INNOVATIVE CAN SATELLITE FOR LOWER SPACE EXPLORATION: ADVANCING SMART CITIES, PRECISION AGRICULTURE AND ENVIRONMENTAL MONITORING

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Keywords:

Atmospheric Data Acquisition, CAN Satellite, Parachute-based Recovery System, Received Signal Strength Indicator (RSSI), Signal-to-Noise Ratio (SNR), Stress and Deformation Analysis, Telemetry Transmission.

Introduction:

The CAN Satellite project is an innovative venture into the realm of low-cost, miniaturized satellite technology aimed at atmospheric data acquisition and telemetry transmission. It is designed to ascend up to 1 km using a launch mechanism and safely descend with a parachute-based recovery system which demonstrates the potential of compact satellites for environmental monitoring. By integrating precision sensors such as the MPU6050 (IMU), BMP280V (barometric pressure and temperature) and NEO-6M GPS along with ESP32-based microcontroller logic, the satellite collects and transmits real-time data to a ground station via LoRa-based communication. This project is highly relevant to academic research, aerospace prototyping and disaster management systems due to its portability, affordability and scalable design.

Figure 1: Structural CAD Model of CAN Satellite
with Parachute-Assisted Descent Mechanism

Objectives:

- To design and develop a compact, cost effective innovative CAN Satellite capable of ascending to an altitude of 1 km, collecting and transmitting real-time atmospheric data.
- To analyze the structural stability and stress response of the satellite architecture through a simulation tool like Fusion 360, ensuring safe operation during launch and descent and thereby implement a parachute-assisted descent system to ensure stable landing and safe hardware recovery.
- To integrate advanced sensors for real-time acquisition of atmospheric parameters such as temperature, pressure, humidity, acceleration, orientation and GPS coordinates.
- To establish a robust wireless telemetry system using LoRa communication for seamless data transmission between the satellite and the ground station.

Methodology:

For mechanical validation, the structural design of the CAN Satellite was created in Fusion 360 using precision CNC-based machine cutting profiles followed by finite element analysis (FEA) simulations to assess stress concentration points, von Mises stress distribution and factor of safety (FOS) during descent. A parachute-assisted recovery mechanism is incorporated to ensure safe landing and retrievability of the hardware.

Figure *2.1*: Structural and Internal Architecture of
CAN Satellite

The project commenced with a detailed system architecture design comprising the ESP32-DevKit microcontroller, responsible for data acquisition and transmission control. The satellite system was divided into two distinct modules—transmitter and receiver—both initially implemented on breadboards for prototyping. The MPU6050 sensor combines a 3-axis accelerometer and 3-axis gyroscope and the BMP280V sensor for barometric pressure and temperature sensing, were interfaced via the I²C communication protocol. A NEO-6M GPS module, communicating through UART, provided real-time geolocation coordinates. For long-range telemetry, the LoRa SX1278 transceiver module operating at 433 MHz was interfaced via the SPI protocol, enabling efficient data transmission to the ground station.

