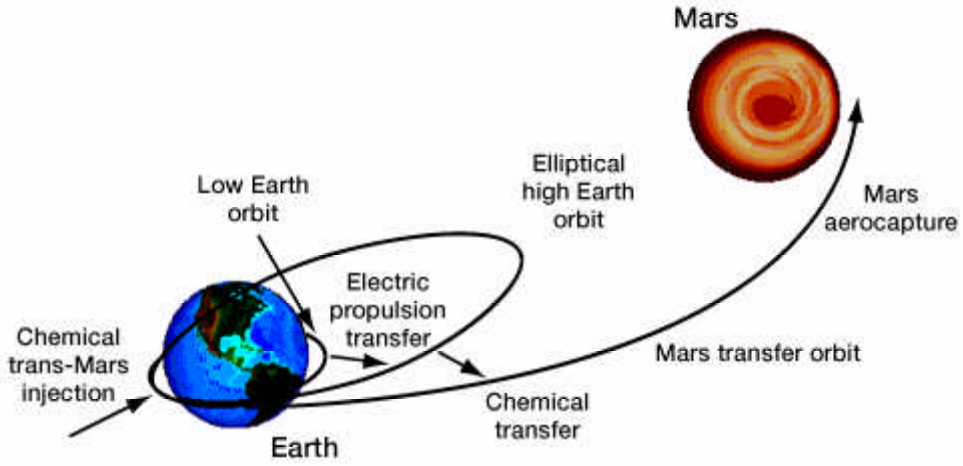
Solar Electric Propulsion for Mars Exploration

Highly propellant-efficient electric propulsion is being combined with advanced solar power technology to provide a nonnuclear transportation option for the human exploration of Mars. By virtue of its high specific impulse, electric propulsion offers a greater change in spacecraft velocity for each pound of propellant than do conventional chemical rockets. As a result, a mission to Mars based on solar electric propulsion (SEP) would require fewer heavy-lift launches than a traditional all-chemical space propulsion scenario would. Performance, as measured by mass to orbit and trip time, would be comparable to the NASA design reference mission for human Mars exploration, which utilizes nuclear thermal propulsion; but it would avoid the issues surrounding the use of nuclear reactors in space.

The mission concept for SEP is illustrated in the following figure. First, the Mars payload, an SEP stage, and a chemical trans-Mars injection stage are placed into low Earth orbit via one or more launches from a chemical rocket of the 80 metric-tonne payload size. Over the next 6 to 9 months, the SEP system slowly raises the vehicle into a highly elliptical, high Earth orbit. This orbit, with an apogee altitude similar to that of a geosynchronous-transfer orbit, prepares the vehicle for trans-Mars injection with an energy change only a fraction of what would be required from low Earth orbit. Once in the desired high Earth orbit, the SEP stage separates from the remainder of the vehicle and the chemical trans-Mars injection stage is fired, sending the payload on to Mars. Because of the reduced velocity changes required for this maneuver, a relatively modest trans-Mars injection stage of the Centaur class can be used. When a crew is part of the Mars payload, they are shuttled to high Earth orbit for a rendezvous with the vehicle just prior to SEP stage separation and trans-Mars injection. In this way, the crew is not exposed to the high-radiation environment of Earth's Van Allen belts during the long, slow spiral from low Earth orbit to high Earth orbit. It is anticipated that the so-called crew taxi would be based on the X-38 space shuttle replacement.



SEP concept for Mars exploration.

For the size of payloads required for a human Mars mission, when optimized for least mass launched to low Earth orbit, the electric propulsion system consumes 600 to 800 kW of power. Thrusters optimally have a specific impulse of 2000 to 2500 sec, which corresponds closely with the characteristics of high-power Hall thrusters currently under development. An SEP system consisting of multiple 50- to 100-kW thrusters is envisioned. High-output, lightweight, deployable solar electric power technologies with specific power in the 10- to 15-kg/kW range are considered critical to the viability of the SEP concept.

The SEP concept for Mars exploration was developed in-house at the NASA Lewis Research Center by members of the Power and Propulsion Office and the Systems Engineering Division in direct support of the Exploration Office at the NASA Johnson Space Center. The SEP concept has been received favorably by Johnson and NASA Headquarters; it is presently being evaluated in greater detail as an alternative to the design reference mission by an engineering team from Lewis, Johnson, NASA Marshall Space Flight Center, and NASA Langley Research Center.

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