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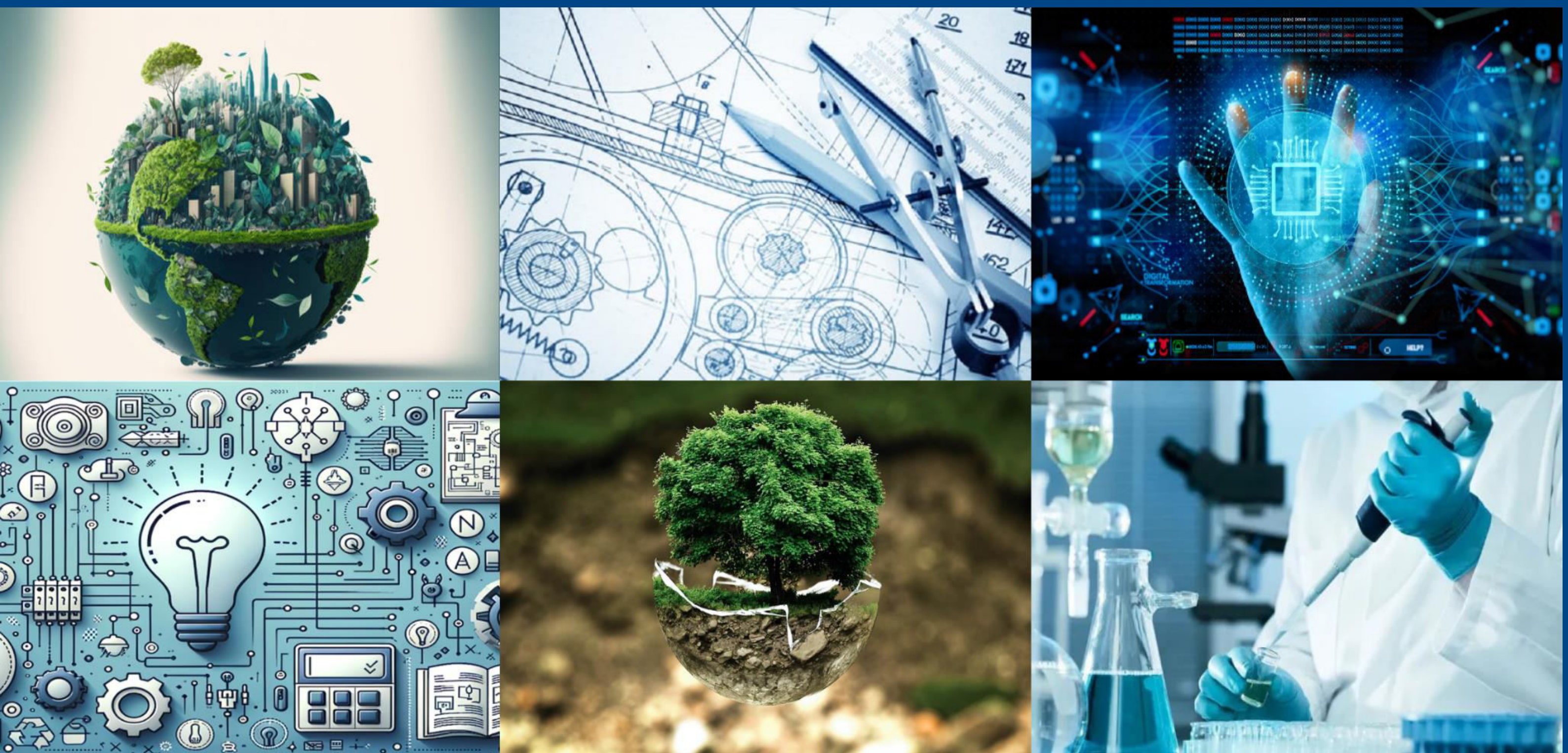

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ASTRON-S3: AI-Enabled Edge Computing CubeSat for Real-Time Telemetry and Fault Detection

