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THREE-BODY MOON-MARS TRANSFER WITH REVISITED WEAK STABILITY BOUNDARY CONCEPT AND AEROBRAKING CAPTURE

Abstract

In recent years, the next declared goal of the human race is landing on Martian soil and, in view of this, the roadmap to Mars envisages, as an intermediate step, the creation of a Moon Village in order to accumulate experience of extraterrestrial life, improving the technological and generation capabilities of energy sources outside our Earth. In light of this, the study carried out within this research work tries to explore possible ways for future unmanned supply missions to the Martian soil both in preparation for subsequent human exploration and for the creation of a possible Mars Village.

Therefore, this paper presents a minimum propellant study for an interplanetary trajectory from the Moon to Mars, focusing on exploiting Weak Stability Boundary (WBS) trajectories and implementing an aerobraking ballistic capture at Mars. The mission assumptions at departure include low-thrust maneuvers, three-body perturbation, and JPL's DE432s ephemerides for the Moon position at epoch. The payload fraction is maximized via a direct shooting method.

The escape trajectory from the Earth-Moon binary system towards Mars is optimized by a revised WSB trajectory that includes an Earth-gravity assisted slingshot at departure. The epoch-dependent position of Mars and the cost to reach it from Earth are derived by solving the Lambert problem and by slicing isocurves at the threshold identifying solution at lower cost using WSB trajectories or traditional Earth-gravity assist strategies. The spacecraft state at the Earth-Moon sphere of influence is patched to the heliocentric leg, which evolves under Keplerian motion.

The Mars planetocentric phase culminates in the aerobraking capture, which implements the Mars Global Reference Atmospheric Model (Mars-GRAM) based on the NASA Ames MGCM and MTGCM data for altitudes respectively below and above 80 km. The analysis includes a study of the trade-off between ΔV and thermal loads during the aerobraking phase in the rarified Martian atmosphere, calculated with the software SPARTA(that executes the Direct Simulation Monte Carlo method), by discretizing the minimum periapsis capture radius at different heights.

Results clearly show that there is a significant bifurcation phenomenon between using WSB trajectories and traditional Earth-gravity assist strategies. Future studies could explore the possibility of using Deimos and Phobos gravity assists to further optimize trajectories and reduce mission costs.