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PERTURBATION THEORY BEYOND THE SPHERE OF INFLUENCE OF A NATURAL SATELLITE WITH APPLICATION TO THE MARTIAN MOONS

Abstract

One of the stages of the Russian Phobos-Grunt mission is the rendezvous of the spacecraft with Phobos, which is made by means of an observation orbit followed by a quasi-synchronous orbit that ensures successful landing [1]. Quasi-synchronous orbits are particular cases of the so-called quasi-satellite orbits of the restricted three-body problem, which are large orbits about the smaller primary (when compared to the radius of its sphere of influence) with retrograde rotation.

Quasi-satellite orbits have been studied in the planar elliptic Hill problem assumptions by several authors (see [2] and references therein). Numerical or analytical-numerical procedures are the common approach, while a general analytical theory has been claimed not to be representative enough for the real Mars-Phobos case. However, higher orders in the computation of perturbation theories are easily reached in this era of computational plenty, which extend their applicability to broader regions in phase space [3].

With the elliptic restricted three-body problem as a model, we compute a higher order, analytical theory based on averaging. Because parallactic terms have been demonstrated to have noticeable quantitative effects in the evolution of quasi-satellite orbits [4], we do not limit to the Hill problem model in our approach and take parallactic terms into account up to the third order. In addition, given that quasi-satellite orbits may have very close arcs to the central body, we also consider the non-centrality of the satellite's potential as given by its oblateness and ellipticity coefficients.

The small parameter of the perturbation method is the ratio of the distance between the spacecraft and the central body to the distance between the primaries, and the averaging is conveniently performed in Delaunay variables in closed form. Despite the known singularities of Delaunay variables for low eccentricities or inclinations, once the generating function of the averaging is computed, it can be applied to any function of Delaunay variables, hence the transformation can be suitably expressed in non-singular elements.

Numerical integrations of the non-averaged problem show that the analytical theory provides a very good approximation in the case of quasi-satellite orbits of the Phobos- and Deimos-Mars systems.

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