HUMAN EXPLORATION OF THE SOLAR SYSTEM SYMPOSIUM (A5)
Human Exploration of Mars (2)

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JOINT OPTIMIZATION OF TRAJECTORY AND PARAMETERS OF NUCLEAR ELECTRIC PROPULSION FOR MANNED MARS MISSION

Abstract

It is analyzed a manned Mars mission using nuclear electric propulsion (NEP). Mission scenario includes following phases: (1) assembling of Manned Martian Space Complex (MMSC) at low earth orbit (LEO); (2) MMSC delivering to the circular high earth orbit; (3) delivering of crew to the MMSC on-board the crew transportation vehicle (CTV); (4) MMSC delivering to the earth escape trajectory, (5) interplanetary transfer to the Mars; (6) spiraling down to the low martian orbit; (7) operation in the Mars vicinity including crew delivering into martian surface using lander and crew returning to MMSC using ascent vehicle of lander; (8) MMSC delivering to the mars escape trajectory; (9) MMSC transferring to the earth flyby trajectory; (10) separating of CTV with crew on-board from MMSC at approach to the earth, entering of CTV capsule into earth atmosphere at hyperbolic velocity, descending and landing; (11) MMSC inserting into a heliocentric disposal orbit. All MMSC flight operations are provided by nuclear electric propulsion while CTV and lander flight operations are provided by conventional chemical propulsion. In contrast with most another studies, there are carried out joint optimization of round-trip trajectory and main NEP parameters. It is used the indirect approach to the optimization based on Pontrjagin's maximum principle. There are presented mathematical statement of the optimization problem including equations of motion, boundary conditions, MMSC mass budget model, and necessity conditions of optimality for fixed-time round-trip expedition. There are optimized NEP thrust switching times and thrust steering, earth departure date, durations of direct transfer to Mars and return transfer to earth, main NEP parameters (thrust, specific impulse, and power). It is analyzed impact of permissible round-trip duration and key technology levels (NEP mass-to-power ratio, NEP efficiency, specific mass of propellant tanks, masses of lander and habitate module) on main mission parameters. It is presented estimation of MMSC initial mass at LEO depending on these parameters. There are presented optimization results for different synodic cycles. It is shown the feasibility of the manned Mars mission for MMSC initial mass at LEO within 200-250 metric tons, NEP electrical power within 2-3 MW, and round-trip duration near 3 years.