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INCORPORATING THE EVOLUTION OF MULTI-BODY ORBITS INTO THE TRAJECTORY TRADE SPACE AND DESIGN PROCESS

Abstract

Libration point orbits have been incorporated in many missions, with the capability of orbiting near L1 and L2 in the Earth-Moon system recently demonstrated during the ARTEMIS mission. While the available periodic and quasi-periodic orbits in the vicinity of the libration points have been well studied, this knowledge is not generally exploited during mission design. In this investigation, strategies to display information about the global solution space in the vicinity of the libration points are explored, and their incorporation into the mission design process is demonstrated.

Several distinct periodic and quasi-periodic orbit types are available in the vicinity of a libration point, and each may offer different advantages. As the Jacobi constant is evolved, the available libration point orbits transform significantly, thus, considering the general framework of the global solution space during mission design is useful. For Jacobi constants near the value corresponding to a collinear libration point, the solution space is defined by a small set of orbit types, namely, the planar and vertical Lyapunov orbits and their associated family of two-dimensional quasi-periodic tori. As the energy level is increased, the space evolves to include halo and quasi-halo orbits, and members of the axial family. A vast number of additional periodic orbits also emerge via period-multiplying bifurcations. For the various energy levels, the stability of the periodic orbits changes, leading to differences in the available quasi-periodic solutions as well. Incorporating knowledge about the evolution of the solution space into the trajectory design process allows the designer to select orbits best suited for the mission constraints, and to consider possible trade-offs between the various orbit types.

In this study, a general framework of the global solution space is charted, facilitating a rapid assessment of the available periodic and quasi-periodic solutions for a range of Jacobi constant values, or energy levels. A design process is presented that exploits information about the available orbit structures, and is demonstrated for several sample design scenarios. To explore the applicability of such a design process within mission design tools, these methods are applied within an interactive environment. Considering the global space, the desired orbits are first selected that best meet the mission requirements. Once the libration point orbits are selected, invariant manifolds may be computed and employed to facilitate transfer. Several mission design scenarios are considered, including transfers to and between libration point orbits. To enable an efficient design process, Poincare maps are employed.