Rob Rountree
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University of Southern California
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Review of: "A feasibility study on low enriched uranium fuel for nuclear thermal rockets - II: Rocket and reactor performance." Venneri, Paolo F. and Kim, Yonghee. Progress in Nuclear Energy Volume 87, March 2016, pp. 156-167.

This paper is the second in a two-part series conducting a feasibility study on a nuclear thermal rocket (NTR) using low-enriched uranium (LEU) fuel. While the first paper in the series studied the feasibility of achieving and maintaining criticality in a LEU NTR, this paper referenced a modified LEU design that met the requirements of the NASA Human Exploration of Mars Design Reference Architecture (DRA) 5.0. This paper examined neutronic and performance parameters for a realistic NTR design, including the radial power and temperature profile, the neutron spectrum, the effects of the control drums on reactivity, changes of the reactivity coefficient over time due to reduced fuel inventory and fission byproducts build-up, and the effects on reactivity due to full water submersion as a result of a flight accident.

NTRs operate by heating hydrogen fuel in a nuclear reactor core before accelerating it through a nozzle. NTRs operate in a "sweet spot" of thrust and specific impulse, enabling key missions such as three-month crewed transits to Mars. Since the promising Nuclear Engine for Rocket Vehicle Applications (NERVA) program in the 1960's and 1970's, significant progress in the NTR field has been made, but it has generally been limited to conceptual studies and laboratory tests – the NERVA program remains the furthest developed NTR program to date. One of the primary reasons for this was the difficulty associated with working with weapons-grade, highly enriched uranium (HEU) fuel, which has been required for NTRs to date. The high quantity of weapons-grade uranium required for NTRs meant that any NTR programs would be tightly controlled by the government, dampening private industry innovation and investment, and likewise presented a non-negligible proliferation risk. NTRs using LEU, however, might reduce regulatory burdens and security costs sufficiently to secure stable funding. In 1994, a proposal submitted to the Department of Energy (DOE) using LEU was rejected on the basis that the mass increase to achieve criticality with LEU would be prohibitive. The design in this 2016 paper presents a feasible LEU NTR with only a modest mass increase over the HEU NTR reference design, and has since been independently verified. In 2023, NASA and DARPA funded a program to design and build a LEU NTR for an in-space demonstration.

The paper is overall straightforward, focused, well-organized, and presents clear and meaningful results. Though the reviewer has some basic knowledge of nuclear thermal propulsion, the paper is presented in a way in which the reader does not need to be a nuclear engineer to understand it. The paper is somewhat light on methodology, although additional methodology would likely require a longer article, as the content is densely packed with results. There are a few minor grammatical errors that do not impair understanding, and a few cases of technical jargon which are not explained. Several graphs depict the effective reactivity constant, however the position of the control drums is not stated – since the graphs generally depict the reactor's reactivity constant as starting at greater than 1, the readers are left to assume that the control drums are positioned to maximize reactivity. The horizontal axis on one graph depicts several "0"s when it should be displaying drops in orders of magnitude (1.0E-1, 1.0E-2, 1.0E-3, etc.). Despite these minor issues, overall the paper is well-organized, presents important results, and is forthcoming about both the merits of its approach and the drawbacks, as well as further research required.

This paper presents relevant and important results for the development of NTRs. Its approach of starting with a built and well-documented engine design and then making significant but realistic modifications to meet the NASA DRA means that its results can be immediately applied to real engineering work. Though much engineering analysis and optimization remains to design, build, and flight test a NTR, this paper presented a design that was a significant step forward in a NTR that can be built in the modern era.