IAF HUMAN SPACEFLIGHT SYMPOSIUM (B3)
Advanced Systems, Technologies, and Innovations for Human Spaceflight (7)

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REUSABLE MARS TRANSPORTATION ARCHITECTURE MODELING FOR LARGER CREWED MISSIONS

Abstract

NASA and its international and commercial partners are returning to the Moon, with a human mission to Mars following in the late 2030's. Larger Mars surface architectures, such as the NASA-award-winning Pale Red Dot by MIT, with 2 nearby sites and 36 crew for surface endurances up to 10 years, would require extensive transportation logistics for cargo and crew. Currently, however, most Mars transportation architectures are being studied and designed for the needs of a single, one-off mission, with a small number of crew, and for endurances from 30 to 600 days. This results in space transportation architectures that do not scale well in terms of cost per ton to the surface of Mars, or to architectures which do not specifically prioritize minimizing radiation dose received in transit. The resulting transportation architectures are not optimized to support future, larger and longer-enduring Mars surface architectures. Hence, we studied a fully-reusable space transportation architecture with the objectives of minimizing radiation exposure for crew, and minimizing cost per ton to Mars for cargo. We assume that crews board the transit spacecraft once it is fully fueled at a high-Earth orbit, and that the TMI burn occurs at perigee, for a non-Hohmann fast transfer. The analysis for crewed flights traded the number of crew, the mass, material and design of radiation shield, and number of tanker launches required to estimate minimum transit time. For cargo flights, the analysis focused instead on the minimum number of tanker launches to deliver 100 tons of cargo to Mars. For crewed transits, using a SpaceX Starship-class vehicle, we estimated that 18 crew with a 70-ton, 35-cm polyethylene radiation shield would require 19 tanker flights to achieve a 113 day (average) outbound transit to Mars starting from a 250 x 200,000km departure orbit and an estimated 84 mSv effective dose of radiation. Return legs would take longer, resulting in 126 mSv of effective dose. For cargo transits, 3 tanker flights to LEO were required to deliver 100 tons of payload to the surface of Mars, with departure from LEO. The analysis informs investment in foundational space transportation technologies and capabilities. Key enabling technologies that need to be matured so as to support large-scale crewed missions to Mars are orbital demonstration flights of reusable upper stages, orbital propellant transfer, crew rendezvous in HEO and propulsive EDL on other bodies.