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Author: Dr. Dale Thomas
University of Alabama in Huntsville, United States, dale.thomas@uah.edu

Dr. Michael Houts
NASA Marshall Space Flight Center, United States, michael.houts@nasa.gov
Dr. Dean Wang
The Ohio State University College of Engineering, United States, wang.12239@osu.edu
Prof. Keith Hollingsworth
University of Alabama in Huntsville, United States, keith.hollingsworth@uah.edu
Dr. Robert A. Frederick, Jr.
Propulsion Research Center, University of Alabama in Huntsville, United States, robert.frederick@uah.edu
Dr. Jason Cassibry
Propulsion Research Center, University of Alabama in Huntsville, United States, cassibj@uah.edu

RESEARCH PROGRESS TOWARD ENGINEERING FEASIBILITY OF THE CENTRIFUGAL NUCLEAR THERMAL ROCKET

Abstract

The Centrifugal Nuclear Thermal Rocket (CNTR) is a Nuclear Thermal Propulsion (NTP) concept designed to heat propellant directly by the reactor fuel. The primary difference between the CNTR concept and traditional NTP systems is that rather than using traditional solid fuel elements, the CNTR uses liquid fuel with the liquid contained in rotating cylinders by centrifugal force. If the concept can be successfully realized, the CNTR would have a high specific impulse (1800 s) at high thrust, which may enable (i) viable near-term human Mars exploration by reducing round-trip times to 420 days and (ii) direct injection orbits for scientific missions to the Solar System outer planets and Kuiper Belt objects. The CNTR could also use storable propellants such as ammonia, methane, or hydrazine at an Isp of 900 s, enabling long-term in-space storage of a dormant system. Research is presently underway to determine resolutions for the significant engineering challenges that the CNTR concept presents. Papers were presented at the 2021 and 2022 IACs which described these challenges, the study plan to address them, and progress to date. In particular, the 2022 paper highlighted the challenge of neutronics driving the heat generation gradient in the liquid uranium annulus, which results in the greatest heat generation on the outer wall of the annulus, where the maximum temperature of the containment wall is constrained to maintain structural integrity. This constraint was resulting in performance projections well below the theoretical projection. This paper provides a follow-on update which summarizes progress of the overall research effort, including strategies and key results to date on leveling the heat generation gradient in the liquid uranium annulus. The paper will also summarize the 3D modeling of the gaseous hydrogen bubbles in the liquid uranium and experimental results on gaseous and liquid analogs to validate the analytical models. Finally, estimates of engine key performance parameters including specific impulse, thrust and thrust to weight ratio will be given, and mission analyses of scientific missions to various Solar Systems destinations including Kuiper belt objects.