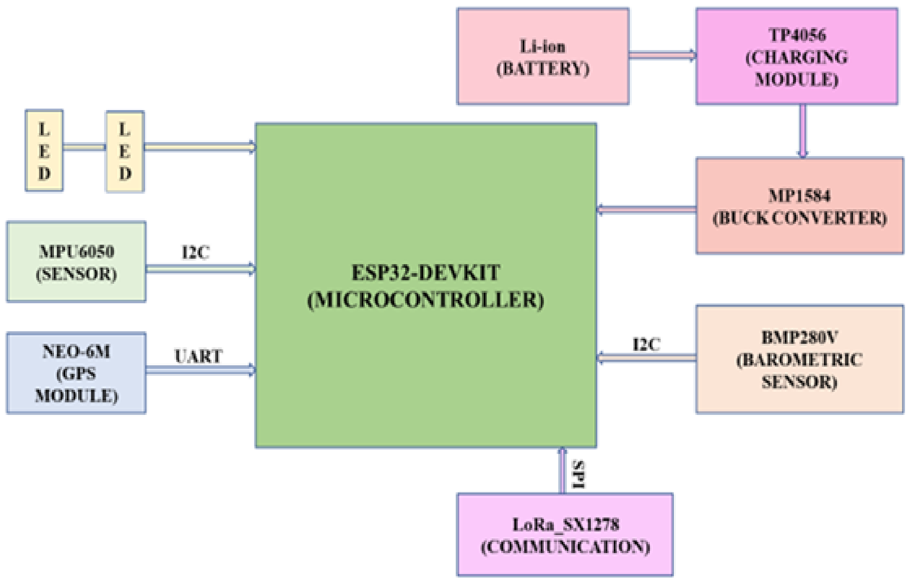


Figure *2.2*: Block Diagram of CAN Satellite

The power system included a rechargeable Li-ion battery with TP4056 charging protection module for safe USB Type-C charging, and MP1584 DC-DC buck converter to regulate voltage levels appropriate for the ESP32 and peripheral devices. The firmware for both modules was developed using Arduino IDE v2.3.5 with serial communication baud rates configured for consistent and stable data flow. Range testing was performed to evaluate signal quality through Received Signal Strength Indicator (RSSI) and Signal-to-Noise Ratio (SNR) values.

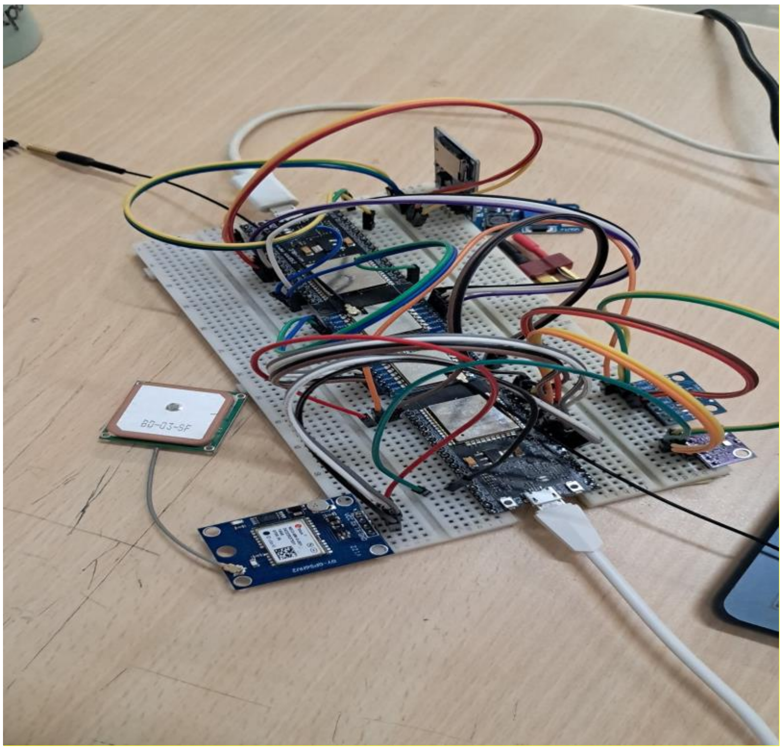
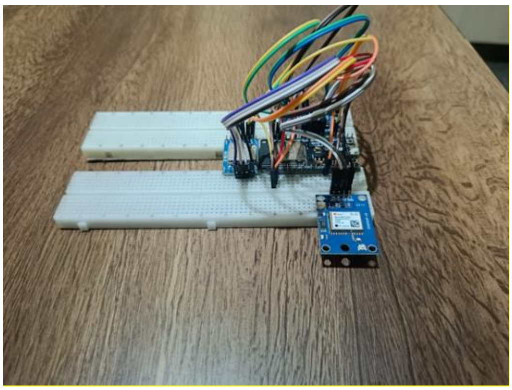


Figure *2.3*: Breadboard Setup of the Transmitter and Receiver Modules

Software algorithms were implemented in Arduino IDE for data acquisition, sensor calibration, and real-time transmission. Range testing was conducted to evaluate RSSI and SNR values, ensuring reliable long-distance communication. A parachute-assisted descent mechanism was designed to stabilize landing and minimize impact force. Breadboard testing was followed by final PCB design and soldering to embed components within the satellite housing.

