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NAVIGATION ANALYSES AND TRADE-OFFS FOR THE MARTIAN MOON EXPLORATION MISSION AROUND PHOBOS

Abstract

The origin of the Martian moons Phobos and Deimos is still unknown despite years of intensive scientific observation of the Martian system. Current theories, which are still under debate, include the capture of the moons by the Mars gravity field from the main asteroid belt or a giant collision between proto-planets. A precise characterization of high order gravitational harmonics could inform on the internal mass distribution of the Martian moon, thereby shedding light on its origin. In this respect, the Martian Moons eXploration (MMX) mission could be a game-changer.

The MMX mission is planned to be launched in 2024 and is designed to closely examine the two Martian moons, Phobos and Deimos. It will be the first mission to observe the surface of the moons in great detail since the Phobos 1 and 2 missions. Furthermore, it will attempt to retrieve pristine samples from the surface of Phobos and return them back to Earth by the end of this decade.

Presently, five planar Quasi Satellite Orbits (QSO) with different reference altitudes around Phobos are under consideration in order to characterize and study the geophysical environment of the Martian moon. Preliminary navigation analyses carried out by our research group revealed that quasi-periodic trajectories, such as spatial retrograde orbits (3D QSOs) and in-plane Swing QSOs, could be capable of delivering better information on the gravitational field of the moon. To solidify and build upon these findings we have used a more complete dynamical model that considers the coupling between Phobos's libration motion and Mars's oblateness.

The MMX's navigation system is designed to rely on ground-based observables but is also equipped with a LIDAR and two onboard navigation cameras. A further objective of our analysis is to assess the performance of an autonomous navigation system that can rely solely on data generated onboard, without ground intervention. The capability to navigate without relying on the Deep Space Network's references could be key to completing certain mission phases, by avoiding the significant time delays throughout the Martian mission pertaining to data links with Earth.

In addition to this, the navigation observables' models have been improved by adding biases to LIDAR measurements and synthetic images, which have been generated for optical navigation. The improved navigation study demonstrates better mission performance and characterisation of the surface of Phobos, even when only data from autonomous navigation are used.