IAF SPACE POWER SYMPOSIUM (C3)
Interactive Presentations - IAF SPACE POWER SYMPOSIUM (IPB)

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SUSTAINABLE NUCLEAR ENERGY ADVANCEMENTS FOR SPACE EXPLORATION AND COLONIZATION MISSIONS

Abstract

The research presented in this paper was accomplished by the Politecnico di Milano's Nuclear4Space research group and was carried out thanks to a collaboration with Thales Alenia Space Italia.

The research activities consisted of two main tasks: investigating Small Space Reactors technologies for primary energy generation on a planetary settlement and discussing the potential of nuclear power for deep space propulsion applications.

The first part of the study focused on re-scaling the 1 kWe NASA's Krusty reactor design up to a power level of 10 kWe, adapted for Space Environment. A preliminary design of the complete system was performed in order to guarantee the operability and reliability of the platform on the surface of the Moon, which was taken as the user case for this design.

An important part of the work was dedicated to develop a methodology to design the system as a whole, stating the interactions between different areas and understanding where and how the inputs and outputs of the neutronics would affect the design of the rest of the system.

The activities included the neutronics analysis of different possible configurations for a space reactor concept that employs HALEU as fuel, coupled by mass optimization and safety analysis. A thermal model of the system as a whole was derived, along with heat pipes and radiator design, thermal analysis and optimization of the position of the heat pipes inside the reactor's core.

The second part of the project discussed the possibility to plan a short manned Mars mission with electric propulsion powered by nuclear reactors.

The first phase of the work consisted in analyzing the state of the art of the technology in order to determine the best-structured design for the type of mission. The chosen propulsion system is the magnetoplasma thruster VASIMR.

An analysis of the possible power conversion systems has been performed considering previous works, and Magneto Hydrodynamic Disk Brayton System has been selected.

A preliminary sizing of the thermal subsystem has been developed considering different scenarios, in order to evaluate the power density of the system, which represents a key factor for the sustainability of the mission.

Lastly, a comparison with Nuclear Thermal Propulsion performances has been carried out in order to evaluate the real potential of the technology considered in this study.