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# TRAJECTORY DESIGN FOR SATURNIAN OCEAN WORLDS ORBITERS USING MULTIDIMENSIONAL POINCARÉ MAPS

**Abstract**

Missions involving low-energy orbits in the vicinity of planetary moons, such as Titan or Enceladus, involve significant end-to-end trajectory design challenges due to the gravitational effects of the distant larger primary. However, the resulting complicated design space also provides opportunities to exploit the multiple gravity fields to reduce maneuver costs and enable missions that would otherwise be infeasible. In this investigation, different types of Poincaré maps are incorporated in an intuitive, visual design process that facilitates preliminary orbit design in a multi-body model. Passage maps describe the short-term behavior of orbits near the smaller primary in the Circular Restricted 3-Body Problem (CR3BP) and are employed to design transits into and out of the region near a planetary moon. Long-term periapsis Poincaré maps reveal the extended behavior of potential science orbits near a moon. By overlaying the maps in an interactive design tool, and providing the ability to easily switch between maps of different types and at different energy levels, orbits in various regimes are linked into a continuous trajectory. The Deep Space Trajectory Explorer (DSTE) design tool allows the identification of families of solutions to a given orbit problem while providing the ability to easily incorporate changing inputs and requirements. Using the DSTE, trajectories within these sensitive planet-moon systems are easily and intuitively selected to satisfy mission constraints.

NASA has recently extended their New Frontiers program to include exploration missions to "Ocean Worlds." Potential applications include orbiters in the Saturnian system searching for signs of life and investigating the possible habitability of Saturn's moons. Enceladus orbits that transit geyser plumes and Titan flyby trajectories are of particular interest. In support of such mission concepts, the current investigation focuses on these complex orbit design objectives at Titan and Enceladus to maximize coverage of regions of interest. New capabilities are developed including visualization of multi-dimensional periapsis Poincaré maps to allow end-to-end trajectory design in the spatial problem. A highly interactive environment allows exploration of multi-dimensional maps and enables visual selection and connection of trajectory arcs. Candidate orbits are then analyzed in reference to volumetric spatial datasets representing targeted regions of interest; for example, geysers in the polar regions of Enceladus. An analysis of alternatives for suitability towards science objectives is developed for selected trajectories.