International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 09 | September - 2023 SJIF Rating: 8.176 ISSN: 2582-3930

Design and Development of a 3D-Printed CubeSat by Go Science

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Abstract: This project outlines the design, development, and construction of a 3D-printed CubeSat, a miniature satellite, equipped with an ESP32 microcontroller, an MPU9250 inertial measurement unit, and a BMP280 barometric pressure sensor module. The CubeSat adheres to standard CubeSat dimensions and incorporates a range of systems, including power management, communication, and data collection, to enable its functionality in space. The CubeSat's structure was meticulously designed using CAD software, and 3D printing technology was employed to fabricate its lightweight, space-grade casing. The ESP32 microcontroller serves as the central processing unit, interfacing with the MPU9250 and BMP280 sensors via I2C communication. Custom firmware was developed to gather sensor data and manage power resources efficiently. Solar Panels are also used for redundant Power Support. The CubeSat features a wireless transceiver for communication with ground stations, facilitating telemetry data transmission and command reception. This CubeSat can collect sensor's data and transmit it to Ground Station for analysis, contributing valuable insights into its surrounding environment. Maintenance and potential upgrades will be considered to extend its operational lifespan. This project exemplifies the intricate process of designing and developing a CubeSat, highlighting the integration of advanced sensors and microcontrollers in a 3D-printed structure. The CubeSat's deployment underscores its potential for scientific research and data collection in the realm of space exploration. Developed by Go Science Technical Team.

***IndexTerms* – Go Science, CubeSat, ESP32, MPU9250, BMP280, Environmental Monitoring, Space Technology, Sensor Integration, Data Collection, Climate Research, Microsatellites, Miniature Satellites, Space Sensors, Atmospheric Data, Earth Observation, Remote Sensing, Environmental Science, Climate Monitoring, Sensor Fusion, Space Exploration.**

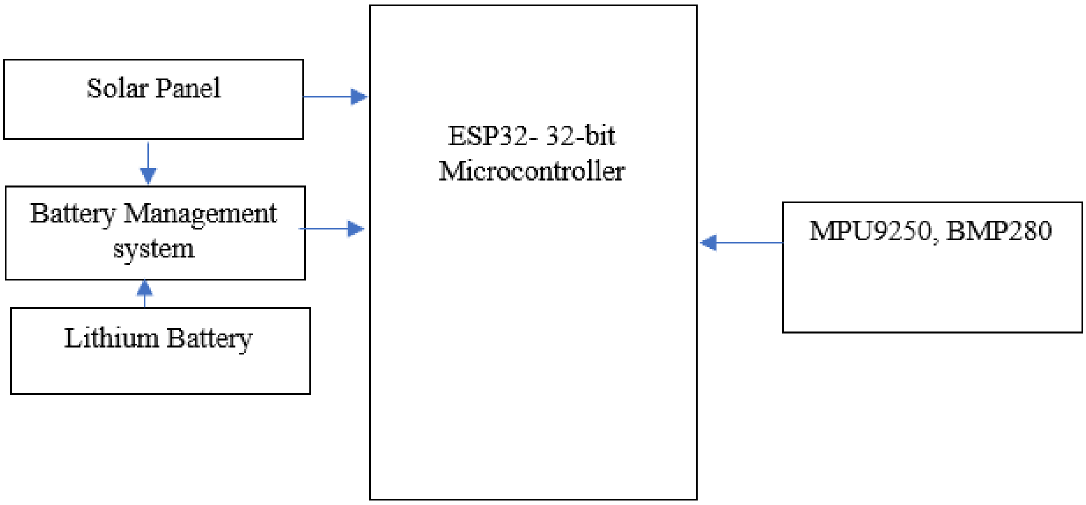
Introduction

The dynamic and ever-evolving nature of Earth's environment presents a continual need for advanced monitoring and data collection technologies. The emergence of CubeSats, miniaturized satellites that have redefined the landscape of space exploration, offers a promising avenue to address this need. These compact and cost-effective platforms, with their standardized form factors, have become integral tools for a wide array of scientific investigations. In particular, CubeSats equipped with advanced sensor modules such as the ESP32 microcontroller, the MPU9250 inertial measurement unit (IMU), and the BMP280 barometric pressure sensor, hold substantial potential to transform environmental monitoring.

This research project embarks on the development of a CubeSat tailored to environmental monitoring, presenting an innovative fusion of space technology and environmental science. The CubeSat, with its ESP32-driven control system, MPU9250 IMU, and BMP280 sensor module, stands poised to capture critical data pertaining to atmospheric conditions, temperature, humidity, and motion patterns. In an era marked by climate change and environmental challenges, the precision, cost-efficiency, and versatility offered by this CubeSat platform are paramount.