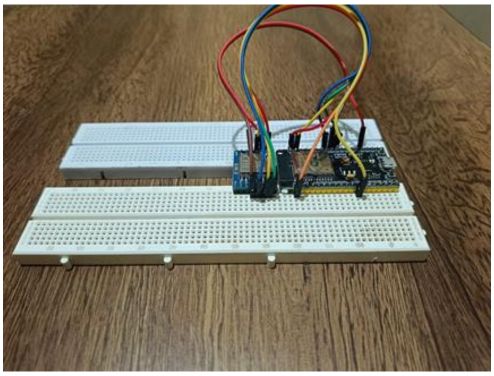
Result and Conclusion:

The CAN Satellite system successfully integrates key components within a compact design to enable real-time atmospheric data collection and telemetry. The ESP32 microcontroller efficiently handled sensor data processing, while the LoRa SX1278 module achieved reliable long-range communication with average RSSI values of -60 dBm and SNR around 9.5dB. Sensor modules, including the MPU6050 for motion tracking, BMP280V for temperature and pressure, and a GPS unit for location tracking, performed accurately during testing. Structural simulation conducted in Fusion 360 validated the mechanical integrity of the payload casing under descent stress, confirming the effectiveness of the parachute-assisted recovery system. The integrated PCB layout reduced space constraints and improved system reliability. The ground tests conducted for the transmitter and receiver modules, developed using Arduino IDE, demonstrated stable signal transmission with minimal packet loss. Additionally, a parachute-based recovery system ensured safe descent in drop tests. Visual data logs and graphs of sensor readings further reinforced system performance and reliability. Photographs and simulation outputs are included to support the observed results. These outcomes confirm the system's readiness for PCB integration and real-world deployment.



```
Transmitting: Temp:32.22C, Pressure:908.90hPa, Alt:907.48m, Accel(872,132,14136), Gyro(-295,-192,-352), GPS(13.116855,77.6347
Transmitting: Temp:32.23C, Pressure:908.87hPa, Alt:907.75m, Accel(848,140,14124), Gyro(-280,-167,-341), GPS(13.116858,77.6347
Transmitting: Temp:32.22C, Pressure:908.87hPa, Alt:907.72m, Accel(852,88,14160), Gyro(-299,-180,-339), GPS(13.116861,77.63477
Transmitting: Temp:32.22C, Pressure:908.90hPa, Alt:907.44m, Accel(976,140,14232), Gyro(-287,-210,-356), GPS(13.116866,77.6347
Transmitting: Temp:32.22C, Pressure:908.88hPa, Alt:907.65m, Accel(840,52,14092), Gyro(-300,-161,-354), GPS(13.116869,77.63478
```

Figure *3.1*: Results from the Transmitter Module



```
Received: Temp:34.16C, Pressure:907.09hPa, Alt:923.93m, Accel(1408,88,14216), Gyro(-275,-172,-358), GPS(13.116921,77.634452)
RSSI: -22
SNR: 9.75
Received: Temp:34.16C, Pressure:907.09hPa, Alt:923.90m, Accel(1472,128,14296), Gyro(-280,-208,-336), GPS(13.116916,77.634454)
RSSI: -23
SNR: 10.50
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```
Received: Temp:32.21C, Pressure:907.30hPa, Alt:921.95m, Accel(1032,136,14320), Gyro(-275,-184,-357), GPS(N/A)
RSSI: -76
SNR: 9.25
Received: Temp:32.21C, Pressure:907.32hPa, Alt:921.80m, Accel(976,124,14148), Gyro(-298,-179,-345), GPS(N/A)
RSSI: -76
SNR: 9.25
```

```
Received: Temp:32.28C, Pressure:907.39hPa, Alt:921.13m, Accel(1072,148,14268), Gyro(-290,-186,-340), GPS(N/A)
RSSI: -96
SNR: -4.50
Received: Temp:32.28C, Pressure:907.39hPa, Alt:921.13m, Accel(852,124,14232), Gyro(-316,-187,-336), GPS(N/A)
RSSI: -95
SNR: -5.75
```

