Paper ID: 17808
oral

ASTRODYNAMICS SYMPOSIUM (C1)
Mission Design, Operations & Optimisation (2) (7)

Author: Dr. Joan Pau Sanchez Cuartielles
Advanced Space Concept Laboratory, University of Strathclyde, United Kingdom, jpau.sanchez@upc.edu

Dr. Elisa Maria Alessi
IFAC-CNR, Italy, em.alessi@ifac.cnr.it
Dr. Daniel Garcia Yarnoz
Advanced Space Concept Laboratory, University of Strathclyde, United Kingdom,
Daniel.Garcia-Yarnoz@strath.ac.uk
Prof. Colin R. McInnes
University of Strathclyde, United Kingdom, colin.mcinnes@glasgow.ac.uk

EARTH RESONANT GRAVITY ASSISTS FOR ASTEROID RETRIEVAL MISSIONS

Abstract

The combination of their ability to deliver new insights into the solar system, their proximity to Earth and plausible future impact hazards have made near-Earth objects prime targets for future space missions. Science missions to these objects are becoming common, while more complex architectures, such as sample return mission and human exploration missions, are currently being discussed. In addition, recent advances in asteroid deflection technologies and dynamical system theory are now enabling new mission concepts, such as practical asteroid retrieval missions. This type of mission envisages the transport of entire objects, or large portions, from the original asteroid orbit back to the Earth's neighbourhood. As a consequence of the inherent costs of transporting a large mass back to Earth, this type of mission requires extremely low-energy transfers in order to become a practical option with near-term technology. One possibility to address this requirement is to analyse the behaviour of the stable invariant manifolds associated with libration point orbits of the Sun-Earth system. These asymptotic trajectories, combined with multiple Earth gravity assists, are natural gravitational paths that can be exploited to achieve extremely low-energy transfers. Though dynamical system theory provides effective methodologies to compute periodic orbits along with their associated stable invariant manifold, exploring a full set of trajectories can become computationally expensive, and even more so when combined with the sensitivities of multiple Earth encounters. This paper then proposes an alternative method for preliminary design of low-energy transfers exploiting multiple Earth resonant gravity assists. Instead of the computationally expensive process of numerically propagating a large set of stable invariant manifold trajectories, we propose to use a 3D extension of the energy kick function (Ross and Scheeres, 2007) to map the evolution of these manifold trajectories through several updates of their osculating elements after each perturbing encounter with the Earth. The osculating elements of these trajectories are updated by means of Picard's first iteration on each Keplerian element, where the perturbing forces of the third body (i.e., the Earth) are given by the Lagrange's planetary equations. This provides a rapid process to scan for sequences of Earth encounters that allow a favourable perturbation to the asteroid orbital elements. The procedure can then be used to optimise sequences of gravity assists for realistic target objects for asteroid retrieval missions and to define feasible distances on the Keplerian phase space from where transfers times for asteroid retrieval are plausible.