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Author: Mr. Alberto Fossà
Institut Supérieur de l'Aéronautique et de l'Espace (ISAE), France, Alberto.FOSSA@isae-supaero.fr

Ms. Giordana Bucchioni
ISAE - Institut Supérieur de l'Aéronautique et de l'Espace, France,
giordana.bucchioni@ISAE-SUPAERO.fr
Mr. Emmanuel Blazquez
ISAE-Supaero University of Toulouse, France, emmanuel.blazquez@isae-supaero.fr
Dr. Elisabet Canalias
CNES, France, elisabet.canalias@cnes.fr
Prof. Stéphanie Lizy-Destrez
Institut Supérieur de l'Aéronautique et de l'Espace (ISAE), France,
Stephanie.LIZY-DESTREZ@isae-supaero.fr
Mr. Alain LAMY
Centre National d'Etudes Spatiales (CNES), France, Alain.Lamy@cnes.fr
Dr. Régis Bertrand
Centre National d'Etudes Spatiales (CNES), France, regis.bertrand@cnes.fr
Mr. Jean-Francois Goester
Centre National d'Etudes Spatiales (CNES), France, jean-francois.goester@cnes.fr

TWO AND THREE IMPULSES PHASING STRATEGY WITH A SPACECRAFT ORBITING ON A EARTH-MOON NRHO

Abstract

The increasing interests in Moon exploration has led, in recent years, to international collaborations between space agencies aimed to assemble and operate the Gateway, an orbiting spaceport located on a Near Rectilinear Halo Orbit (NRHO) about the second libration point of the Earth-Moon system (EML-2). In this context, transfer strategies between the Earth and the spaceport cover a key role for both assembly and resupply missions.

The presented work is thus focused on one leg of the transfer: the phasing strategy. This sees an active spacecraft, chaser, performing two or more maneuvers to reach a location in the vicinity of the passive Gateway before proximity operations can start.

The innovation brought by the proposed strategies is intrinsic in the scenario. The challenges related to such a complex operational environment require the design of novel phasing strategies that have never been implemented and rarely studied in the literature. In fact, the Earth-Moon condition opens new horizons for trajectory design that have never been explored before. The aim of this work is to take advantage of the peculiarity of the environment to explore new phasing approaches to take advantage of this complex environment offers.

The proposed phasing methods are designed exploiting the dynamical properties of Halo-orbits and associated invariant manifolds. The use of these trajectories may bring multiple advantages for the feasibility, reliability and energy savings of the maneuver. Such structures are mathematically formulated under the hypothesis of the Circular Restricted Three Body Problem (CR3BP).

Two strategies are investigated: Halo parking-orbit to NRHO two-impulse transfer and direct phasing with manifold exploitation.

The first strategy is an optimal two-impulse transfer departing an EML-2 southern Halo and targeting the baseline NRHO. Several members of the Halo-family are considered and a phasing constraint is included to ensure a proper target/chaser configuration at the transfer's start. It is demonstrated that viable transfer options exits with $\Delta V < 80\ m/s$ and total time of flight less than 40 days. The second strategy considers the chaser already injected on the Gateway's NRHO. Poincare maps are employed to identify unstable/stable manifolds intersections in search of low-energy phasing trajectories that leave the reference orbit along the unstable branch before re-entering it via the stable one. Three-impulse transfers with similar costs are found patching together these arcs.

The two strategies are thus compared to highlight their advantages and disadvantages with a particular focus on the future possible operational aspects.