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Design and Development of a Weather Balloon-Launched CubeSat Prototype for Atmospheric Data Collection

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Extended Abstract

CubeSats, a category of picosatellites, have become increasingly popular due to their cost-effectiveness and their capacity to foster hands-on experience in satellite design, manufacturing, and testing. Despite these advantages, preparing CubeSat hardware and software for space missions presents a considerable challenge. Conventional space simulation methods, such as vacuum chambers and thermal testing, are often prohibitively costly, complex, and time-intensive, posing barriers to streamlined CubeSat development and deployment.

Advances in miniaturized electronics and power technology have enhanced their capabilities. Carolyn Mayer's 2011 research utilized weather balloons to test 3D-printed CubeSats equipped with sensors, providing an affordable means to simulate near-space conditions and identify potential issues before costly launches [1]. Similarly, in summer 2019, NASA's Jet Propulsion Laboratory interns tested a 6U CubeSat and Qualcomm Snapdragon flight computer using high-altitude balloons, effectively simulating orbital conditions and verifying CubeSat readiness at a low cost [2]. Previous research has overlooked the reusability of CubeSats, and these designs and prototypes are still not affordable and accessible for student research.

This paper presents the design and development of a CubeSat prototype optimized for atmospheric data collection, emphasizing both deployment via a weather balloon and subsequent multi-sensor data analysis. The CubeSat's payload includes five distinct sensors:

temperature, humidity, gas/ion detection, air pressure, and air quality. In addition to these sensing capabilities, two innovative features are incorporated: a quick-release mechanism and horizontal movement capability. The quick-release mechanism ensures a safe and controlled separation from the balloon, deploying a parachute for a secure descent, while the horizontal movement capability enables lateral maneuvers, enhancing the CubeSat's functional adaptability in the atmosphere.

The prototype is constructed entirely from weather-resistant 3D-printed plastic to ensure durability and cost efficiency. The system design was modeled using SolidWorks, as illustrated in Fig. 1, with the primary control architecture divided into two subsystems: the flight control subsystem and the data acquisition subsystem. The flight control subsystem manages the balloon launch, utilizing a quick-release mechanism along with a propeller-based horizontal movement system. Servo motors are employed for actuation, while BLDC motors provide propulsion. The data acquisition subsystem controls the sensor suite for real-time atmospheric monitoring, featuring the five sensors mentioned earlier. Power management for the CubeSat is maintained through a solar energy management board, and the printed circuit board (PCB) design is shown in Fig. 2. Initial testing of sensor functionality has been successfully conducted and quick release mechanism is in design phase currently. The CubeSat's design prioritizes reusability, affordability, and component accessibility, contributing to an economical and sustainable atmospheric research tool.

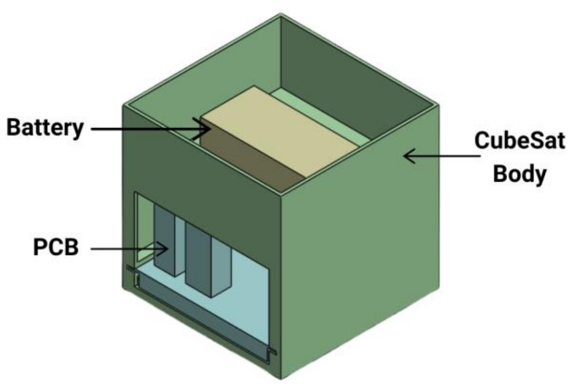

Figure 1: CubeSat system design in SolidWorks.

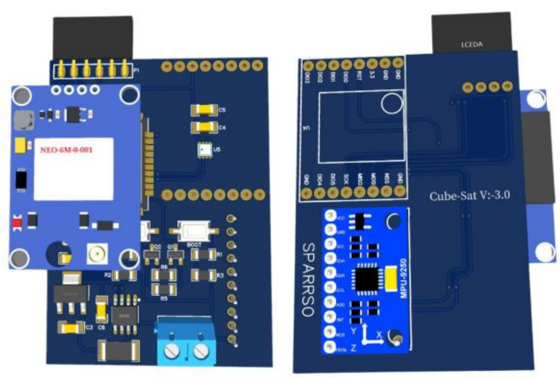

Figure 2: PCB design of the connection circuit.

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