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UNITED KINGDOM'S ADVANCES IN NUCLEAR POWER TECHNOLOGY FOR SPACE EXPLORATION

Abstract

Nuclear power continues to emerge as a critical enabler for ambitious space exploration missions, addressing the increasing demand for power in both robotic and human exploration. As commercial and multinational space missions expand, the need for continuous and scalable power solutions becomes increasingly vital.

The UK's extensive expertise in nuclear and space technologies naturally positions it as a key contributor to international efforts in advancing nuclear technology for deep-space exploration, surface operations on the Moon and Mars, and advanced propulsion systems.

Recent advancements have strengthened the UK's capabilities across three key areas:

1. **Heat and Power for Robotic Missions** — The UK has made significant progress in developing Radioisotope Power Systems (RPS), leveraging its domestic supply chain and expertise in fuel processing and power conversion. A key focus has been the advancement in the development of americium-241-based RPS, an alternative to plutonium-238, offering a sustainable and domestically available fuel source for long-duration missions. New designs prioritise improved efficiency, modularity, and adaptability, enabling lunar night survival, Mars surface operations, and deep-space missions beyond Jupiter. Ongoing research includes compact Stirling and thermophotovoltaic RPS designs, enhancing power conversion efficiency over traditional thermoelectric generators.
2. **Fission Power for Human Lunar Exploration** – The UK is actively engaged in multiple national and international cooperation projects to advance surface fission power technology and systems. These efforts focus on developing compact modular reactor architecture technologies, fuel manufacture, high-efficiency power conversion, thermal management, and high-temperature materials, ensuring potential for reliable, scalable, and long-duration energy solutions for sustained lunar and planetary surface operations.
3. **Nuclear Propulsion for Deep-Space Missions** – Advancements in Nuclear Thermal Propulsion (NTP) and Nuclear Electric Propulsion (NEP) are enabling faster, more efficient interplanetary travel. UK industry and academia are engaged in technology advancements related to fuel element development, high-temperature materials testing, and power system integration for nuclear propulsion applications.

In parallel, the UK is actively contributing to international regulatory frameworks to ensure the safe, responsible, and sustainable development of nuclear space systems. This includes contributions to UN, ESA, and national regulatory efforts, ensuring compliance with space nuclear safety standards, non-proliferation protocols, and export control regulations.

This paper provides an updated overview of ongoing technical developments, key engineering challenges, and future plans for UK-led technology development to support the next generation of nuclear space initiatives.