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Author: Dr. Ralph L. McNutt, Jr.
Johns Hopkins University Applied Physics Laboratory, United States

Mr. william Alan Delamere
Delamere Support Services, United States

HUMAN EXPLORATION OF MARS: COST REALITIES OF A FIRST MISSION

Abstract

There is a growing discussion of sending humans to Mars. NASA discussions, as detailed in the Mars Design Reference Architecture (DRA) 5.0 and its more recent derivatives, envision multiple launches in support of ground activities in the Mars system, as well as providing for propellant for the return home. Even for minimum energy transfers, the total velocity change is ∼10 km/s. This physical reality, along with requirements of mass for food, breathable air, potable water, and living space for a minimum crew size drive the scope of the effort. Even with the use of *in situ* resource utilization (ISRU) to provide propellant for a return to Earth with maximum recycling of expendables, the mission scope will still be large. For the sake of "bounding the box," the simplest mission is to send a few people to the surface of Mars, place a footprint, and return to Earth safely. Cost is ultimately driven by the initial mass in low Earth orbit (IMLEO). For the lowest energy conjunction-class missions, trip times are ∼900 days with stays of up to ∼500 days at Mars. Opposition-class missions can cut the total time to ∼500 days, at the expense of larger energy requirements, a shorter stay of ∼1 month at Mars, and the use of a gravity assist at Venus. Such numbers are not new; they have been well known since the time of the Early Manned Planetary-Interplanetary Roundtrip Expeditions (EMPIRE) studies of the 1960s. Two things are new: (1) we have lost the capability to build nuclear thermal rocket (NTR) engines, developed under the Nuclear Engine for Rocket Vehicle Application (NERVA) program of the 1960's and 1970's and (2) we have learned what is required to design, assemble, and maintain a six-person permanent outpost in space, the 420-mt International Space Station (ISS). At a zeroth level of analysis, a 400-mt interplanetary transfer vehicle taken through a delta-V of 10 km/s at an NTR specific impulse of 850 would require a total IMLEO of ∼1300 mt. Scaled to the ∼$150 B cost for the ISS, the IMLEO would imply $500 B for a Mars mission, which does not include the cost of the nuclear items and contingencies. These simple scalings suggest that up to ∼$1T for a "foot-print" mission to Mars is not an unreasonable cost estimate.