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Technology Roadmaps for Space Exploration (09)
Advancing Propulsion Technologies (4)

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NUCLEAR CRYOGENIC PROPULSION STAGE FOR MARS EXPLORATION

Abstract

The fundamental capability of Nuclear Thermal Propulsion (NTP) is game changing for space exploration. A first generation Nuclear Cryogenic Propulsion Stage (NCPS) based on NTP could provide high thrust at a specific impulse above 900 s, roughly double that of state of the art chemical engines. Characteristics of fission and NTP indicate that useful first generation systems will provide a foundation for future systems with extremely high performance. The role of the NCPS in the development of advanced nuclear propulsion systems could be analogous to the role of the DC-3 in the development of advanced aviation. Progress made under the NCPS project could help enable both advanced NTP and advanced NEP. With an advanced, hybrid bimodal nuclear thermal electric propulsion (BNTEP) system being explored as a possible Mars architecture option for international collaborations, the viability of this technology also needs to be investigated by the NCPS project since it offers the potential of significantly shorter round trip Mars missions, smaller vehicles, and variable thrust and specific impulse capabilities. Advanced NTP fuels (such as ternary carbides) also offer the potential for significantly enhanced mission performance, and should be investigated as budget permits. Modern design and manufacturing techniques, coupled with an advanced development and qualification plan, could enable affordable utilization of the NCPS. For second generation systems, the extremely high energy density of fission could also enable higher NCPS performance by incorporating advances in materials, fluid dynamics, and fundamental system design. Unlike current chemical engines, fission systems do not rely on chemical reactions for energy, and the potential exists for tremendous flexibility in the choice of propellant. Second generation (and beyond) space fission systems could enable rapid, affordable access to any point in the solar system. The overall objective of the NCPS project is to address critical NTP technology challenges and issues through development, analysis, and testing of NTP technology hardware and thereby establish adequate confidence in the affordability and viability of NTP systems such that NTP can be seriously considered as the baseline technology for future NASA human exploration missions. Issues will be addressed at both an engine and stage level.