Computation of libration point heteroclinic orbits in a coherent model for the Sun-Earth-Moon dynamics

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The dynamics about the libration regions of the Sun-Earth and Earth-Moon systems have been used for the last decades in several missions, both for nominal orbit determination and transfer trajectory design. Beyond such approaches, the gravitational influence of the Earth, the Sun, and the Moon can be combined to produce effcient transfers in the extended Sun-Earth-Moon-spacecraft system.

Historically, the dynamics of a small particle in the Sun-Earth-Moon system has been approximated as two coupled Circular Restricted Three Body Problems (CRTBP), the Sun-Earth (SE) and Earth-Moon (EM) systems. The hyperbolic manifolds of the orbits about EML2 and SEL1;2 provide dynamical channels that can be suitably combined to produce low-energy trajectories. This so-called coupled CRTBP approximation has been previously used to compute various types of connections, including low-energy Earth-Moon transfers, Earth-to-EML2 trajectories, and free SEL1;2-to-EMl2 transfers. The later type is of particular interest to better understand the natural coupling between the two systems that underlies all these low-energy transfers.

The coupled CRTBP approximation of the Sun-Earth-Moon system relies on the fact that the dynamics associated with the EM and SE subsystems are partially preserved in the four-body context. However, for every computed trajectory, this option requires both a specific Sun-Earth-Moon configuration and an arbitrary connection between the two CRTBPs, which prevents the use of this model as a basis for a systematic search.

In this talk, we discuss about the obtaintion of SEL1;2-to-EML2 heteroclinic orbits (free transfer orbits) in a single coherent model of the Sun-Earth-Moon system called the Quasi-Bicircular model. The sets of staging orbits and their associated hyperbolic manifolds are obtained semi-analytically at both ends of the transfer, using the parameterization method, taking into account the explicit time-dependency of the dynamics. A systematic search for connections is then performed in the parameterization space: initial conditions on the center-unstable manifold at EML2 are propagated forward in time and projected on the center manifold at SEL1;2. A transfer is found each time that the distance of projection is close to zero. These solutions are refined solving a two-point boundary value problem, for which the boundary conditions are easily written in the parameterization space. This process can be coupled with a continuation procedure to obtain families of natural connections and translated into very realistic models of the SEM regime by means of differential correction schemes.

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