Advanced Design and Implementation of a CanSat for Environmental Monitoring and Data Transmission

[1]Darshan S P, [2]Chandrababu Gowda, [3]Chandu H Y, [4]Darshan K, [5]Dr. Chandrika J
[1,2,3,4] Dept of Computer Science and Engg. Malnad College of Engineering, Hassan, India
[5]Guide & HOD, Dept of Computer Science and Engg. Malnad College of Engineering, Hassan, India

***Abstract*—This paper presents the innovative design and de- velopment of a CanSat model for environmental monitoring and educational applications. The project features a compact, miniaturized structure equipped with calibrated sensors to mea- sure temperature, pressure, humidity, and GPS coordinates. A reliable NRF-based communication system enables seamless real-time data transmission. To ensure a safe and controlled descent, a dual-parachute mechanism is incorporated, enhancing redundancy and reducing descent speed. In case one parachute fails, the other ensures a safe landing. Furthermore, an egg- molding case is integrated to absorb impact forces and protect delicate components during landing.**

This conceptual design addresses gaps in communication reliability and system redundancy identified in prior research. By offering a cost-effective and scalable solution, it aims to advance small satellite technology, with potential applications in environ- mental data collection and hands-on educational experiences.

I. INTRODUCTION

The CanSat concept, evolved through initiatives launched by the ESA and NASA initially, is essential in space studies and environmental conditions, and more importantly, inexpensive and deployable. Its short length of about 115 millimeters and only 66 millimeter diameter makes CanSat suitable even for educational activities, and early satellite missions too. Small satellite technology can be accessed and reached in a cheaper and more accessible way for research and education purposes using CanSats.

This paper covers the design and development of an ad- vanced model of CanSat to be used in environmental mon- itoring and research. The proposed CanSat will integrate sensors such as temperature, pressure, humidity, and GPS modules to obtain real-time environmental data. A reliable communication module based on NRF technology ensures flawless data transmission to a ground station. To guarantee a controlled descent and safeguard the payload, the mechanism includes redundancy in case one parachute fails due to a dual- parachute mechanism. Moreover, the egg-molding case pro- tects the payload by absorbing impact forces during landing. The paper is structured as follows: it begins with a lit- erature review that discusses key advancements, challenges, and research gaps in CanSat technology. The design and implementation section covers the mechanical, electrical, and software systems, detailing the integration of the sensors, communication modules, and parachute descent mechanism. All communication framework and process of data handling are shown as circuit diagrams by the receiver as well as trans- mitter. Whole paper ends by giving acknowledgements and references, which will prove instrumental in further developing the ideas portrayed.

II. LITERATURE SURVEY OVERVIEW

A. *Introduction to the Section*

The literature survey reveals significant advancements in CanSat technology, while also highlighting recurring chal- lenges such as communication reliability, sensor calibration, and material durability. This study builds on prior research to address these gaps, focusing on enhancing modularity, redundancy, and environmental resilience.

B. *Individual References*

Belhaj et al., 2015: Designed a CanSat with a dual-stage descent mechanism using a parasheet and spring-loaded rods. Integrated sensors like BMP180 for altitude and temperature. Challenges included environmental interference and parachute fabrication precision. Our study extends this work by exploring more reliable descent mechanisms and improved materials.

Dilena et al., 2015, conducted a comparative study of barometric, GPS, and accelerometer-based height measure- ments, noting discrepancies caused by external factors such as weather. Our design addresses these concerns by integrating calibrated sensors to minimize errors in height measurements. Klitgaard et al., 2015, developed a CanSat with two-way communication and an onboard camera. While successful in data collection, issues with camera failure and data stor- age were reported. Our system addresses these challenges by integrating a reliable NRF-based communication module and robust redundancy mechanisms to ensure consistent data transmission and safeguard the system during descent.

C. Survey Outcome

The reviewed studies highlight the need for improved communication reliability, sensor accuracy, and environmental resilience. This study contributes by implementing enhanced data-handling systems, and advanced telemetry to ensure reli- able data collection and transmission.

III. DESIGN AND IMPLEMENTATION

A. Mechanical Design

The CanSat's body is 3D-printed using lightweight, durable materials, ensuring structural integrity and modularity. Shock- absorbing materials are incorporated to protect sensitive elec- tronics during landing. A parachute system ensures controlled descent, with deployment triggered by altitude data from BMP280 sensors.

