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OPTIMAL LAUNCH WINDOWS FOR ARTEMIS III AND BEYOND LEVERAGING CONTOUR MAPS

Abstract

The upcoming NASA Artemis missions will be incremental steps towards establishing a sustainable and long-term human presence in the vicinity of the Moon. While the first two missions will serve as proving grounds for the next generation of spaceflight vehicles, Artemis III and beyond will leverage a mission architecture that supports science operations in lunar orbit and on the surface. These subsequent Artemis missions will leverage the Gateway spacecraft, an orbital laboratory planned to be in a 9:2 lunar resonant Near-Rectilinear Halo Orbit (NRHO). While the NRHO provides many benefits to scientific operations, the multi-body gravitational regime produces complex dynamics that can make orbital transfers difficult to optimize. This study provides a comprehensive examination of NRHO rendezvous transfers subjected to operational constraints associated with Artemis III and beyond mission architectures. Analysis was performed using the Astrodynamics Software and Science Enabling Toolkit (ASSET) developed by the Astrodynamics and Space Research Laboratory at University of Alabama to generate an ephemeris model of an outbound NRHO rendezvous bounded by parameters such as Earth parking orbit, ΔV requirements, and transfer time constraints expected from Artemis III and subsequent missions to the NRHO. The ASSET model was used to compute ΔV optimal transfers to Gateway at different epochs corresponding to different positions on the NRHO. Optimality was confirmed via first order Karush-Kuhn-Tucker conditions. With an ephemeris model of the mission architecture verified, ASSET was then used to generate contour plots of transfer ΔVs across a range of Gateway rendezvous epochs and cis-lunar transfer durations. These contour plots allow mission designers to view the entire solution space over a selected window of dates instead of just point solutions for a given epoch, which is particularly useful for a problem that has multiple local minima. Further, these contour plots were used to create smooth launch windows that ensure optimal transfers for each launch date in the window. Finally, with a ΔV optimal launch window generated, a method was developed to convert the ASSET solutions rapidly and automatically into initial guesses to a Copernicus model. Copernicus is a point solution trajectory optimization tool used by NASA for trajectory design and flight operations on the Artemis missions. The benefit of this rapid conversion is that the ASSET contours can be used to explore the full solution space presented by the problem. Subsequently, optimal results can then be modeled and verified by Copernicus, the Artemis flight operations tool.