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APPLICATION OF NUCLEAR THERMAL PROPULSION FOR SUSTAINABLE CISLUNAR EXPLORATION

Abstract

NASA has recently identified Nuclear Thermal Propulsion (NTP) as a critical technology for the human exploration of Mars. Recent studies have also demonstrated its unique capabilities towards enabling deep space exploration robotic missions with higher payload mass and/or reduced trip times. This game changing technology can also provide the efficient cargo and crew transportation through cislunar space for sustained human presence on the Moon. The NTP systems capability of generating both high thrust and high specific impulse (over twice of the best chemical propulsion systems) can enable a variety of reusable lunar missions which can play critical role in the next phase of lunar exploration. Even with this revolutionary capability, majority of literature studies on the NTP have focused on the human missions to Mars and little attention is given on mission architectures which can be enabled by the NTP for the lunar exploration missions.

The purpose of this study is to investigate the applications of the NTP for sustainable cislunar exploration and identify the most efficient architectures and engine system trades for host of lunar missions. NTP systems use low molecular weight hydrogen to achieve higher specific impulse however its volumetric constraints due to low density requires hydrogen to be stored as liquid at extremely low temperatures. This constitutes a challenge of cryogenic propellant boil off due to heat radiation from the Sun and other celestial bodies in proximity to the NTP system. This paper will present the evolutionary path of NTP systems for lunar missions with initial architectures utilizing NTP systems integrated with chemical propulsion system as a solution to eliminate the dependency of long duration liquid hydrogen storage. The later stages of the architecture make use of in-situ propellant which enables single stage, fully reusable lunar transfer vehicle. The architectures and engine trades are performed using high-fidelity mission analysis model 'Spacecraft Integrated System Model' (SISM) which is developed using the model-based approach. Preliminary results have demonstrated that an NTP system configuration with an in-line propellant tank can enable reusable lunar missions with more than twenty percent of payload mass fraction and trip time reduction by more than a factor of two when compared with the traditional propulsion systems.