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Mission Design, Operations and Optimization - Part 1 (1)

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TRAJECTORY DESIGN IN PROXIMITY OF MARS FOR ROUND-TRIP MISSIONS

Abstract

We present mission configurations for round-trip expeditions to the Mars system that access one of its moons, Phobos and Deimos, or the planet's surface. With applications to both robotic sample-return missions and human expeditions, we explore trajectory design options and strategies in proximity of Mars assuming short-stay and long-stay options. Phobos and Deimos are of scientific interest for determining the origins of the moons and providing insight into Mars's past. Such a mission can be conducted by robotic emissaries or astronaut-geologists during precursor missions to the Martian system before a surface landing is attempted. We present maneuvers required to visit either one or both Martian moons given the spatial and temporal boundary conditions of the arriving and departing asymptotes dictated by the mission's heliocentric trajectory. Assuming an impulsive propulsion system, we discuss strategies for minimizing propellant usage including the use of aerobraking. A sample-return mission to Mars's surface is considered an important step towards understanding the planet's warm and wet past, since a laboratory analysis of soil and rock samples can provide more insight than remote sensors. For human missions to the surface of Mars, a widely held and long-term goal of space exploration, we investigate trajectory design options related to the Mars orbit rendezvous architecture. This mission concept, analogous to the Apollo lunar architecture, calls for the interplanetary spacecraft transporting crew to be parked in Mars orbit, while a small transfer vehicle descends the crew to a pre-deployed surface habitat. For the return leg, the crew ascends back to the interplanetary spacecraft, ditches the small transfer vehicle, and executes a trans-Earth injection maneuver. Since the interplanetary spacecraft, along with its equipment and supplies necessary for long-duration spaceflight and Earth reentry vehicle, would be significantly more massive than the dedicated Mars ascent vehicle, it is of interest to park the former in a high-energy, highly elliptical Mars orbit while the crew conducts its surface mission to minimize the propellant needed for trans-Earth injection. We study the stability and control of such a high-energy orbit to satisfy boundary conditions for entry and exit from the Mars system while maintaining accessibility requirements from the landing site. We provide results from numerical simulations of design reference trajectories for robotic and human missions and find that propulsive requirements fit near-term chemical capabilities.