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VERSATILE NUCLEAR THERMAL PROPULSION (NTP)

Abstract

Nuclear Thermal Propulsion (NTP) is game changing for space exploration. For human Mars missions NTP can provide faster transit and/or round trip times for crew; larger mission payloads; off nominal mission opportunities (including wider injection windows); and crew mission abort options not available from other architectures. The use of NTP can also reduce required earth-to-orbit launches, reducing cost and improving ground logistics. In addition to enabling robust human Mars mission architectures, NTP and NTP-derived systems could be extremely useful in cis-lunar space. A first generation NTP system 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. Progress made under the NTP project could also help enable high performance fission power systems and Nuclear Electric Propulsion (NEP).

NTP development efforts in the United States have demonstrated the viability and performance potential of NTP systems. For example, Project Rover (1955–1973) completed 22 high power reactor and fuel tests. Peak performances included operating at a fuel element hydrogen exhaust temperature of 2550 K and a peak fuel power density of 5200 MW/m3 (Pewee test), operating at a thrust of 930 kN (Phoebus-2A test), and operating for an accumulated time of 109 minutes (NF-1 test). Cermet fuels, developed primarily for use in high performance space fission power systems, also show potential for enabling high thrust, high Isp NTP systems.

Test facilities built in the US during Project Rover are no longer available. However, advances in analytical techniques, the ability to utilize or adapt existing facilities and infrastructure, and the ability to develop a limited number of new test facilities may enable viable development and qualification for NTP. The use of low-enriched uranium (LEU) will reduce cost both directly through savings related to safeguards and security, and indirectly by enabling use of an optimal development approach and team. Advances in materials and manufacturing techniques may enable better performing NTP fuels. Potential examples include cermet fuels, advanced carbide fuels, and dual-use fuels. Initial work has shown the potential to design NTP stages that are monopropellant (hydrogen only), provide additional space radiation shielding for crew, and use NTP features to augment overall spacecraft robustness.