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Author: Dr. Elisa Maria Alessi
IFAC-CNR, Italy, em.alessi@ifac.cnr.it

Dr. Camilla Colombo
University of Southampton, Italy, camilla.colombo@polimi.it
Dr. Joan Pau Sanchez Cuartielles
Advanced Space Concept Laboratory, University of Strathclyde, United Kingdom, jpau.sanchez@upc.edu
Dr. Markus Landgraf
European Space Agency (ESA), Germany, Markus.Landgraf@esa.int

OUT-OF-PLANE EXTENSION OF RESONANT ENCOUNTERS FOR ESCAPE AND CAPTURE

Abstract

In the past years, the idea of taking advantage of sequences of ballistic gravity assists has been widely considered to optimize interplanetary transfers. In the framework of multi-body dynamics, successive encounters with a third body affect all the orbital elements, though the main effect, exploited to reduce the propellant requirements, is the variation in semi-major axis and eccentricity. A successful example is represented by the SMART-1 lunar mission, which used the perturbation of the Moon to raise the perigee of the orbit to get captured by it. Other mission concepts have been hypothesized on the same basis, such as tours of planetary moons about Jupiter and Saturn. With this work we extend the studies performed so far, mainly established on a planar approximation and numerical explorations, to the three dimensional case. The aim is to address the role of the angle of approach with the third body in the variation of the pericenter of the orbit, providing an analytical estimation of the range of values this parameter must take in order to obtain a desired effect. When the trajectory does not lie on the same plane of the perturbing body, the secular variation of inclination and longitude of the ascending node due to third body perturbations must be taken into account. To assess these issues, we consider the Lagrange planetary equations applied to the third body perturbation, doubly averaging the variation of the Keplerian elements over one orbit evolution of the spacecraft and over one orbital evolution of the perturbing body. The energy change, which also depends on the approaching phase to the perturbing planet, is instead determined by an energy kick function, which can be easily computed by a first iteration of the Picard's method applied to the Lagrange planetary equations with third body perturbation. A successful sequence of encounters, i.e. one that achieves a beneficial change on the orbit of the spacecraft, can then be ensured by a combination of small leveraging maneuvers. As practical application, we show how to dispose spacecraft in highly elliptical orbits at the end of their life by either decreasing the perigee towards the re-entry into the atmosphere or increasing the perigee towards the Moon. The identification of the correct angle of approach with the Moon at the apogee of the orbit is a crucial aspect to achieve one situation or the other.