Design and Implementation of an Affordable CanSat for Weather Sensing and Gyroscope Measurement While Protecting an Egg Inside

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***Abstract*— Can Sat, short for "Can Satellite," is a small satellite system that fits inside a regular soda can. Can Sats are positioned as an economical and practical resource for aviation and space scientific research, housing sensors and communication equipment for controlled launches. This technology provides hands-on data collection activities, providing a significant opportunity for practical learning. Its tiny form enables for flexibility deployment, making it an effective tool for researchers and professionals. Can Sat serves as a low-cost alternative for gaining real-world insights via controlled satellite launches, indicating its potential as a significant asset in the field of space research and technology.**

Keywords— Can Sat, CubeSat, satellite, education, aerospace engineering, hands-on learning, sensors, communication systems, data collection, microcontroller.

I. INTRODUCTION

The CanSat concept has paved the way for a broader exploration of aerospace education, encompassing not only CanSats but also Nano Satellites. Nano Satellites, or CubeSats, represent another facet of miniaturized satellite technology. Unlike CanSats, which are typically launched from rockets as part of educational programs, CubeSats are actual satellites deployed for various purposes, including scientific research, Earth observation, and technology demonstration.

Like CanSats, Nano Satellites have size restrictions and are frequently standardized in size, like the CubeSat form factor. Nano Satellites are furnished with all the necessary parts, including as onboard computers, sensors, power systems, and communication modules, despite their little size. For professionals and students alike, these spacecrafts provide a useful platform to explore the complexities of satellite development, construction, and operation.

Nano Satellites are important educational tools because they give students practical experience with space technology and develop their skills in electronics, programming, data analysis, and project management. Launching and operating Nano Satellites involve collaboration and teamwork, enhancing communication and problem-solving abilities—attributes critical not only in the aerospace sector but also in broader scientific and technological fields.

The integration of both CanSats and Nano Satellites in educational programs contributes to a holistic approach in preparing future aerospace practitioners. It not only offers a glimpse into satellite technology but also nurtures a comprehensive understanding of space systems, from design concepts to practical implementation. This multifaceted educational approach is instrumental in shaping a new generation of professionals well-versed in the complexities of aerospace engineering and technology.

Figure 1: CubeSat Version 3 (Final)

II. PROPOSED SYSTEM AND METHODOLOGY

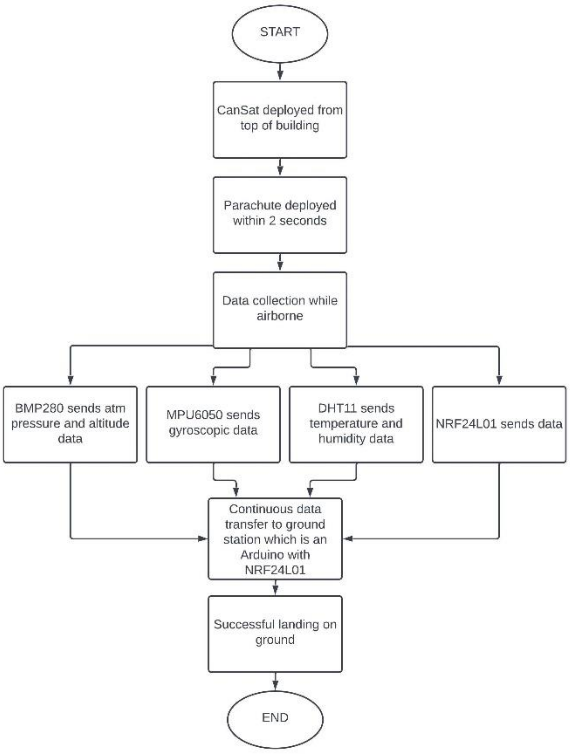

Figure 2: CanSat System Topology

The development of CanSat system was a detailed process that took careful assembly of various components. Two Arduino UNO R3 microcontrollers were used, intricately linked to an array of sensors, including the MPU6050 gyroscope, BMP280 pressure and altitude module, and DHT11 temperature module. The sensors needed calibration process to ensure their optimal functioning, with specific attention given to the gyroscope for orientation tracking, BMP280 for altitude and pressure measurement, and DHT11 for temperature sensing.

To facilitate real-time wireless communication, NRF24L01 radio modules were used in the system. The CanSat was secured with a parachute system and was deployed from a significant height to collect data. The idea was to collect necessary data while the CanSat is free falling with a parachute and receive the data from the other end, in this scenario, another Arduino with NRF24L01.

Basic parachute physics was applied to this project. Simple use of aerodynamic mechanics was used. The idea was to keep the design as simple as possible.

The performance analysis was a critical part of the project as it is a low-cost system designed to get weather information from a basic deployment from a high place. Alongside receiving the data, a comprehensive analysis was undertaken to extract valuable insights into various environmental parameters during the controlled descent.

