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Author: Mr. Burhani Burhani
Khalifa University of Science and Technology (KUST), United Arab Emirates, 100052952@ku.ac.ae

Mr. Adham Alkhaja
Khalifa University of Science and Technology (KUST), United Arab Emirates, 100049385@ku.ac.ae
Dr. Elena Fantino
Khalifa University of Science and Technology (KUST), United Arab Emirates, elena.fantino@ku.ac.ae
Dr. Roberto Flores
International Center for Numerical Methods in Engineering (CIMNE), Spain, rflores@cimne.upc.edu
Dr. Elisa Maria Alessi
Consiglio Nazionale delle Ricerche (CNR), Italy, elisamaria.alessi@cnr.it

A LOW-THRUST LUNAR CYCLER OF THE MOONS OF SATURN

Abstract

All our knowledge about Saturn and its icy ring system comes from the data obtained during the flybys of Pioneer 11, Voyager 1, Voyager 2 and Cassini, as well as from the observations carried out by Hubble Space Telescope. The discovery of water vapor plumes at the poles of Enceladus and other compelling evidence of the existence of subsurface water in the major moons of Saturn has driven scientific interest and revived plans to return to Saturn. In order to gain insight into the features of this planet and its Inner Large Moons (ILMs), i.e., Mimas, Enceladus, Tethys and Dione, an in situ mission is needed. In general, reaching orbit around a giant planet is very demanding in terms of fuel, partly due to the large amount of propellant required to decelerate and allow the spacecraft to be captured by the planet's gravity. It is even more challenging to achieve orbit around a system of moons very close to a giant planet, like the ILMs. The majority of the proposed solutions to tour the system of icy moons is based on the patched conics technique with chemical propulsion. The alternative, less costly approach proposed here is the concept of a lunar cycler of the ILMs based on low-thrust (LT) propulsion and low-energy transfers in the circular restricted three-body problems (CR3BP) composed by Saturn and each moon. For the lunar cycler, the hyperbolic invariant manifolds of planar Lyapunov orbits around the equilibrium points L1 and L2 of each Saturn-moon system are used to loop around the corresponding moon and to provide initial conditions to move between nearby moons. To carry out these moon-to-moon transfers, a control algorithm based on low-thrust maneuvers is designed and applied so as to minimize the amount of propellant consumed. In a previous work, LT and gravity assist with Jupiter was used to substantially reduce the hyperbolic excess speed at Saturn, hence LT can again be used to achieve these moon-to-moon transfers. Although using LT causes much longer transfer times than impulsive maneuvers, the spiraling orbital motion of the spacecraft can be exploited to collect data of the inter-moon environment, rings and moonlets.