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Author: Mr. John Scott
National Aeronautics and Space Administration (NASA), United States

THE VALUE PROPOSITION OF MULTI-MEGAWATT ELECTRIC POWER/PROPULSION FOR THE HUMAN EXPLORATION OF MARS

Abstract

NASA has been offering its stakeholders an architecture for the human exploration of Mars that has remained essentially unchanged since the 1960's. The mission duration and launch mass are the two first order figures of merit that drive the total cost of a given architecture. The options to date center on the "conjunction class" or "Long Stay" mission, in which surface infrastructure elements are sent ahead on uncrewed, slow trajectories requiring a minimum amount of propellant, and the crewed elements are sent at the synotic cycle's shortest trajectory, left on Mars until the next close alignment, and then sent back to Earth. Total crewed mission durations for these architectures range from 900 to 1100 days, with variations driven primarily by trades between the amount of propellant launched and the effective specific mass of the propulsion technology assumed (e.g., chemical, nuclear thermal, solar electric, nuclear electric). Propulsion options assumed in mission architectures studied to date have all resulted in architectural figures of merit that drive the cost to a level of "too much."

However, nuclear electric propulsion (NEP) technology offers a "knob" that might be turned to enable a radically different Mars architecture, whose launch mass and mission duration may enable a value proposition more palatable to mission stakeholders. Mars architectures studied to date assume an NEP system providing 2.5 MWe at a specific mass of 20 kg/kWe. This has often been seen as obtainable with a moderately high temperature fission reactor. An NEP system providing 30 MWe at specific mass of ¡ 3 kg/kWe, though, could enable a short stay (30 days on surface) Mars mission, requiring only two or three SLS-class launch vehicles and a total mission duration of under one calendar year.

However, turning this NEP "knob" would involve a high risk development program to bring about innovation on the order of that delivered by the Manhattan Project, but for a fraction of the cost. Any technology option that might offer such a capability at such a development cost now stands at a low Technology Readiness Level (TRL ¡3), would be based on a nuclear energy source (likely fusion), and would require an extremely high risk (and rapid) development effort. The aggressive, parallel path project management paradigm exemplified by the original Manhattan Project might have the best chance of success.