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Author: Dr. Nicola Baresi
Surrey Space Centre, University of Surrey, United Kingdom, n.baresi@surrey.ac.uk

Dr. Diogene Alessandro Dei Tos
Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (JAXA), Japan, diogenealessandro.deitos@ac.jaxa.jp
Dr. Hitoshi Ikeda
Japan Aerospace Exploration Agency (JAXA), Japan, hitoshi.ikeda@isas.jaxa.jp
Dr. Yasuhiro Kawakatsu
Japan Aerospace Exploration Agency (JAXA), ISAS, Japan, Kawakatsu.Yasuhiro@jaxa.jp

ORBIT DESIGN AND MAINTENANCE IN THE ELLIPTICAL HILL PROBLEM WITH APPLICATIONS TO THE PHOBOS SAMPLE RETURN MISSION MMX

Abstract

Fifty years after the first images of the Martian moons were downlinked from the Mariner 7 and 9, Phobos and Deimos remain mysterious objects of the Solar System. On the one hand, the near-equatorial near-circular orbits of these remote bodies suggest that Phobos and Deimos are likely the product of a giant impact between a protoplanetary object and Mars' ancestor. On the other hand, the spectral and geophysical features observed by several spacecraft missions indicate that both of the Martian moons are extremely dark asteroids captured by the gravity well of the Red planet. The goal of the Martian Moons eXploration (MMX) mission–currently under development by JAXA and international collaborators–is to finally settle the debate on the moons' origin by retrieving pristine samples from the surface of Phobos. The samples will be collected in 2027 after extensive observation campaigns carried out from low-altitude retrograde orbits around the Martian satellite.

This paper presents the orbit design and maintenance strategy for the proximity phase of MMX. We will start by reviewing the equations of the elliptical Hill problem in order to account for irregular gravity field of Phobos. The resulting non-autonomous system is populated by families of quasi-periodic orbit invariant tori that are generated through numerical continuation procedures on stroboscopic mappings. Five baseline trajectories are selected with different altitude profiles to meet the scientific instrument requirements of the MMX mission. Each of the candidate trajectories is tested under navigation errors and mismodeled dynamics to assess the operational feasibility of the newly found solutions and identify points of minimum and maximum sensitivity. A two-burn impulse per day strategy is implemented in order to track the reference retrograde orbits. Preliminary results show that the proposed relative trajectories can be maintained around Phobos for more than 30 days with less than 10 m/s.