SPACE NUCLEAR PROPULSION FOR DEEP SPACE SCIENCE MISSIONS

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The use of nuclear thermal propulsion (NTP)[1] and nuclear electric propulsion (NEP)[2] systems on deep space science missions to the outer planets and into the interstellar medium[3] can yield significant spacecraft system and mission performance benefits and improvements relative to the use of conventional chemical propulsion systems. Several recent and ongoing programs are developing the technologies and systems required to realize a near-term deep space nuclear propulsion capability.

NTP provides improved propulsion efficiencies compared to chemical propulsion, while also providing substantial thrust. This combination of high thrust and increased specific impulse (I_{sp}) provides high acceleration and extended thrusting periods, enabling greatly reduced trip-times on certain types of missions compared to various propulsive alternatives. For examples, compared to a baseline mission using chemical propulsion, NTP-powered missions to Jupiter or Uranus could deliver approximately 2.4-3.6 times more payload (in the case of Jupiter, the payload delivery is significantly larger than the *Juno* spacecraft). In this comparison, the higher end of the payload advantage is obtained when the trip time is held equal for the NTP-powered vehicle and a vehicle using a chemical propulsion departure stage.

NTP systems are presently under development by multiple government agencies. NASA's Space Nuclear Propulsion (SNP) project aims to demonstrate a hydrogen-fed NTP engine at 900 s specific impulse (I_{sp}) and approximately 10-15 klb_f of thrust. DARPA's Demonstration Rocket for Agile Cislunar Operations (DRACO) program is targeting a demonstration of an NTP system in the cislunar space between the Earth and the Moon. An appropriately phased development plan that applies the development of the reactor technology for an NTP engine in this performance class and leverages mature, existing liquid rocket component hardware provides a path to a lower cost propulsion system that can be realized on a shorter development schedule.

NEP, with high I_{sp} in the 2,000-8,000 s range, can also provide advantages over chemical propulsion, including a much greater payload delivery mass and the flexibility for planners to trade between delivered mass and a wider window of mission trajectory options. Electric propulsion (EP) systems have demonstrated great utility, performing notably on the *Dawn* mission to enable rendezvous and orbital insertion at two separate bodies, Vesta and Ceres. An NEP-powered vehicle would have a similar capability to visit multiple bodies, loitering at each before moving to the next. A 10 kW_e NEP system provides a power-rich environment on the spacecraft that is simply not possible using present radioisotope power systems, giving mission planners more scientific instrument and communication hardware options.

Several programs and projects are presently developing NEP systems and subsystems in the 10 kW_e power range, leveraging past reactor work and recent nuclear power generation risk-reduction demonstration activities such as the Demonstration Using Flattop Fission (DUFF) and the Kilopower Reactor Using Stirling TechnologY (KRUSTY). The goal of the Air Force Research Laboratory's Joint Energy Technology Supplying On-Orbit Nuclear Power (JETSON) program is an in-space demonstration vehicle that has a 10 kW_e-class fission power source. These past and present efforts can be combined with the ongoing development of 10 kW_e-class electric propulsion systems (notably the NEXT-C ion thruster or the Hall-effect thrusters for Power and Propulsion Element of the Lunar Gateway) to provide a pathway to a low-cost, reliable NEP system for deep space science application.

References

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