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AGILE SOLAR SAILING IN THREE-BODY PROBLEM: MOTION BETWEEN ARTIFICIAL EQUILIBRIUM POINTS

Abstract

It is well-known that the circular restricted thee-body problem (CR3BP) yields five equilibrium solutions, or Lagrange points. Adding a solar sail to the CR3BP complements these Lagrange points with an infinite set of artificial equilibrium points (AEPs). The accessibility of these AEPs is only limited by the available sail technology, which can be expressed through the sail lightness number that is a function of the spacecraft mass to sail area. Using this lightness number, the infinite set of AEPs can be parameterised into equilibrium surfaces of constant lightness number.

Despite the wealth of AEPs available, the literature, as well as real mission concepts, usually target only one AEP. A clear example is the Sun-Earth sub-L1 point. Located along the Sun-Earth line Sunward of the classical L1-point, it allows for increased warning times for space weather events and as such will be targeted by the NASA Sunjammer mission, scheduled for launch in 2014.

Instead of targeting only one, static AEP, this paper investigates sail trajectories between different AEPs to generate an agile solar sail platform that allows for different mission objectives at different AEPs during different parts of the mission. To increase the range of mission possibilities even further, transfers between AEPs that are located on the same equilibrium surface are investigated along with transfers between different equilibrium surfaces (e.g. those attached to L1 and L2).

The overall objective is to minimise the time-of-flight required to move between these AEPs, requiring the solution to an optimal control problem. This paper defines this optimal control problem and finds solutions using a direct pseudospectral method.

Results are provided for transfers between a range of AEPs that are of particular interest. For example, transfers from a sub-L1 point to the AEP with the maximum out-of-ecliptic displacement are considered. From this vantage point, high-latitude observations of the Earth are enabled. In addition, to observe both the Earth's northern and southern hemispheres, transfers between AEPs located above and below the ecliptic plane are generated. Finally, to demonstrate transfers between AEPs on different equilibrium surfaces, transfers between the sub-L1 and sub-L2 points, Sunward of the L2-point, will be considered, which is an ideal viewpoint for astronomy and Earth observation.

Through the transfers introduced in this paper, an agile solar sail concept is created extending a static sail mission to a dynamic, multi-objective mission, combining a range of potential applications including space weather, Earth and astronomical observations.