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# MARS-PHOBOS SYSTEM DYNAMICS EXPLOITATION FOR MARTIAN EFFECTIVE CONSTELLATIONS DESIGN

**Abstract**

Interest in Mars has been increasing for many years, as witnessed by the numerous robotic missions flown so far. Missions' main objective is not only to perform intense studies of the Mars environment but also to prepare the framework to support next decades manned and robotic expeditions.

As long as interplanetary missions are considered, ground operations represent a significant portion of the overall technical and financial effort of a space mission, since the Earth link is still the baseline to answer the navigation needs of a planetary probe. Moreover, Phobos is considered a site of interest as an outpost to lighten the required effort for future missions.

To cope with multiple scientific and technical demands and facilitate lighter, cheaper, easier to operate planetary spacecraft implementation, a versatile local infrastructure which takes care of communication relay and navigation services in martian environment would be greatly beneficial.

The paper proposes a distributed space infrastructure to offer the Martian environment continuous spatial and temporal coverage and takes advantage of the multi-body dynamics environment offered by Mars and its moons to effectively design a proper constellation.

Quasi Satellite Orbits (QSO) are considered to maximize the Martian moon's coverage while lightening the station keeping demand. Indeed, stability regions are observed for defined ranges of distances with respect to the moon. QSOs give the satellites the possibility to hover the moon, even if its gravitational pull is too weak to allow closed canonical orbits. These trajectories seem to be promising to enhance the Martian moon's scientific observations.

The constellation coverage is increased by coupling the QSOs with triangular point orbits, such as Tadpoles and Horseshoes to serve the Martian equatorial regions too with a continuous communication relay service. Moreover, Phobos' proximity to the red planet's surface guarantees a higher data-rate compared to higher-altitude trajectories (such as Areostationary orbits).

The non-Keplerian dynamics is well suited for supporting the navigation service to users with no need for ground-based observations. Indeed, the asymmetry of the gravitational field avoids state reconstruction ambiguity when only relative measures are available: relative measurements are enough to reconstruct the absolute state of all satellites in the constellation, which is a mandatory functionality to offer the users a calibrated reference for navigation. The paper explores the topic of Martian constellation design, focusing on the possible orbital architectures, and studying the advantages and disadvantages in terms of navigation performance, constellation maintenance, and communication with Martian users.