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REVOLUTIONIZING SMALLSAT POWER SYSTEMS: SODIUM-ION STRUCTURAL BATTERIES FOR ENHANCED EFFICIENCY AND PAYLOAD ALLOCATION IN LOW EARTH ORBIT MISSIONS

Abstract

Smallsats have become predominant in recent space missions, primarily due to their cost-effectiveness compared to larger satellites. However, optimizing the internal volume of these smaller platforms is crucial for achieving efficiency. Lithium-ion batteries, though commonly used for their high energy density, present challenges in meeting space mission requirements such as peak power, charge-discharge cycles, operational temperatures, and safety. Sizing the battery pack to address these constraints often results in compromises, impacting the overall performance of the system in terms of gravimetric and volumetric energy density. This is particularly evident in 3U cubesats, where the battery pack can occupy up to approximately one-third of the internal volume.

To overcome these limitations, this paper introduces a cutting-edge energy storage solution for smallsats: an innovative structural battery utilizing sodium ion chemistry. This structural battery, resembling a conventional sandwich panel, serves a dual purpose by functioning as both as a structural element and a battery pack. By leveraging the mass and volume of the satellite's structures for electrical energy storage without intruding on internal space, this technology addresses the challenges associated with conventional battery packs.

The proposed structural sodium-ion battery boasts advantages such as increase of available internal volume, reduced mass, twice the power density of lithium-ion batteries, superior cyclability, a wider operating temperature range (especially at lower temperatures), and improved safety due to the absence of thermal runaway. The paper investigates the operational principles and design techniques for integrating this structural battery into satellite platforms based on mission-specific requirements. Results from the study demonstrate that this innovative technology enables the storage of all necessary mission energy and power within the satellite's structures. This breakthrough allows for the internal volume originally dedicated to battery packs to be allocated for additional payload or propellant, enhancing the overall viability of the platform and mission. This new approach to energy storage unlocks new level of performances achievable by spacecrafts both in LEO orbits and for deep-space or extra-terrestrial explorations with limited impact on construction costs. In addition, the unique environment of space provides an ideal testing ground to validate structural batteries. This technology not only advances space applications,

but also has the potential for widespread application on Earth, particularly to support and enable the electrification of the transportation sector.