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ANALYSIS OF A MANNED MARS MISSION WITH NUCLEAR ELECTRIC PROPULSION (NEP) SYSTEM

Abstract

The goal of this paper is to analyze the performance of a ion NEP system for a manned mission to Mars. The objectives are to evaluate whether NEP could reduce journey's time and mass of propellant compared to chemical and Nuclear Thermal Propulsion (NTP). To these authors' knowledge this is the first time that a manned Mars mission using NEP has been analyzed in detail. The trajectory assumed consists in a slow acceleration spiral to leave LEO, followed by acceleration with constant thrust after reaching escape speed until a ΔV = 16.68 km/s (with a 333 MWt reactor), or 20.75 km/s (500 MWt reactor) has been achieved. Thereafter the spacecraft decelerates, with a final ΔV = -21.19 km/s (333 MWt) or -25.18 km/s (500 MWt). These are the ΔV needed to capture a Low Martian Orbit (LMO) through a spiral. Reactor sizing has been realistically done using Los Alamos National Laboratory data for Particle Bed Reactors. The shield uses Be, LiH and W and its architecture has been designed based on a simplified model obtained with the neutronic MCNP code. After optimization, reactor mass, including shielding, is 4600 kg (333 MWt), and 5000 kg (500 MWt). The NEP system consists of a parallel assembly of 20 (30) ion thruster modules, each with thrust 15.55 N, beam diameter 0.4 m and power 5 MWe. Total thruster power assumed after thermal to electric conversion is 100 MWe (150 MWe). Specific impulse with Xe propellant is 32,780 s, 30 times greater than that of a NTP system using hydrogen. The calculated non-Hohman trajectory with a 333 MWt reactor yields 400 days (316 days with a 500 MWt reactor) transit time. Return does not depend on planetary conjunction. Total spacecraft mass to lift to LEO is 112 t for a 333 MWt reactor (120 t for 500 MWt). The spacecraft mass budget at convergence includes structure, propulsion system, propellant, environmental control and life support system, water, avionics, crew, crew accommodation (including food) and modules for Mars landing and travel back to Earth. Calculated propellant consumption is only 20-30% the total mass of the spacecraft. Since this mission foresees a stay on Mars, the mass budget includes also modules and equipments to allow activity on the planet. The conclusions indicate that NEP is likely a serious contender for more economical manned Mars missions.