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MISSION DESIGN STRATEGIES FOR RENDEZVOUS AND SERVICING OF SUN-EARTH LIBRATION POINT MISSIONS

Abstract

With the launch of the James Webb Space Telescope (JWST) and future launches of the Roman Space Telescope (RST) and larger telescopes such as the proposed Habitable Worlds Observatory (HWO), the questions of where and how to rendezvous to enable servicing of these telescope missions arise. To aid in determining the allowable locations to rendezvous for servicing from a trajectory design approach, our previous research and analysis has shown feasible transfer trajectories between the Sun-Earth Libration L2 region (Quasi-Halo orbit) and the Earth Moon vicinity (Distant Retrograde Orbit (DRO), Quasi-Halo Orbit, Halo Orbit, and Near Rectilinear Halo Orbit (NRHO)), along with the related transfer constraints and the corresponding total fuel mass costs. We now focus on operational-like optimal scenarios for these transfers to complete a rendezvous to permit servicing at various Libration orbit locations. In this paper, we address how operational navigation and maneuver execution uncertainties impact the rendezvous timing and fuel mass (via ΔV). While optimization techniques are applied to ensure minimal ΔVs, we also analyze various transfer trajectory durations and rendezvous arrival geometries.

The analysis presented includes dynamical system approaches and applies optimization through several tools including the Adaptive Trajectory Design (ATD) module as an initial guess, numerical computation using the General Mission Analysis Tool (GMAT) and Systems Tool Kit (STK) with higher fidelity perturbation modeling, and recently developed optimization tools that incorporate dynamical systems directly into the optimization process. Transfer trajectory options examined include a direct transfer from Earth versus departures from the previously examined Earth-Moon regime orbits, e.g. NRHOs and DROs. A return from Sun-Earth to lunar vicinity for a complete servicing after a rendezvous in Sun-Earth orbit is also considered. The resultant ΔV's for each scenario is provided with discussions on various transfer trades, rendezvous considerations, and orbital limitations from the dynamical systems. A Poincare-like mapping of trajectory and rendezvous conditions categorize feasible and optimum transfer approaches, dependent on Sun-Earth orbit mission parameters.

The focus of this research addresses questions for upcoming trades regarding servicing options for current and future Sun-Earth L1 and L2 missions. By doing a comprehensive analysis approach (dynamical systems + high fidelity optimization with true operational constraints), this paper will serve as a guide for mission architecture and operational trade considerations.