ADVANCED ELECTRIC PROPULSION FOR FAST MANNED MISSIONS TO MARS AND BEYOND

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One of the most serious challenges of human exploration of Mars lies in the long transfer time required, at least 180 days using chemical or nuclear thermal propulsion. A significant reduction in transfer time would relieve many issues, both technical and psychological, for human Mars missions.

High-power electric propulsion systems are probably the best candidate for near-future fast manned Mars missions. They can provide a specific impulse as high as 10 times the one given by chemical propulsion, leading to a significant reduction of the propellant mass. However, this translates into a significant reduction of the transfer time only if the mass of the power source is kept well below 10 kg/kW.

High-power nuclear electric power systems are considered as possible solutions to this problem. Today a space nuclear reactor can be realized with a specific mass of 30 kg/kW; however in the medium term, using advanced power-generation technologies that, while challenging, are considered feasible, for example a high-temperature Rankine conversion cycle, it could be possible to reach a specific mass of 5 kg/kW . This would allow a transfer time of about 120 days, 60 days less than the best transfer time with chemical propulsion.

A very fast Earth-to-Mars transfer in less than 120 days appears to be unrealistic in the medium term because it depends on a hypothetical breakthrough with the nuclear electric power source, requiring a specific mass that would typically be less than 1 kg/kW.

This paper also proposes an advanced electric propulsion concept, Laser-powered Electric Propulsion (LEP), where the nuclear reactor is replaced by a light-weight photovoltaic (PV) collector. A high-power laser beam from an in-space laser power source is aimed at the PV collector on the target spacecraft, where it is converted to electric power for an advanced electric propulsion system.

The PV collector/converter on the spacecraft can be tuned to the laser wavelength, thus achieving high monochromatic conversion efficiencies, currently ~ 50% with the potential to reach 80% in the near future. Such a light-weight power source could have a specific mass of less than 1 kg/kW, enabling very fast manned missions to Mars and beyond.

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