B. Electrical System

- Microcontroller: We may choose either Arduino Nano or ESP32-C3 for efficient data processing and control.

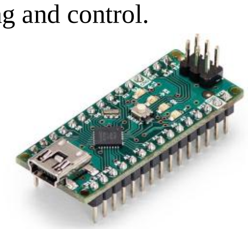

Fig. 1. Arduino Nano Microcontroller

Fig. 2. ESP32-C3 Microcontroller

- Sensors:
  - MPU6050 for orientation.

Fig. 3. MPU6050 Sensor (Orientation)

  - BMP280 for pressure and altitude.

Fig. 4. BMP280 Sensor (Pressure and Altitude)

  - DHT22 for temperature and humidity.

Fig. 5. DHT22 Sensor (Temperature and Humidity)

- Power: A lithium polymer battery with a monitoring circuit ensures consistent power supply.
- NEO-07 GPS module for location tracking.

C. Communication System

The NRF module is used for reliable data transmission. Ini- tial range and interference tests ensure robust communication up to a predefined height.

Fig. 6. Lithium Polymer Battery

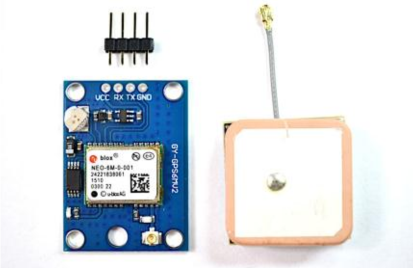

Fig. 7. NEO-07 GPS Module

D. Software Integration

- A MERN-stack web platform processes and visualizes data in real time.
- Ground station systems initiate a POST request to store data in a cloud-based database for redundancy.
- Algorithms handle sensor data validation, filtering, and visualization through charts and graphs.

IV. PRELIMINARY DESIGN

A. Overview

The proposed CanSat design is a comprehensive integration of mechanical, electrical, and software systems, aimed at envi- ronmental monitoring and educational applications. The design emphasizes reliability, redundancy, and modularity, ensuring that it meets the mission objectives of data collection and safe descent. The CanSat is designed to fit within the standard dimensions of 115mm in length and 66mm in diameter, while accommodating a suite of sensors, communication modules, and a descent mechanism.

B. Mechanical Design

The mechanical design of the CanSat is centered around a lightweight yet durable structure, primarily using acrylic filament for its strength-to-weight ratio. The CanSat is divided into modular sections for easy access and component replace- ment. The layout ensures that sensors and communication modules are strategically placed to avoid interference, with shock-absorbing materials protecting sensitive components.

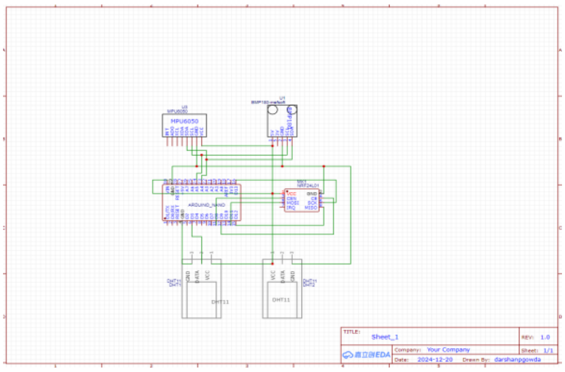

Fig. 8. Transmitter Circuit Diagram

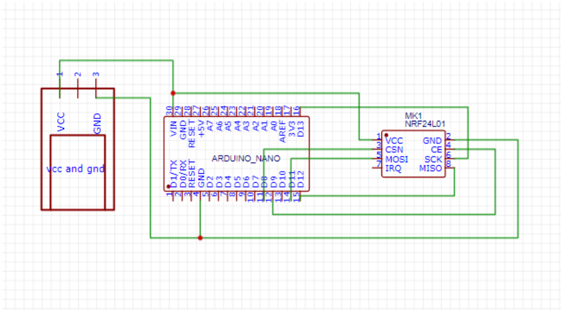

Fig. 9. Receiver Circuit Diagram

The design includes a heat shield and insulation to manage thermal conditions during descent.

C. Descent Mechanism

The descent mechanism incorporates a dual parachute sys- tem for redundancy, with a main parachute and a backup parachute deployed based on altitude data from GPS and barometric sensors.

