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SPNEX: A COST-EFFECTIVE 6U CUBESAT FOR SPACE PLASMA CHARACTERIZATION AND EARTH OBSERVATION

Abstract

This paper details the design and implementation of the Space Plasma Nano-satellite Experiment (SPNEX), a 6U CubeSat developed by the Egyptian Space Agency and The Academy of Scientific Research & Technology (ASRT). The mission addresses two critical challenges: characterizing ionospheric plasma variability and demonstrating low-cost Earth observation capabilities. SPNEX integrates multiple payloads, including Langmuir probes for plasma measurements, a high-resolution optical camera delivering a ground sampling distance of 7.5m, four viewfinder cameras for multi-angle imaging, and an SRAM experiment to evaluate radiation effects.

The satellite employs a modular architecture with a stack-through bus design supporting standardized interfaces (SPI, RS-485) for seamless integration. A key innovation is its FPGA-based payload controller, enabling real-time data handling and compression. The hybrid UHF/S-Band communication system, featuring variable downlink rates (32–256 kbps) via adaptive modulation, optimizes data throughput while reducing operational costs. The dual-redundant On-Board Computer (OBC) and Centralized Control Unit (CCU) framework ensures fault tolerance during extended missions.

By leveraging commercial off-the-shelf (COTS) components—such as an STM32-based OBC and deployable CubeSpace ADCS sensors—SPNEX achieves Technology Readiness Level 7 at a cost 40% lower than conventional platforms. Lessons from subsystem integration and radiation-hardening strategies offer actionable insights for future CubeSat missions. This approach establishes a scalable blueprint for emerging space nations and NGOs, empowering them to address environmental and agricultural challenges through affordable Earth observation.

SPNEX demonstrates that small satellites can substitute for resource-intensive missions. Its innovative design delivers enhanced spatial coverage and high-resolution measurements, outperforming ground-based

or aerial platforms. Slated for launch in Q4 2025, preliminary ground tests validate its plasma measurement accuracy. SPNEX's advances provide a roadmap for reshaping satellite deployment strategies and advancing global Earth science initiatives.