MISSION CHARACTERISTICS OF SMALL NTP WITH LOX-AUGMENTATION.

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Abstract: Exploration architectures that require substantial payload capability (e.g., Mars Lander/Sample Return; Jupiter, Saturn, Neptune, or Uranus Orbiters) or rapid trip times (e.g., human Mars missions) [1], [2], have been shown to benefit from nuclear thermal propulsion (NTP) because of the 2X Specific Impulse (ISP) increase over cryogenic chemical propulsion. These architectures will need the nuclear propulsion to be demonstrated early on smaller launch systems before program commitment to the technology for more complex human or high-value robotic missions. One path to early NTP demonstration is for qualification using Atlas 5 or Delta 4 launch systems. Use of a small NTP stage on these launchers could lead to expanded use for missions with these or other Expendable Launch Vehicles (ELV) later [3].

Exploration missions across the Solar System need technologies that reduce the time of flight, provide efficient payload capability, and reduce the size and the number of launch systems in order to reduce mission risk and cost. NTP is a technology that enables rapid transit, can minimize the number of spacecraft stages and move some payloads to smaller launch vehicle systems. NTP enables robust, continuous exploration and expansion across the Solar System. NTP has been proven scientifically and many engineering challenges have been addressed in past ground testing of the larger reactor cores. The NTP to consider today is a smaller core based on the knowledge gained from past research and development. The final validation and verification is to prove the NTP in a flight demonstration. Recent NASA and industry studies have defined a small NTP system that is no bigger than current cryogenic rocket engines and can provide an approach for an affordable flight demonstrator.

The benefit of an NTP smaller than previously developed NTPs is an affordable approach for higher performance in-space propulsion. The small NTP provides a development cost benefit with a smaller physical reactor core with less uranium content and is more easily tested with a smaller facility foot-print. The smaller facility and lower exhaust flow rate provides for less effluent to clean and manage, which, in turn, reduces the development cost due to environmental safety and nuclear material security concerns. Fundamentally a small NTP can reduce the development, procurement, and operational costs making it a more affordable NTP system for a nuclear cryogenic propulsion stage.

A smaller NTP would notionally be in the 150 megawatt class. This size NTP can provide greater than 900-seconds ISP while providing 30-40 kN of thrust. Additional thrust is possible using a non-nuclear turbopump system with liquid oxygen to augment the hot hydrogen exhaust producing 100%-200% more thrust at >600 seconds ISP [4].

Aerojet Rocketdyne (AR) has been working on the design of such a small NTP with wide scalability to robotic and human exploration spacecraft systems. Studies performed in 2011 through 2013 identified NTP approaches for increasing the capability of Solar System missions [5]. This paper will discuss recent trade studies performed with small NTP stages, with and without liquid oxygen augmentation, for missions to Mars and the outer planets and for a rapid cis-lunar crew transport system. The implications to stage volume using liquid hydrogen and oxygen augmentation, to burn times for the NTP, and to payload capacity for various launch systems will be discussed.

References:

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