Figure *3.2*: Results from the Receiver Module

Project Outcome and Industry Relevance:

The project validates the feasibility of using miniaturized satellites for short-range atmospheric research making it highly applicable in academic, defence and meteorological sectors. It offers potential applications in weather monitoring, early disaster warning systems and aerospace prototyping. The modular payload design ensures adaptability for additional sensors or mission-specific modules. By using advanced simulation (Fusion 360), microcontroller integration (ESP32) and wireless communication protocols, this project enhances student-driven innovation and promotes interdisciplinary learning in embedded systems, IoT and aerospace engineering. Its practical implementation in educational institutes and research labs positions it as a low-cost tool for experimental validation and training in satellite technology.

Working Model vs Simulation Study:

This project involves the development of a fully functional embedded hardware prototype of a CAN Satellite equipped with integrated MEMS-based sensors (MPU6050 for inertial measurement, BMP280V for barometric pressure and temperature), GPS for geolocation and LoRa SX1278 for long-range telemetry communication via the SPI protocol. The microcontroller unit (ESP32) facilitates real-time data acquisition, processing and transmission. Additionally, comprehensive structural integrity and aerodynamic simulations were conducted using Autodesk Fusion 360, focusing on finite element analysis (FEA) and stress distribution under descent conditions. Hence, the project combines both a physical prototype implementation and computational simulations, ensuring design validation, system robustness and operational reliability.

Future Scope:

The CAN Satellite system developed in this project serves as a foundational model for various future enhancements and real-world applications. The following points outline the potential scope for advancement:

1. **Advancing Smart Cities:** The CAN Satellite system can be adapted to support smart city infrastructure by deploying multiple units across city zones, the system can enable **air quality monitoring, urban heat mapping** and **real-time weather updates** contributing to sustainable urban planning. Additionally, sensor modularity makes the system customizable for diverse urban applications such as traffic management, flood detection and noise monitoring which makes it a scalable, cost-effective solution for enhancing urban living and resilience in smart cities.
2. **Cloud Integration:** The collected telemetry data can be integrated with cloud platforms such as **AWS, Azure or Firebase** for real-time visualization, storage and analysis and **machine learning models** for anomaly detection, predictive analysis and automated decision-making during flight. This transition enables smart, scalable and remote monitoring capabilities.
3. **Disaster Monitoring:** Future iterations can incorporate additional sensors such as **gas sensors** for atmospheric pollution monitoring, **radiation sensors** to

study cosmic ray exposure at higher altitudes, **humidity and UV sensors** to enhance environmental profiling which makes the system more versatile for environmental science, climate studies and disaster monitoring.

4. **Educational and Research Applications:** The system can serve as a low-cost, reusable platform for **STEM education** in schools and universities. It can also be adapted for research in **aerospace engineering**, **remote sensing** and **atmospheric physics**. It's integration with **unmanned aerial vehicles (UAVs)** or **balloon payloads** allows higher-altitude exploration beyond 1 km.
5. **Precision Agriculture:** The satellite integrates sensors like **BMP280V (temperature and pressure)** and can easily be upgraded with **humidity, soil moisture or CO_2 sensors**. This helps us to assess microclimatic conditions which affects crop health and predict weather-related stress on plants. The integrated **GPS module** allows real-time geotagging of sensor data which can be used for field mapping to identify zones with specific issues like low moisture thereby incorporating **Variable rate technology (VRT)** by applying water, fertilizer or pesticides only where needed, saving resources and improving crop quality.