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HUMAN EXPLORATION OF THE MOON AND MARS SYMPOSIUM (A5)
Going Beyond the Earth-Moon system: Human Missions to Mars, Libration points, and NEO's (4)

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A VALUE PROPOSITION FOR REVOLUTIONARY TECHNOLOGIES APPLIED TO CREWED MARS MISSIONS

Abstract

In 2009, NASA released Design Reference Architecture 5.0 (DRA5.0), detailing its baseline architecture for crewed Mars exploration. This document is the latest in a long line of NASA-developed Mars architectures based on current and evolutionary technologies. Various revolutionary technologies have also been independently studied and applied to crewed Mars missions in a one-at-a-time fashion. However, there has been little work to compare revolutionary technologies to one another alongside conventional technology baselines in an organized, systems-level manner.

This paper presents the preliminary results of an ongoing effort to quantify the benefits of developing a variety of revolutionary technologies for inclusion in crewed Mars missions. An array of technologies in propulsion, materials, and power are investigated individually and in various combinations with respect to their effects on overall mission performance, economic, and safety figures of merit. These technology-infused architectures are compared against the baselines laid out by DRA5.0.

Conceptual level performance and cost modeling is performed for high-impact systems and subsystems. For conventional, well-studied technologies such as liquid rocket engines and crew habitats, well-established relations and models are employed. More advanced, less-defined technologies are modeled using the best published information, analogies to similar systems, or order-of-magnitude estimates with levels of uncertainty defined for performance, cost, and reliability. For the safety figures of merit, crew radiation dose and spares needed act as surrogates for crew health and vehicle reliability respectively. Because of the uncertainty involved with revolutionary technologies, value propositions are determined for break-even analyses to establish minimum initial figure-of-merit design guidelines.

The results show how important mission duration is to crewed Mars missions. Faster missions enabled by revolutionary propulsion and power perform significantly better in both safety figures of merit. The shorter trip time also yields measureable improvements in performance and operational economic metrics, such as initial mass in low Earth orbit and overall cost. Advanced materials did well in improving performance and cost metrics, but do not appear to improve safety sufficiently on their own. While further work is required to establish technology investment prioritization, it seems clear that if Mars is the goal for safe and affordable human exploration, technologies that reduce trip time are needed to enable the mission.