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DEVELOPMENT OF A HIGH POWER NUCLEAR ELECTRIC PROPULSION SYSTEM FOR INTERPLANETARY MISSIONS

Abstract

There is a renewed interest in the development of nuclear fission power sources for space applications. With the large growth in the space sector, missions requiring nuclear fission reactors are again being considered, as demonstrated by NASA planning to fly a prototype nuclear thermal propulsion system 2025. Example missions include: to the Moon, as part of human's return to the lunar environment, space tugs for heavy cargo transport, and missions exploring the far solar system where solar power is unfeasible. Many of these missions require a nuclear fission power system for operating a high power electric propulsion system (i.e. an ion thruster) that drives the spacecraft towards these distant endeavours. As part of a UK Space Agency funded consortium, through its enabling space exploration call, this paper presents our work to develop a cohesive and concurrently designed nuclear electric propulsion system, with the electric propulsion system designed from outset for integration of a space suitable nuclear fission reactor, and vice versa. Within the minimum year-long project, a Hall ion thruster has been developed for operation at high power, with a power requirement of at least 10 kW. The Hall ion thruster is designed for operation with a variety of different propellants, including both standard gaseous propellants and also condensable propellants such as magnesium. These propellants require heating into a vapour phase, which can be

completed using excess heat available from the nuclear fission reactor system. This thruster has been designed, and will be manufactured for testing to be completed within the University of Southampton facilities in the summer of 2023. From the nuclear reactor perspective, we will develop a nuclear reactor concept within the 10 – 100 kW range that can be integrated with the electric propulsion system. We will make use of Low Enriched Uranium (LEU) Tri-structural Isotropic (TRISO) fuel particles, and through partners expertise previously developed components wherever possible. Two power conversion system options will be considered: Stirling Engines and static Thermo-Electric (TE) methods. Using our broad computational tools for the analysis of the proposed reactor type and associated power conversion systems, core physics, including both neutronic and thermal, will be assessed with tools that are computationally efficient, allowing the use of global optimisation methods. This enables the effective exploration of the many trade-offs that exist to find fission power systems that have minimal mass and volume whilst meeting mission requirements.