IAF SPACE EXPLORATION SYMPOSIUM (A3)
Interactive Presentations - IAF SPACE EXPLORATION SYMPOSIUM (IP)

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INNOVATIVE DEPLOYMENT AND OPTIMIZATION OF LUNAR FEMTOSATELLITE SWARMS FOR ADVANCED SPACE WEATHER MONITORING

Abstract

As humanity prepares for an era of sustained lunar exploration and habitation, the need to unravel the Moon's complex space weather environment has never been more urgent. Solar winds, radiation bursts, and magnetic anomalies pose critical risks to infrastructure and astronauts. However, traditional monitoring systems—reliant on bulky satellites or isolated probes—lack the spatial resolution and adaptability required for comprehensive lunar science. This study uniquely investigates the deployment strategy, storage optimization, and operational reliability of femtosatellite swarms released from a 3U CubeSat in lunar orbit, aimed at advanced space weather monitoring. It highlights innovations in integrating precise ejection mechanisms and maximizing storage capacity within the CubeSat's volumetric constraints. Dynamic simulations in Adams were implemented to model femtosat ejection mechanics, complemented by orbital analyses in GMAT that validated formation trajectories for distributed data collection. Thermal and communication strategies combining passive and active solutions were also applied to ensure operational stability under the Moon's extreme environmental conditions. Results demonstrate that femtosatellite swarms can effectively expand spatial coverage, enabling precise measurements of solar wind, radiation, and magnetic fluctuations. The viability of CubeSat-based storage and deployment mechanisms for lunar operations is confirmed. Furthermore, the integration of advanced simulation techniques and resilient thermal-communication architectures enables scalable, cost-effective femtosat networks.