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Continuous Mars Habitation with a Limited Number of Cycler Vehicles

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We present cycler and semi-cycler trajectories to transport crews from Earth to a Mars base and back. It is assumed that the Mars base should never be abandoned and that the cycler vehicles safely and comfortably transport twelve people at a time. Since these cycler vehicles involve a significant investment, as few as possible should be built. We examine trades between the number of vehicles, the trajectory ΔV, and the crew mission duration. The trajectory ΔV drives propulsion system requirements and the mission duration affects the crew's health. One-, two-, and three-vehicle scenarios are presented to sustain the colonization of Mars.

I. Introduction

The appeal of traveling to Mars in a safe, comfortable, and (consequently) massive interplanetary transfer vehicle has produced much interest in cycler and semi-cycler trajectories. These trajectories replace propulsive maneuvers at Earth, Mars, or both with gravity assists, thereby transferring the ΔV requirements of the transfer vehicle to a smaller taxi vehicle. Thus as the ratio of transfer vehicle to taxi mass increases, cyclers and semi-cyclers could become less expensive than traditional missions (i.e. architectures without gravity assists).

Assuming that the crew transits between Earth and Mars are short (at most one year) and that Mars is to be continuously inhabited, significant trades develop between the number of transfer vehicles, the duration the crew is away from Earth, and the trajectory ΔV requirements. In previous mission studies, it is assumed that the crew stays on Mars for approximately 1.5 years before returning to Earth, and that Mars is uninhabited for several months before the next crew arrives.[1–11] On the other hand, it may be prudent to construct a permanent base on Mars and continue exploration and development of Mars without interruption. In this case, the crew remains on Mars for two to four years, significantly increasing the time they are away for Earth. Also, transportation architectures have previously involved two,[4,6] three,[5,10] or four[11] cycler vehicles. We examine four different cycler and semi-cycler architectures: 1) one outbound cycler vehicle with one inbound cycler, 2) two outbound cyclers with one inbound cycler, 3) one outbound cycler with two inbound cyclers, and 4) a single semi-cycler vehicle.

II. Modeling Assumptions

The semi-cycler and cycler trajectories are modeled as conics in a point-mass gravity field. All gravity assists are modeled as instantaneous rotations of the $\mathbf{V}_\infty$ vector, and the minimum flyby altitude is 300 km above the planet's surface. Single-vehicle semi-cyclers are constrained to have a total time of flight (TOF) of less than one synodic period (780 days). The ΔV is minimized in all cases.

Earth taxis include a single upper stage to depart LEO and rendezvous with the cycler vehicle. Mars taxis include three stages: 1) a descent stage for landing, 2) an ascent stage to launch from the surface to low-Mars orbit, and 3) an upper stage to depart LMO and rendezvous with the cycler. The rendezvous ΔV is approximated as

$$\Delta V_{\text{rendezvous}} = \Delta B / \Delta T \tag{1}$$

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