Paper ID: 56043
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Author: Mr. Kir Latyshev
Skolkovo Institute of Science and Technology, Russian Federation, kir.latyshev@skoltech.ru

Ms. Sydney Dolan
Massachusetts Institute of Technology (MIT), United States, sydneyidolan@gmail.com
Dr. Bruce Cameron
Massachusetts Institute of Technology (MIT), United States, bcameron@alum.mit.edu
Dr. Olivier de Weck
Massachusetts Institute of Technology (MIT), United States, deweck@mit.edu
Prof. Edward Crawley
Massachusetts Institute of Technology (MIT), United States, crawley@mit.edu

TRANSFERS BETWEEN NEAR RECTILINEAR HALO ORBITS AND THE MOON FOR HUMAN LUNAR EXPLORATION MISSIONS IN CASE OF PERMANENT BASE AT THE SOUTH POLE

Abstract

The international space community is actively preparing for the next phase of human space exploration – sustainable exploration beyond low Earth orbit. It is almost universally agreed that this phase should start with returning humans to the Moon, this time with the intent of making human cis-lunar presence permanent. A habitable deep space station (currently known as the Gateway) is believed to be one of the key elements of the next human lunar exploration endeavor.

The station orbit choice will define the set of trajectories to travel between the Earth and the Moon and thus will greatly affect the lunar transportation architecture. One of the orbit classes currently seen as a promising Gateway location is near rectilinear halo orbits (NRHOs) near Earth-Moon libration points L1 and L2. In recent years, multiple investigations analyzing different aspects of having the Gateway in NRHO have been conducted. Among the issues considered are performance requirements for transfers between the Earth and NRHO, stationkeeping, eclipse avoidance. At the same time, the important operation of delivering humans from the Gateway to the lunar surface has received less attention in the literature.

This paper studies transfers between NRHOs and the lunar surface with the goal of identifying the corresponding performance requirements (delta-V, time of flight) for the elements of the human landing system (HLS) as well as surface access characteristics (surface access/departure frequencies, surface stay times). The analysis is limited to the case of a single landing site at one of the lunar poles. It is assumed that all transfers between the Gateway and the lunar surface are performed through an intermediate 100-km circular polar low lunar orbit (LLO). Trajectory modeling and optimization was performed in STK 11 within the force model that included the LP165P lunar gravity field to degree and order 8 and point-mass fields of Earth and Sun.

Two families of two-impulse NRHO-to-LLO and LLO-to-NRHO transfers that can be used for human missions are explored. It is shown that for nominal transfers, the optimal (in terms of delta-V) time of flight of 3-5 days can be significantly reduced (up to 0.5-1 day) for a relatively small additional cost in delta-V. Apart from nominal transfers, potential abort strategies are investigated. The necessity of having abort opportunities for human missions proved to impose certain restrictions on surface access frequency and increase HLS performance requirements. The numerical results are obtained for NRHOs of L1 and L2 types.