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A SURVEY OF DIFFERENT CLASSES OF EARTH-TO-MOON TRAJECTORIES IN THE PATCHED THREE-BODY APPROACH

Abstract

The increasing complexity of modern space missions requires that N-body models N$\geqslant$3 are employed in the preliminary design of trajectories.

The simplest mathematical model to provide trajectories other than the Keplerian conics is the planar Circular Restricted Three-Body Problem (CR3BP). Fundamental solutions of the CR3BP have been used to obtain trajectories that fulfill modern space missions requirements. For example, in 2010, the two probes of the ARTEMIS mission navigated to the Earth-Moon L_1 and L_2 Lagrangian points and were kept in unstable quasi-periodic orbits to investigate how the Sun's radiation interacts with the Moon, and to survey the applicability of lunar regions as staging or communication relay locations. Also, the rescue trajectory for the Hiten mission is a paradigmatic example for a class of low-energy Earth-to-Moon orbits obtained by considering the gravitational effects of the Earth, the Moon, and the Sun on the motion of the spacecraft simultaneously. Such transfers can be obtained employing the patched three-body approximation in which the restricted four-body system Sun-Earth-Moon-Spacecraft is modeled by two coupled restricted three-body systems: Sun-Earth-Sc and Earth-Moon-Sc.

The present contribution investigates Earth-to-Moon transfers in the patched three-body approximation, exploiting alternative pathways involving a bi-parametric family of quasi-periodic orbits around the Earth in the Sun-Earth-Sc system, besides the standard transit-non-transit orbit connections which follow the transport channels provided by the invariant manifolds associated to unstable periodic orbits around the Lagrangian equilibria of the two subsystems. These alternative quasi-periodic solutions provide complete transfers with reduced flight time, while still providing ballistic capture into low lunar orbit.

In this work, we survey preliminary mission solutions obtained from sets of initial conditions around the Earth consistent with current infrastructure for space exploration and having distinct dynamical properties. In particular, we give concrete examples, comparing fuel consumption and total flight time of different solutions and analyze the patching possibilities for chosen departure and arrival energy levels, and optimal coupling phases.