Orbital Operations Strategy in the Vicinity of Phobos

Hitoshi Ikeda,[1*] Shinji Mitani,[1] Yuya Mimasu,[1] Go Ono,[1] Kenichiro Nigo,[1]
and Yasuhiro Kawakatsu[1]
[1]*JAXA, Japan*
ikeda.hitoshi@jaxa.jp

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Interest in the exploration for the Martian moons Phobos and Deimos has been growing, with the view of not only the scientific aspect but also the potential destination for future human exploration. The Japan Aerospace Exploration Agency (JAXA) is currently studying the possibility of Martian moon exploration mission that surveys two Martian moons, and return samples from Phobos. The scientific objectives of the mission are to reveal the origin of the Martian moons, and further our understanding of planetary system formation and of primordial material transport around the border between the inner and the outer part of the early solar system.
Following the Earth-Mars transfer phase, the Mars Orbit Insertion (MOI) operation that consists of three large maneuvers, will be conducted to enter orbit around Mars. After the MOI operation, spacecraft will be injected into Phobos coplanar orbit and perform the terminal rendezvous for Phobos. As the nominal scientific orbit, Quasi-Satellite Orbit (QSO) is adopted in consideration of the characteristic dynamical environment of Mars-Phobos system. QSO is a periodic orbit in CR3BP and a type of Distant Retrograde Orbit (DRO)[1]. In order to make scientific observation of Phobos and to acquire the samples from Phobos' surface, several kind of operation will be performed. The proximity operation is classified into eight cases, especially from the point of view of spacecraft dynamics (Fig. 1.)
As to the orbit transfer between different altitude QSOs, a 3-impulse method and a swing QSO method are evaluated. Three-impulse method is known as an optimal transfer for fuel consumption[2], however the method consists of three impulses in the direction of along-track at periapsis and apoapsis that will only work if all manoeuvres succeed. On the other hand, swing QSO method that uses liberating stable QSO, is relatively robust for delta-V error and enable safer orbital transfer between different QSOs.
In parallel with the trajectory analysis, orbit determination covariance analysis was conducted that consider the dynamical model error (e.g., Phobos gravity, Phobos ephemeris, Mars gravity, Mars ephemeris, Solar radiation pressure). According to the OD analysis, the error of Phobos gravity and ephemeris become dominant error sources and have a significant impact on the navigation accuracy and stable operation at low altitude. In order to improve the OD accuracy, we must estimate the Phobos gravity and ephemeris using radiometric, optical, and altimetric measurements.
In this paper, the results of trajectory analysis in terms of the terminal rendezvous, QSO insertion, maintenance, transfer, hovering and utilization of 3D-QSO are describes. The navigation strategy around Phobos is also mentioned.

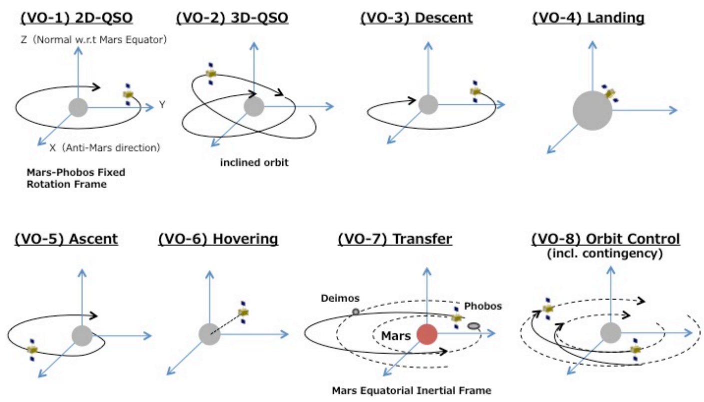

Fig. 1 Proximity Operation

References
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