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Author: Mr. Zachary Strimbu
The Ohio State University College of Engineering, United States, strimbu.3@osu.edu

Mr. Alex Cummings
The Ohio State University College of Engineering, United States, cummings.289@osu.edu
Mr. Howard Schulman
The Ohio State University College of Engineering, United States, schulman.30@osu.edu
Mr. Jeff Bramlage
The Ohio State University College of Engineering, United States, bramlage.17@osu.edu
Mr. Nick Salamon
The Ohio State University College of Engineering, United States, salamon.31@osu.edu
Dr. John M. Horack
The Ohio State University College of Engineering, United States, horack.1@osu.edu
Dr. Elizabeth Newton
The Ohio State University, United States, newton.387@osu.edu

MISSION ARCHITECTURE FOR A PROOF-OF-CONCEPT NUCLEAR THERMAL PROPULSION INTERPLANETARY MISSION

Abstract

Nuclear thermal propulsion (NTP) represents a mission enabling technology by providing a rapid transit capability that is needed to extend and sustain human exploration beyond low Earth orbit (LEO). NTP derives energy from the controlled fission of uranium or other fissionable material while conventional chemical propulsion produces energy through combustion. In an open-cycle NTP design, a turbopump pressurizes liquid hydrogen monopropellant through coolant channels within the reactor where it is superheated and expelled through a supersonic nozzle to generate thrust. Thus, hydrogen is used as both the coolant and propellant without the need for an oxidizer – allowing for the attainment of specific impulse values reaching 900 seconds. Ground-tested high enriched uranium (HEU) NTP systems in the Rover/NERVA (Nuclear Engine for Rocket Vehicle Applications) programs demonstrated this efficiency while producing up to 930kN thrust, having multiple start/restart cycles, and accumulating burn times exceeding 100 minutes. With these characteristics, NTP systems are attractive systems for future human space flight due to the capability of flexible abort scenarios and rapid transit trajectories which reduce exposure to galactic radiation and the zero gravity environment.

Proposed solid core low enriched uranium (LEU) NTP systems provide similar performance to HEU NTP systems with the added value of: 1) political and international acceptance; 2) program flexibility with development between NASA, Department of Energy (DOE), and commercial entities; and 3) cost reduction in facilities development and security. To develop the technology for manned missions, a proof-of-concept mission is needed to prove-out a LEU NTP system through successful flight mission operations. This research is an analysis to establish mission requirements, identify mission constraints and assumptions, characterize spacecraft subsystems, estimate the budget, and set the timescale of a LEU NTP mission to Mars from authorization to proceed to spacecraft disposal. Methods of study include applying structural and thermal analysis software to determine loads, stresses, and fatigue on components and the integrated structure. Trajectories and propulsion analyses are completed in MATLAB and

compared to other software to ensure rapid transit feasibility given mission constraints. All subsystems are characterized at a high level to satisfy their function and estimate cost both individually and in the integrated system. Alternative mission concepts are being selected for analysis that include longer mission times, disposal trajectories, and varying payload options. The data gathered will be presented as a possible mission architecture for a proof-of-concept nuclear thermal propulsion interplanetary mission.