Design of an NH_3 AF-MPDT for Bimodal Nuclear Propulsion

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The Bimodal Ammonia Nuclear Thermal and Electric Rocket (BANTER) project, funded by the European Innovation Council, aims to develop a versatile nuclear propulsion system for deep-space missions. Unlike conventional bimodal systems, which use separate propellants for nuclear thermal and nuclear electric propulsion, BANTER employs ammonia (NH_3) as a single propellant. This unified approach simplifies spacecraft design, increases mission flexibility, and enables in-situ resource utilization (ISRU), while maintaining competitive performance in both modes.

Ammonia's higher molecular mass limits nuclear thermal specific impulse relative to hydrogen-based systems. BANTER compensates via in-core ammonia decomposition: within the reactor, NH_3 dissociates into nitrogen and hydrogen before nozzle expansion. This reduces effective molecular weight, increases exhaust velocity, and yields an estimated nuclear thermal specific impulse of ~500 s, well above conventional chemical propulsion.

In electric propulsion mode, BANTER uses an advanced power conversion system with ammonia as the working fluid in an open, asynchronous Brayton cycle. This supplies spacecraft and propulsion power while reducing thermal management needs and eliminating large radiators typical of closed-cycle nuclear electric systems.

The electric propulsion subsystem employs an Applied-Field Magnetoplasmadynamic Thruster (AF-MPDT) for its high thrust density and specific impulse. Externally applied magnetic fields provide additional thrust and performance gains. The system's high-power demand matches BANTER's nuclear power availability, enabling efficient high-power operation.

The AF-MPDT is developed by the Institute of Space Systems (IRS) at the University of Stuttgart and the University of Pisa, building on the SX3 thruster heritage. The final design targets 100 kW, with a 1 kW prototype tested on NH_3 at IRS to validate performance and stability. Simultaneously, hollow cathode development and testing are conducted at the University of Pisa's Electric Propulsion Laboratory.