OPUS-1: An Ultracompact Satellite-Based Galactic Cosmic Ray Sensor

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Galactic Cosmic Rays (GCRs) pose a significant hazard to any spacecraft operating outside of the Earth's magnetosphere, capable of penetrating through thick radiation shielding and damaging vital electronics and DNA. Current detectors capable of analyzing these rays are large, expensive, and power-intensive, making them unsuitable for operation on satellites outside of the Earth's magnetic field. This project aimed to design a compact, low power particle sensor able to accurately identify and characterize GCRs in space. The final design utilizes a novel lead/scintillation fiber matrix, which allows for a higher maximum detectable particle energy than traditional scintillation-based detector systems. As GCRs pass through this material, photons are produced, which are counted by a S14161-6050HS silicon photomultiplier. A low-power microcontroller processes and amplifies the signal, determining particle energy, trajectory, and scattering. The system is designed to operate within a 2U CubeSat form factor (10cm × 10cm × 20cm) and function with only 5V of power. To assess the efficacy of this design, Monte Carlo simulations were conducted in Geant4. Interactions with six particle types (p+, He2+, e-, gamma, p-, and HZE ions) were tested across energies from 0–400 MeV. The detector accurately measured the energies of protons and high-energy ions up to 204 MeV with over 90% accuracy, accounting for ~90% of GCRs. Alpha particles were detectible up to 400 MeV, although these particles compose only a small percentage of GCRs. Differences in scattering patterns can be utilized to determine the type of particle detected.

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