré map).

This paper will present the influence of those design parameters on the cost function (total delta-v and duration) and will suggest some recommendations to plan a rendezvous at EML2.