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ABSTRACT: This project focuses on the design and development of ASTRON-S3: AI-Enabled Edge Computing CubeSat for Real-Time Telemetry and Fault Detection, aimed at improving the efficiency, autonomy, and reliability of small satellite systems. Traditional CubeSat architectures mainly depend on ground stations for data processing, monitoring, and fault analysis, which leads to communication delays, higher bandwidth consumption, and limited real-time responsiveness. To overcome these challenges, the proposed system introduces an intelligent CubeSat platform capable of onboard processing and anomaly detection using artificial intelligence edge computing technologies, IOT (Internet of Things). A key feature of the proposed system is its real-time telemetry monitoring capability, where sensor data is collected, processed, and analysed directly within the satellite. ThingSpeak cloud platform is implemented.

KEYWORDS: Edge Computing, IOT (Internet of Things), ThingSpeak.

I. INTRODUCTION

ASTRON CubeSat is a compact 1U satellite system designed for intelligent telemetry monitoring, wireless communication, and real-time data analysis. The proposed system follows the standard CubeSat dimension of **10 × 10 × 10 cm**, providing a lightweight and space-efficient architecture suitable for educational and research applications. The system integrates various hardware modules such as Arduino Nano, ESP32-S3, GPS module, DHT sensor, ESP32-CAM, solar panel, and MicroSD storage module for efficient data acquisition and monitoring. The collected telemetry data, including environmental and system parameters, is processed using onboard microcontrollers and transmitted wirelessly to the ground station through Wi-Fi and HTTP protocol. The ESP32-S3 based ground station uploads the received data to the ThingSpeak cloud platform for remote monitoring and visualization. The proposed system also includes power management using a rechargeable battery, TP4056 charging module, and buck-boost converter to ensure stable operation.

II. LITERATURE SURVEY

Recent advancements in CubeSat technology have focused on developing compact, low-cost, and efficient satellite systems for communication, telemetry monitoring, and scientific research. Several researchers and space organizations such as ISRO, NASA, ESA. and JAXA have developed CubeSat platforms for environmental monitoring, Earth observation, and onboard data processing. Existing systems mainly concentrate on telemetry transmission, sensor integration, and power management using lightweight architectures.

