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TOWARDS A FEASIBILITY STUDY FOR A LUNAR SPACE NUCLEAR REACTOR

Abstract

To establish a sustainable human presence on the Moon and facilitate future Mars exploration, nuclear fission surface power emerges as a promising solution, overcoming most of the limitations of large photovoltaic-based systems. It enables continuous and reliable energy supply essential for sustaining life-support infrastructure and advanced operational equipment through the extensive lunar nights. While this technology has been well-established on Earth, its transport, commissioning, and utilization on the lunar surface introduce several challenges, arising from the specific engineering requirements that need to meet the unconventional operational settings. Among the constraints, the limitations of weight and size to fit available orbital launchers payload specifications, and the adhesion to stringent safety and reliability requirements. In response to the growing global interest in leveraging nuclear power for extraterrestrial bases, evidenced by initiatives in the USA, UK, and China, the Italian National Agency for New Technologies, Energy, and Sustainable Economic Development (ENEA) has established a working group at the Fusion and Technologies for Nuclear Safety Department to conducts option-engineering studies on space nuclear reactors. As a first step, a pivotal collaboration between ENEA and the Italian Space Agency aims to explore the feasibility of a 350-kWe nuclear reactor system, focusing on compactness, lightweight design, reliability, and safety. The main objectives and goals of the study, encompassing technical feasibility, supply chain considerations and a roadmap to industrialization are presented. This paper delineates the study's main objectives, including technical feasibility, supply chain analysis, and a roadmap towards industrialization. It elaborates on the methodologies employed to ensure the system's adherence to principles of modularity, reliability, redundancy, and compactness. These principles are critical for meeting the operational, flexibility, and deployment requisites in the harsh lunar environment. The study also evaluates the materials, the specific technological solutions and operational conditions to guarantee system

resilience against extreme temperature variations, reduced gravity, radiation, micro-meteorite impacts, and abrasive lunar dust. Further, it presents a comprehensive layout proposal of the system, detailing and integrating the nuclear core and the main subsystems for the heat distribution, the energy conversion and the heat rejection. An assessment according to high-level performance metrics, including mass and volume, is finally proposed.