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# CHARACTERIZATION OF IN-SPACE PROPULSION TRADE SPACE TO SUPPORT INITIAL HUMAN MARS CAMPAIGN

**Abstract**

The National Aeronautics and Space Administration's (NASA's) Exploration Systems Development Mission Directorate has been developing architecture concepts for human missions to Mars in alignment with the agency's Moon to Mars blueprint objectives. The focus of the Architecture Development Office has been to decompose the blueprint objectives into the characteristics and needs for both lunar and Mars missions and develop functional needs to enable an integrated end-to-end mission architecture. One of the key components of a human Mars mission is the in-space transportation system that delivers crew and cargo to Mars vicinity and returns the crew safely back to Earth. The Mars Architecture Team has been evaluating four in-space transportation options to satisfy this functional need: 1) Hybrid Nuclear Electric/ Chemical Propulsion, 2) Nuclear Thermal Propulsion, 3) Hybrid Solar Electric/ Chemical Propulsion, and 4) All-Chemical propulsion. To answer the question "which transportation option is best?" decision makers will need to understand the performance characteristics—and limitations—for each architecture in the context of their preferred metric. Each option could be considered "better" than the others, depending on whether the primary selection criteria is fast, cheap, maximum cross-government applicability, maximizes commercial capabilities, and/or any other desired metrics.

The Mars Architecture Team has completed considerable analysis on the Hybrid Nuclear Electric/Chemical Propulsion concept over the past three years. The Space Nuclear Propulsion program has also conducted significant work on the Nuclear Thermal Propulsion concept. The Hybrid Solar Electric/Chemical Propulsion concept, derived from technology planned for the Gateway program, was originally configurated for minimum vehicle stack mass (and, hence, minimum Earth-launched mass/cost), leveraging a highly efficient propulsion system on a minimum energy Conjunction Class trajectory. Historically, All-Chemical concepts were considered impractical due to the enormous propellant mass required, even for minimum energy Conjunction Class/long stay mission opportunities. However, considering the emerging commercial heavy-lift capabilities, the concept must be reevaluated across a range of concepts that leverage reusable launch vehicle capabilities to reduce the cost of launching large quantities of transportation elements needed for missions of various duration. This paper aims to provide an overview of the in-space transportation assessment work that is on-going within NASA.