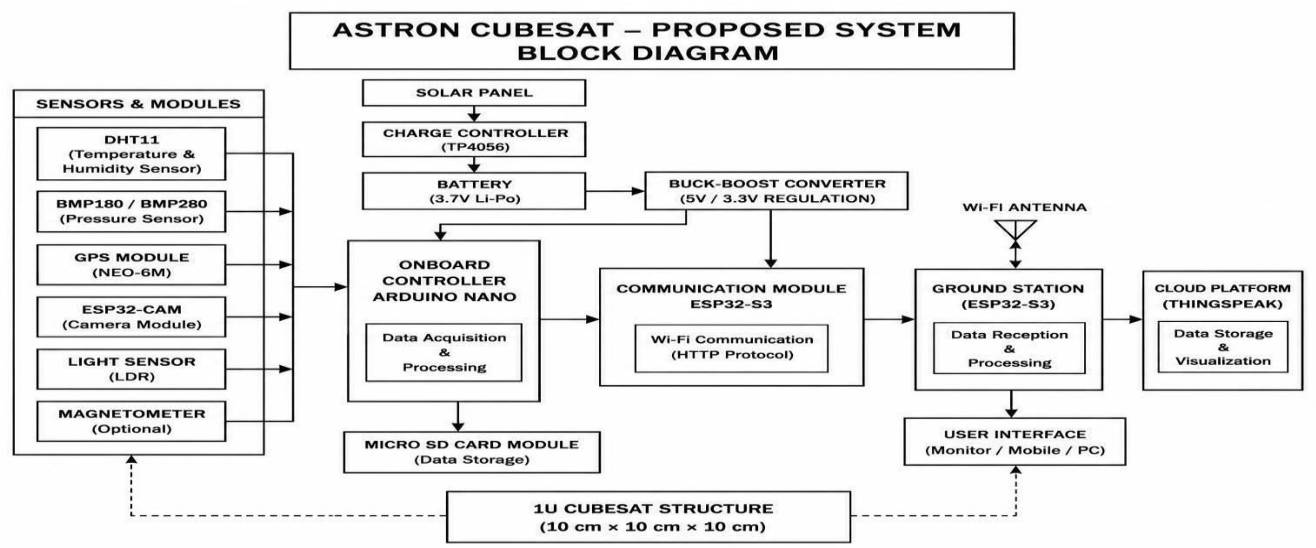
III. EXISTING SYSTEM AND LIMITATIONS

Existing systems have high dependency on ground stations for data analysis and decision-making. They also suffer from communication delay, higher power consumption, and inefficient transmission of raw data. In addition, many systems lack intelligent fault detection and real-time onboard processing capabilities.

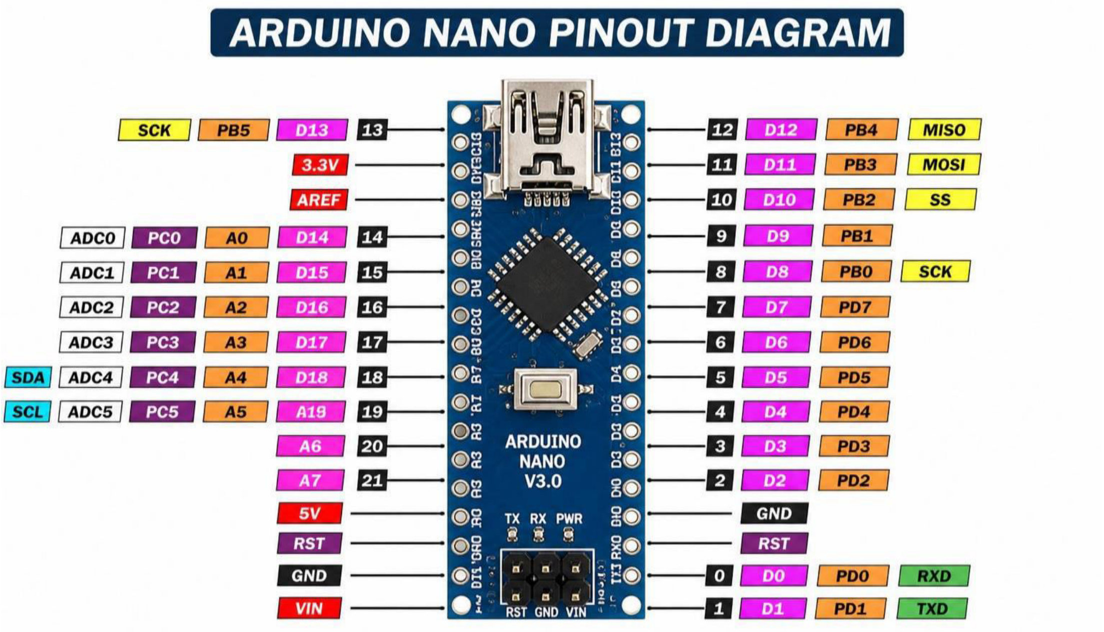
IV. PROPOSED SYSTEM

The proposed ASTRON CubeSat is a compact 1U satellite system designed for real-time telemetry monitoring, intelligent data processing, and efficient wireless communication. The system integrates components such as Arduino Nano, ESP32-S3, GPS module, DHT sensor, ESP32-CAM, and cloud connectivity to monitor environmental and system parameters continuously. Sensor data is processed onboard and transmitted to the ground station using Wi-Fi and HTTP protocol for real-time visualization through the ThingSpeak cloud platform.

