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MISSION DESIGN FOR CLOSE-RANGE LUNAR MAPPING BY QUASI-FROZEN ORBITS

Abstract

With the growing interest in returning humans back to the Moon as a testing-ground for future manned inter-planetary missions, lunar missions have once again taken center-stage among mission designers. In particular, recon-missions for hi-resolution, accurate mapping of the lunar surface is the need of the hour. Historically, design of lunar missions, in general, and low-altitude missions, in particular, have suffered from inaccuracies due to unavailability of a high-fidelity gravity model. JPL's Gravity Recovery and Interior Laboratory (GRAIL) mission provided the Lunar gravity model with much improved accuracy, allowing better design and execution of future missions. Incorporation of high-fidelity models become indispensable for low-altitude orbit design and station-keeping (SK) purposes due to the Moon's peculiar gravitational anomalies.

NASA in 2018, confirmed the presence of water-ice on the south-pole of the Moon, which could be used as in-situ resources for future lunar manned missions. This would require hi-resolution, close-range imaging of the surface, especially, the south-pole for identifying usable landing spots and planning exploration routes. Due to lumpy gravity field of the Moon, sustaining a spacecraft in a low-altitude orbit generally translates to unrealistic station-keeping SK budgets, whereas frozen orbits are extremely rare, occurring only at specific inclinations. We have identified candidate quasi-frozen orbits (QFO) [1] and provided respective SK budgets for sustenance over a period of one month in the presence of a high-fidelity lunar gravity model and third-body perturbations from the Earth and Sun.

In this paper, we study transfer trajectories from a geostationary transfer orbit to a candidate QFO. Specifically, we investigate the utility and advantage of hybrid optimization methods to overcome the typical challenges associated with solving such challenging optimal control problems with increased complexities due to the Moon's gravitational model. We have developed a framework [2] for trajectory design in highly-perturbed environments and its utility for low-Earth orbit transfer maneuvers is demonstrated while taking into account the perturbations due to first four zonal harmonics. Due to the many-revolution, long-time of flight and the complicated gravity model, a hybrid strategy will be incorporated in the framework and its application for the problem will be investigated.

References:

[1] Feasibility study of quasi-frozen, near-polar and extremely low-altitude lunar orbits, Sandeep Singh, R M Woollands, E Taheri and John Junkins, AAS/AIAA SFM Conference, January 2019

[2] Efficient Computation of Optimal Low Thrust Gravity Perturbed Orbit Transfers, R M Woollands, E Taheri and John Junkins, AAS/AIAA SFM Conference, January 2019