ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (2) (4)

Author: Dr. Joan Pau Sanchez Cuartielles
Cranfield University, United Kingdom, jp.sanchez@cranfield.ac.uk

Dr. Camilla Colombo
Politecnico di Milano, Italy, camilla.colombo@polimi.it
Dr. Elisa Maria Alessi
IFAC-CNR, Italy, em.alessi@ifac.cnr.it

SEMI-ANALYTICAL PERTURBATIVE APPROACHES TO THIRD BODY RESONANT TRAJECTORIES

Abstract

In the past years, the idea of taking advantage of a sequence of resonant encounters with a given planet, or moon, in order to obtain a change on the trajectory that would otherwise require propellant consumption, has widely been considered in order to reduce the cost of interplanetary transfers. In the framework of multi-body dynamics, successive encounters with a third body, even if well outside of its sphere of influence, noticeably alter the trajectory of a spacecraft. A successful example of this is represented by the SMART-1 lunar mission, which used the perturbation of the Moon to raise the perigee of its orbit sufficiently to get ballistically captured by it. Other mission concepts have been hypothesised on the same basis, such as tours of planetary moons in Jupiter, Saturn or Neptune, as well as disposal strategies from Earth's High Eccentric or Libration Point Orbits.

With the previous framework of application in mind, the paper revises classical general perturbation approaches based on averaged dynamics developed by Brouwer (1959) and Kozai (1962), as well as Opik's close encounter theory. These methods have generally been applied to two extreme cases; the first is that of a spacecraft whose orbit always remains very far from the perturbing body (i.e., the ratio between the spacecraft and the third-body distance from the central planet is well below 1), while the second one is that of a spacecraft that at some point along its trajectory undergoes an extremely close approach of the third body, well within its sphere of influence. However, we also seek solutions that do not fall in any of the previous situations. These are trajectories that undergo close approaches that are in the order of the sphere of influence of the third body. We thus explore the accuracy of the classical averaging methods for this kind of scenario, but also explore a semi-analytical approach that is based instead on a series expansion in the mass parameter of the Circular Restricted Three Body Problem (CR3BP) as an extension of the so-called kick map method.

Hence, the paper attempts to gain insight into the accuracy of the different approximations, as compared with the motion in the CR3BP. The results explore the domains of applications for each technique for different orbits (i.e., semimajor axis, eccentricity and inclination), but also for different systems (i.e., Earth-Moon, Sun-Earth, Sun-Jupiter, etc) and resonant or non-resonant conditions.