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MISSION DESIGN AND ANALYSIS FOR MARS AND PHOBOS MISSIONS VIA LUNAR AND MARS-PHOBOS DISTANT RETROGRADE ORBITS

Abstract

This paper focuses on the mission design and mission analysis for missions destined to explore Mars and Phobos departing from a lunar Distant Retrograde Orbit (DRO) and arriving into a Mars-Phobos DRO. A Mars-Phobos DRO is a relatively stable environment which would make both the surfaces of Mars and Phobos available for a reasonable propellant expenditure. If refueling was available at the departing lunar DRO and at the targeted Mars-Phobos DRO via the use of In-Situ Resource Utilization (ISRU) by, for example, mining Earth's Moon and Phobos, lunar DRO to Mars-Phobos DRO transfers would require as low as a third of the total mission Δv per mission segment required for direct Low Earth Orbit (LEO) to Low Martian Orbit (LMO) transfers that do not make use of intermediate refueling. This paper lays out the Concept of Operations (ConOps) for possible Mars and Phobos robotic and human exploration missions that utilize such ISRU opportunities, with an emphasis on mission analysis to maximize the mass delivered to cis-martian space. Results regarding total Δv and Time-of-Flight (TOF) for various arriving Mars-Phobos DROs using full ephemeris planetary data are presented. Such results show that propellant-optimal trajectories from lunar DROs to a specified Mars-Phobos DRO could be used to develop staging locations in Mars-Phobos DROs to explore both Mars and Phobos at a reasonably low propellant expenditure. In fact, direct LEO to LMO trajectories would have higher overall mission Δv due to the additional stops at lunar DRO and Mars-Phobos DRO; however, the proposed mission design would have considerably lower Δv per mission segment, and thus lower initial mass in LEO (or lower gear ratio) thanks to the added "pit stops" located at the proposed DROs. This results in a lower overall spacecraft dry mass that needs to be launched into space from Earth's surface. Alternative mission ConOps present in the literature and that do not make use of lunar DROs and/or Mars-Phobos DROs are provided and compared to the main aforementioned ConOps.