IAF ASTRODYNAMICS SYMPOSIUM (C1)
Orbital Dynamics (1) (6)

Author: Dr. Marc Jorba-Cuscó
Centre National d'Etudes Spatiales (CNES), France

Dr. Richard Epenoy
Centre National d'Etudes Spatiales (CNES), France

LEVERAGING MANIFOLDS OF TORI ASSOCIATED WITH QUASI-SATELLITE ORBITS TO DESIGN LOW-FUEL MARS-PHOBOS TRANSFERS

Abstract

Quasi-Satellite Orbits (QSOs) are considered by JAXA's MMX mission, in which CNES is involved [1], for the scientific observation of the Martian moon Phobos prior to landing and sample return operations. These periodic orbits, originally defined in the Mars-Phobos Circular Restricted Three-Body Problem, generally lose periodicity once the eccentricity of Phobos' orbit is taken into account. In this case, QSOs are replaced by quasi-periodic tori [2]. Recent work on MMX project include, amongst many others, station-keeping strategies around QSOs exploiting invariant tori [3]. This study has been carried out considering the elliptical Hill problem.

In this work, we first compute a resonant QSO in the Mars-Phobos Circular Restricted Three-Body Problem. Then, by continuation on the eccentricity of the secondary, we build a family of periodic QSOs parametrized by the eccentricity in the Elliptic Restricted Three-Body Problem. Notice that considering resonant orbits enables us to preserve the periodicity of the QSOs when the eccentricity is non-zero. After reaching the eccentricity of Phobos, we build a family of invariant tori by continuation on the frequency till convergence to the target torus. The tori are computed here in the Elliptic Restricted Three-Body Problem. As a matter of fact, the later model is more precise than the Hill problem at far distance from the secondary and thus more adapted to handle Mars-Phobos transfers. In the next step, we compute the stable invariant manifold emanating from the target torus. Finally, we build nearly-ballistic two-impulse transfers between a parking orbit around Mars and different points on the manifold trying to minimize the total delta-v. Interesting transfer trajectories will be shown allowing for a ballistic capture by Phobos. Here, instead of targeting directly a QSO as done in [4], the spacecraft reaches first the invariant manifold before coasting along the manifold until encountering the target torus.

References

[1] Elisabet Canalias, Laurence Lorda, Julien Laurent-Varin, "Design of Realistic Trajectories for the Exploration of Phobos", *AIAA Space Flight Mechanics Meeting*, 8-12 January 2018, Kissimmee, USA.

[2] Àngel Jorba and Jordi Villanueva, "On the Persistence of Lower Dimensional Invariant Tori under Quasi-Periodic Perturbations", *Journal of Nonlinear Science*, Vol. 7, pp. 427-473, 1997.

[3] Nicola Baresi, Diogene Alessandro dei Tos, Hitoshi Ikeda, Yasuhiro Kawakatsu, "Orbit Design and Maintenance in the Elliptical Hill Problem with Applications to the Phobos Sample Return Mission MMX", Paper IAC-19-C1.4.7, 70^{th} *International Astronautical Congress*, 21-25 October 2019, Washington D.C., USA.

[4] Kenta Oshima and Tomohiro Yanao, "Spatial Unstable Periodic Quasi-Satellite Orbits and their Applications to Spacecraft Trajectories", *Celestial Mechanics and Dynamical Astronomy*, 131:23, 2019.