4.1 BLOCK DIAGRAM OF PROPOSED SYSTEM



4.2 ARDUINO NANO PIN DIAGRAM



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4.3 SYSTEM DESIGN

1. ON BOARD

- DHT-SENSOR
- 18650 Li-ion battery
- LED
- Arduino Nano

2. COMMUNICATION SYSTEM

- HTTP
- ThingSpeak

3. GROUND STATION

- ESP32-S3
- Laptop for Data visualization

4. HARDWARE COMONENTS

- Arduino Nano is a compact microcontroller board based on the ATmega328P processor It is used for processing sensor data and controlling the overall CubeSat operations. The board supports digital and analog input/output pins with low power consumption.
- The DHT sensor is used to measure environmental temperature and humidity values.It provides real-time atmospheric data for telemetry monitoring applications.The sensor is compact, low-cost, and easy to interface with Arduino Nano.
- ESP32-S3 is a high-performance microcontroller with built-in Wi-Fi and Bluetooth support.It is used for wireless communication between the CubeSat system, ground station, and cloud platform.The module supports fast data processing, low power operation, and real-time IoT communication.

5. WORKING PRINCIPLE

- The sensors continuously collect environmental and system data such as temperature, humidity, and location.
- Arduino Nano processes the collected data and controls the onboard system operations.
- ESP32-S3 transmits the processed telemetry data wirelessly to the ground station using HTTP protocol.
- The ground station uploads the received data to the ThingSpeak cloud platform for real-time monitoring and visualization.

6. CIRCUIT AND SOFTWARE DESIGN

- The system integrates Arduino Nano, ESP32-S3, sensors, and power management modules through a compact PCB-based circuit design for efficient operation.
- The software is developed using Arduino IDE to acquire sensor data, process telemetry information, and control wireless communication.
- HTTP protocol and ThingSpeak cloud platform are used for real-time data transmission, monitoring, and visualization through the ground station system.

V. RESULT AND DISCUSSION

- The proposed ASTRON CubeSat system successfully collected and monitored real-time telemetry data such as temperature, humidity, and GPS location.
- Wireless communication between the CubeSat, ESP32-S3 ground station, and ThingSpeak cloud platform was achieved successfully using HTTP protocol.
- The system demonstrated stable power management, efficient data transmission, and reliable cloud-based monitoring within a compact 1U CubeSat structure.

ADVANTAGES OF PROPOSED SYSTEM

- Compact and lightweight 1U CubeSat design with efficient space utilization.
- Real-time telemetry monitoring using sensors and cloud integration.
- Wireless communication through ESP32-S3 and HTTP protocol.
- Solar-powered energy management with stable voltage regulation.
- Local and cloud-based data storage for reliable monitoring.
- Low-cost, scalable, and suitable for educational and research applications.

APPLICATIONS

- Real-time satellite telemetry monitoring and communication.
- Educational and academic CubeSat research projects.
- Environmental and weather monitoring applications.
- GPS-based tracking and navigation systems.
- IoT-based remote sensing and cloud monitoring systems.
- Space technology testing and nanosatellite experiments.
- Image capturing and surveillance using onboard camera modules.

VI. FUTURE SCOPE

- LoRa technology.
- Advanced AI and machine learning algorithms.
- Additional environmental sensors.
- Higher-capacity solar panels.
- Inter-satellite networking for future CubeSat missions.

VII. CONCLUSION

The proposed ASTRON CubeSat system successfully demonstrates a compact and efficient 1U satellite platform for real-time telemetry monitoring and wireless communication. The integration of Arduino Nano, ESP32-S3, sensors, GPS, and cloud connectivity enables reliable data acquisition and monitoring. The system achieved stable communication between the CubeSat, ground station, and ThingSpeak cloud platform using HTTP protocol. Efficient power management using solar energy and battery regulation improved system reliability. The project provides a low-cost and scalable solution for educational, research, and future nanosatellite applications.

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