D. Sensor and Communication Systems

The CanSat is equipped with a suite of environmental monitoring sensors, including temperature, pressure, humidity, and GPS sensors. The communication strategy involves using NRF for long-range data transmission, ensuring reliable data transfer. Data compression and encryption techniques are used to optimize bandwidth usage and secure data transmission.

E. Power System

The power system utilizes a high-energy-density lithium polymer battery, managed by a low-power microcontroller to optimize power distribution. The design includes a power allocation strategy to prioritize critical systems during low-power situations, with a battery monitoring system to track charge levels and health.

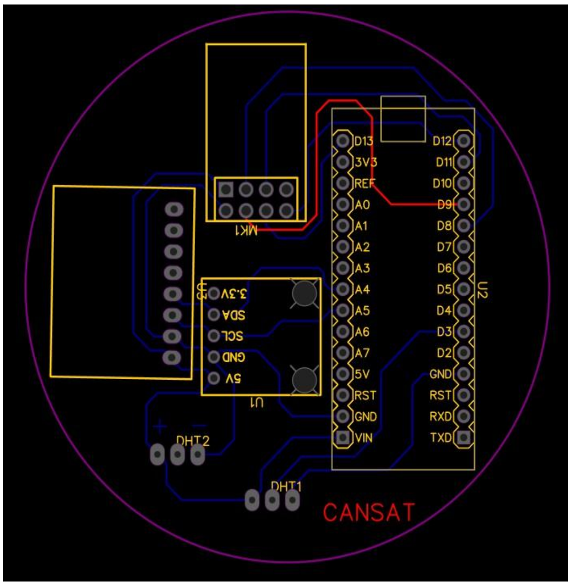

Fig. 10. Transmitter Routing Diagram

V. CHALLENGES AND DESIGN CONSIDERATIONS

In the process of designing the CanSat, several challenges are anticipated based on research, literature reviews, and best practices. This section outlines these challenges and suggests possible mitigation strategies.

A. Potential Challenges and Mitigation Strategies

1) *Mechanical Robustness:* Challenge: Withstanding launch vibrations and landing impact.
   Proposed Mitigation: Research suggests reinforcing the structure using lightweight, shock-absorbing materials. Egg molding could also be a viable option for ensuring safe landing by absorbing impact and enhancing durability.
2) *Power Management:* Challenge: Ensuring sufficient bat- tery life for the entire mission.
   Proposed Mitigation: Efficient power management strategies, including the use of low-power components and power-saving modes, have been recommended to optimize power consump- tion and ensure mission longevity.
3) *Communication Reliability:* Challenge: Potential signal loss or interference.
   Proposed Mitigation: Based on best practices, redundancy with reliable communication modules like nrf and the use of directional antennas can help enhance signal strength and reliability.
4) *Sensor Calibration:* Challenge: Maintaining sensor ac- curacy over time.
   Proposed Mitigation: Automated calibration routines, as found in various studies, ensure consistent sensor performance. Self-calibration techniques could also be implemented to en- hance sensor accuracy.

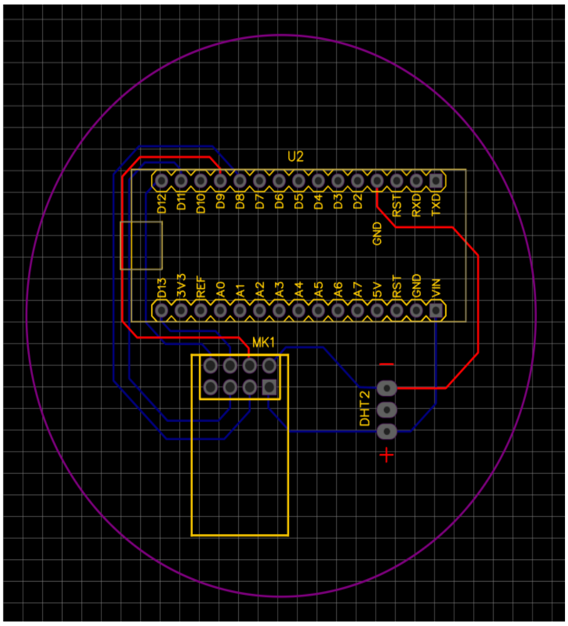

Fig. 11. Receiver Routing Diagram

5) *Environmental Conditions:* Challenge: Exposure to ex- treme temperatures and humidity affecting electronics. Proposed Mitigation: Using components rated for harsh environments, along with thermal management solutions like heat shields and protective casings, can mitigate the effects of extreme conditions.

