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TRAJECTORY EVOLUTION IN MULTI-BODY REGIMES WITH APPLICATIONS IN THE SATURNIAN SYSTEM

Abstract

Recent discoveries by the Cassini spacecraft have generated interest in future missions to further study Saturn's moons. In planning tours of the Saturnian system, designing fuel-efficient trajectories is of primary importance. Incorporating multi-body dynamics into the preliminary trajectory design can significantly reduce the cost of maneuvers required to achieve various objectives. However, preliminary orbit design in a multi-body model is challenging; this work focuses on the development and application of design tools to facilitate preliminary trajectory design in a multi-body model.

Within the context of the Circular Restricted 3-Body Problem, the effects of a distant larger primary (P1) on the evolution of a trajectory in the vicinity of the smaller primary (P2) are investigated. By parameterizing trajectories in terms of radius and angle at a periapse passage, the short- and long-term behaviors of the trajectories are predictable. For a given value of Jacobi constant, the state of a trajectory at a periapse passage reveals whether it will escape the vicinity of the smaller body or remain in orbit about the smaller primary for a given span of time. Distinct shapes, outlined in the planar case by the stable and unstable manifolds associated with the L1 and L2 Lyapunov orbits, define regions of capture and escape.

Periapsis Poincaré maps are thus employed to define sets of initial conditions for which trajectories impact or escape the vicinity of P2 through the L1 and L2 gateways, to identify regions of initial conditions for which the spacecraft will remain captured for extended periods of time, to locate quasi-periodic trajectories in both the rotating and inertial frames of reference, and to identify trajectories with other notable characteristics, for example, quasi-frozen orbits in the inertial frame. Initial conditions that yield a trajectory with a particular set of desired characteristics can thus be easily selected from the maps. The analysis is performed in the Sun-Saturn and Saturn-Titan systems, with applications to future missions to explore Saturn's moons. The methodology is also applicable to other Sun-planet and planet-moon systems, including the Earth-Moon system. From experience, it is clear that these results can be transitioned to a full ephemeris model.

A previous work investigated the use of periapsis Poincaré maps in several Sun-planet and planet-moon systems for planar trajectories. The current work extends this analysis to the spatial case, investigating the evolution of out-of-plane trajectories and applying the results to trajectory design within the Saturn system.