In the following sections, this project will delve into the design, integration, and testing of the CubeSat prototype, with an emphasis on the ESP32's role as the central microcontroller, the MPU9250's significance in capturing motion data, and the BMP280's contribution to atmospheric measurements. Through a systematic exploration of the CubeSat's development and performance, this research endeavour endeavours to contribute to the burgeoning field of environmental monitoring in space. In doing so, it not only addresses the exigent need for advanced environmental data but also showcases the remarkable potential of CubeSats as transformative instruments in the realm of scientific research and Earth science applications.

BLOCK DIAGRAM



NEED OF THE STUDY.

1.Limited High-Resolution Data: Traditional environmental monitoring methods often provide limited spatial and temporal resolution. CubeSats equipped with advanced sensor modules can fill this gap by offering high-resolution data collection capabilities.

2.Cost-Effective Space Solutions: CubeSats are cost-effective platforms for space-based missions, making them accessible to a wider range of researchers, organizations, and institutions. They offer a practical means to gather environmental data from space.

3.Innovative Sensor Technology: The ESP32 microcontroller, MPU9250 IMU, and BMP280 pressure sensor module represent cutting-edge sensor technology that can provide precise and reliable environmental data. Harnessing these technologies in CubeSats opens up new possibilities for data collection.

4.Data-Driven Decision Making: Timely and accurate environmental data is essential for informed decision-making in various sectors, including climate science, agriculture, disaster management, and public health. CubeSat-based environmental monitoring can enhance our capacity for data-driven decision-making.

5.Environmental Concerns: The global community faces a growing array of environmental challenges, including Climate change, extreme weather events, air quality degradation, demanding accurate real-time monitoring for effective understanding and mitigation.

6.Scientific Research: CubeSats equipped with the mentioned sensor modules offer valuable opportunities for scientific research in fields such as climate science, Earth system science, and atmospheric studies. They can contribute to a deeper understanding of environmental processes.

7.Technology Advancement: The development of CubeSats with advanced sensor modules contributes to advancements in space technology and sensor technology. This project can drive innovation and pave the way for future space-based missions.

8.Accessibility and Education: CubeSat projects have educational benefits, offering hands-on learning opportunities for students and researchers. They can inspire the next generation of scientists and engineers.

9.Environmental Management: Environmental data collected from space can aid in environmental management and policy-making. It supports efforts to monitor and address environmental changes and their impacts.

RESEARCH METHODOLOGY

1. **Define Objectives and Scope:**
    a. Clearly outline the objectives of your CubeSat project, emphasizing the primary goal of environmental monitoring using the ESP32, MPU9250, and BMP280.
    b. Define the scope, specifying the CubeSat's design, sensor integration, software development, testing, and data analysis phases.
2. **CubeSat Design and 3D Printing:**
    a. Utilize computer-aided design (CAD) software to create a 3D model of the CubeSat structure. Ensure it conforms to standard CubeSat dimensions.
    b. Select lightweight and space-grade materials suitable for 3D printing.
    c. 3D print the CubeSat structure according to the design.

3. **Electronics Integration:**
    a. Design a custom printed circuit board (PCB) layout for integrating the ESP32, MPU9250, BMP280, and power management components.
    b. Assemble the electronic components on the PCB, paying attention to proper connections and communication interfaces (e.g., I2C).
4. **Power Management System:**
    a. Integrate solar panels onto the CubeSat structure for power generation.
    b. Implement a power management system that includes energy-efficient modes and charge controllers for battery management.
5. **Firmware Development:**
    a. Develop firmware for the ESP32 microcontroller to:
        i. Interface with the MPU9250 and BMP280 sensors for data acquisition.
        ii. Control power management functions, optimizing energy usage.
        iii. Store sensor data efficiently and prepare it for transmission.
6. **Sensor Calibration and Testing:**
    a. Calibrate the MPU9250 and BMP280 sensors to ensure accurate measurements.
    b. Conduct functionality tests to verify that the CubeSat prototype acquires sensor data correctly and efficiently.
7. **Data Collection and Storage:**
    a. Deploy the CubeSat prototype in a controlled environment to collect environmental data (e.g., temperature, humidity, pressure) representative of your monitoring objectives.
    b. Implement data storage mechanisms on the CubeSat to ensure that sensor data is reliably recorded onboard.