B. Additional Design Considerations

Based on existing research, several other considerations for the CanSat design include:

- Parachute Deployment: Dual parachute systems with fail-safe mechanisms are commonly employed in CanSat missions to minimize the risks of deployment failure.

- Environmental Resistance: Heat shields and protective casings will safeguard the CanSat's components during descent, protecting them from environmental factors.

VI. CONCLUSION

The developed CanSat model showcases a robust and mod- ular design tailored for environmental monitoring and educa- tional outreach. By integrating calibrated sensors, dual-stage descent mechanisms, and a reliable communication system, the model effectively addresses recurring challenges such as communication reliability, sensor accuracy, and landing stabil- ity. The inclusion of advanced data-handling systems ensures seamless data collection and visualization. Future work will focus on further optimizing power efficiency and exploring additional applications in atmospheric studies and ecological monitoring. This study demonstrates the potential of CanSats as versatile tools for advancing scientific research and practical education in satellite technology.

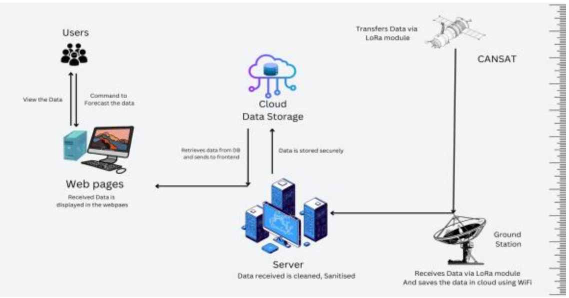

Fig. 12. Data Flow Model

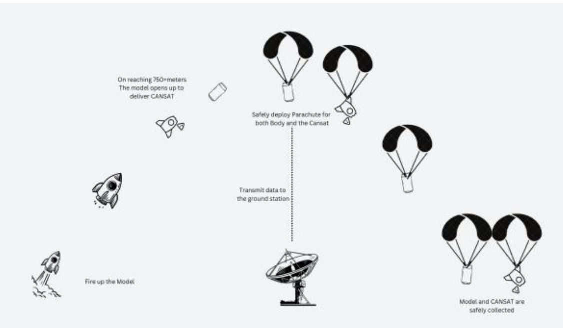

Fig. 13. Flight Depiction

REFERENCES

[1] Belhaj, Y., Grant, A., Sandler, M., Guerr, A., and Rustan, S. (2015). *Final Design Report - Team 18: CanSat*. Proceedings of the International Symposium on CanSat. Introduced a dual-stage descent mechanism with a parasheet and spring-loaded rods. Integrated BMP180 for altitude and temperature, an accelerometer for impact force, and GPS for tracking. Challenges included parachute fabrication precision and environmental interference.

[2] Dilena, M., Haberl, D., and Weichbold, F. (2015). *CanSat Height and Position Measurement Comparison in CFP-15-AlpSat Mission*. Proceed- ings of the International Symposium on CanSat. Conducted a compara- tive study of barometric, GPS, and accelerometer-based measurements. Highlighted discrepancies in height calculations due to external factors such as weather, emphasizing sensor selection.

[3] Klitgaard, J., Glent-Madsen, M., Baattrup, M. H., and Dyrby, N. (2015). *CFP-15-SG Can Science 2015: A Solid CanSat Taking On-Demand Photos*. Proceedings of the International Symposium on CanSat. Developed a CanSat with two-way communication and an onboard camera. Primary mission measured temperature and pressure, while issues such as camera failure and data storage errors highlighted areas for improvement.

[4] Timurova´, M., and Gasparjan, A. (2015). *CFP-15-GirlSAT 2015*. Pro- ceedings of the International Symposium on CanSat. Implemented redundancy with dual ground stations to ensure data reception. Mis- sions included air temperature, pressure measurement, 3D acceleration, magnetic field data, and GPS. Challenges: material fragility and data connectivity issues.

[5] Estra´n Buyo, G., Gonza´lez, A., Prado, J., Gonza´lez, J., Rojas, F., and Bernat, P. (2015). *CFP-15-Rosetta-Can*. Proceedings of the International Symposium on CanSat. Inspired by ESA's Rosetta mission, designed a CanSat with a maple-seed-inspired descent for aerodynamic stability. Achieved stable descent but faced communication and data storage issues.