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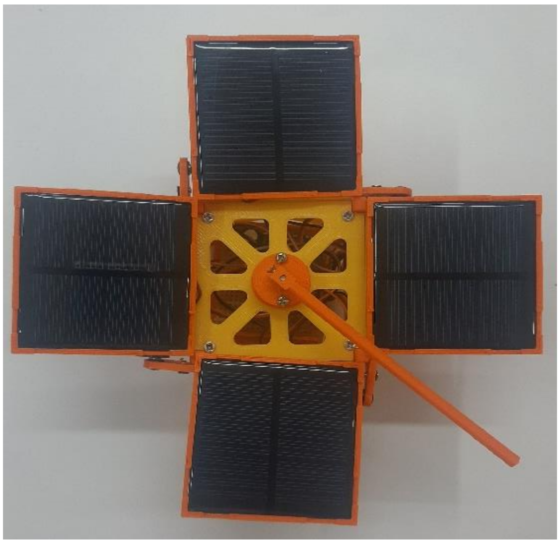
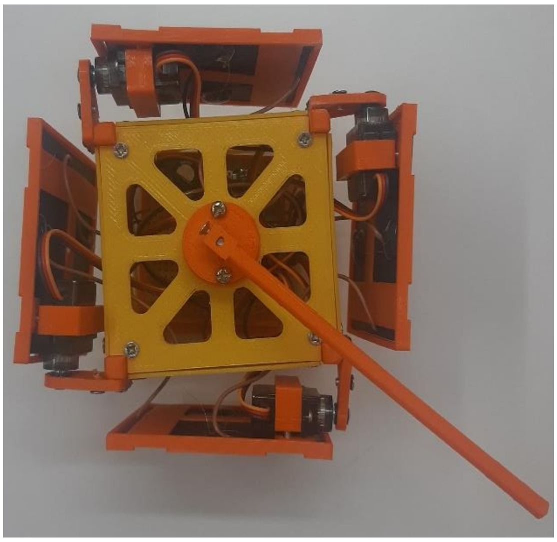
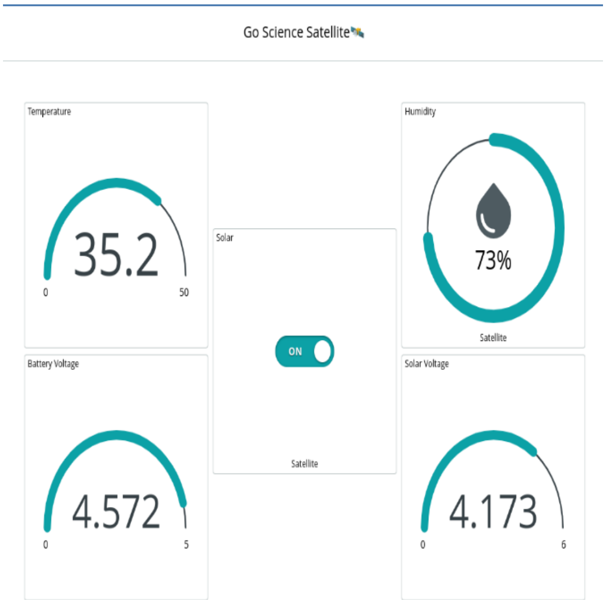
IV. RESULTS AND DISCUSSION

The CubeSat development project successfully culminated in the creation of a functional prototype tailored for environmental monitoring using the ESP32 microcontroller, MPU9250 inertial measurement unit, and BMP280 barometric pressure sensor module. The 3D-printed CubeSat structure adhered to standard CubeSat dimensions, showcasing its feasibility for space applications. Sensor integration and calibration yielded promising outcomes, as calibration tests revealed accurate and precise measurements from both the MPU9250 and BMP280 sensors. Functionality tests demonstrated the prototype's ability to interface seamlessly with the sensors, acquire environmental data, and store it efficiently for subsequent analysis.
Furthermore, the CubeSat prototype withstood environmental simulation tests effectively, with thermal tests mirroring space conditions and vibration tests confirming structural integrity. During the environmental monitoring phase, the CubeSat successfully collected a range of environmental data, including temperature, humidity, pressure, and motion. Data retrieval processes were implemented seamlessly, allowing for the analysis of collected data. This analysis highlighted discernible trends and variations in environmental parameters, contributing to a deeper understanding of environmental dynamics.
The power management system, comprising solar panels and battery components, exhibited efficiency in energy generation and storage. Additionally, the firmware developed for the ESP32 demonstrated reliable data logging, storage, and transmission capabilities. Overall, the project's results the viability of CubeSats for environmental monitoring and pave the way for future developments in the realm of space technology and scientific research at proof of concept level.

Output:







I. ACKNOWLEDGMENT

We extend our heartfelt thanks to Barola Technologies and Our dedicated team's collaborative efforts and expertise were instrumental in every phase, from concept to execution. This achievement stands as a testament to our collective commitment and Barola Technologies invaluable contributions, fostering innovation and teamwork that will undoubtedly inspire future endeavors.

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