The classic Nano is the oldest board in the Arduino Nano family. It is similar to the Arduino Duemilanove, however it is designed for use with a breadboard and lacks a dedicated power connector. Successors to the classic Nano include the Nano 33 IoT, which includes a WiFi module, and the Nano 33 BLE Sense, which includes Bluetooth Low Energy and various ambient sensors.

IV. HARDWARE DEVELOPMENT

The DHT11 is a basic and widely used sensor for measuring temperature and humidity in various electronic projects. It comes in a small package with three pins: VCC (+), OUT, and GND (-). Let's break down the connections theoretically: The VCC pin (also labeled +) is the power supply pin. It needs to be connected to a +5V power source, as the DHT11 operates on 5 volts.

The OUT pin is the data output pin. It provides a digital signal that represents the temperature and humidity readings. Connect this pin to a digital input/output (DIO) pin on your microcontroller or development board. In this case, it's connected to D2, which typically stands for digital pin 2. The GND pin (also labeled -) is the ground or common reference voltage. Connect this pin to the ground (GND) of your power supply or microcontroller.

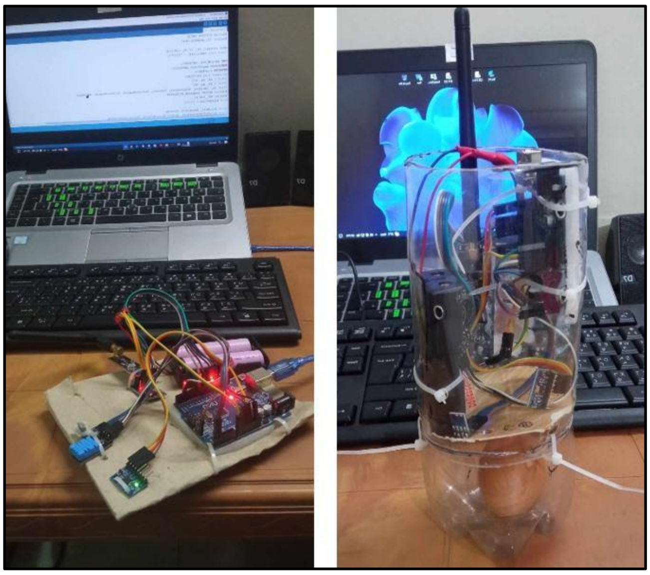

Figure 3 & 4: CanSat Version 1 & 2

The BMP180 is a barometric pressure sensor that also measures temperature. It uses the I2C (Inter-Integrated Circuit) communication protocol for data transfer. Here's the theoretical explanation for the connections: The VCC (Voltage Common Collector) pin is the power supply pin. It requires a +5V power source, so connect this pin to the 5V output of your microcontroller or a separate power supply. The GND (Ground) pin is the ground or common reference voltage. Connect this pin to the ground (GND) of your power supply or microcontroller, ensuring a common ground for the circuit. The SDA (Serial Data) pin is used for bidirectional data transfer between the BMP180 and your microcontroller. Connect this pin to the SDA or data line of the I2C bus on your microcontroller. In this case, it's connected to A4, which typically represents analog pin 4 on Arduino boards. The SCL (Serial Clock) pin is used to synchronize data transfer between the BMP180 and your microcontroller. Connect this pin to the SCL or clock line of the I2C bus on your microcontroller. In this case, it's connected to A5, which typically represents analog pin 5 on Arduino boards.

The MPU-6050 is a popular accelerometer and gyroscope sensor combination that often comes integrated on a single chip. It communicates over the I2C (Inter-Integrated Circuit) protocol. Here's the theoretical explanation for the connections: The VCC (Voltage Common Collector) pin is the power supply pin. The MPU-6050 typically operates at 3.3V. Connect this pin to the 3.3V output of your microcontroller or a separate 3.3V power supply. The GND (Ground) pin is the ground or common reference voltage. Connect this pin to the ground (GND) of your microcontroller or the ground of your power supply, ensuring a common ground for the circuit. The SDA (Serial Data) pin is used for bidirectional data transfer between the MPU-6050 and your microcontroller. Connect this pin to the SDA or data line of the I2C bus on your microcontroller. The SDA line is where the actual data is transferred. The SCL (Serial Clock) pin is used to synchronize data transfer between the MPU-6050 and your microcontroller. Connect this pin to the SCL or clock line of the I2C bus on your microcontroller. The SCL line ensures that data is transferred at the correct timing.

Figure 5: MPU 6050 data on Ploter

The I2Cdev library is used in this Arduino program to communicate with the MPU6050 accelerometer and gyroscope sensor. It receives raw acceleration and gyroscope readings from the MPU6050 and sends them to the Serial Plotter. The Serial Plotter shows tab-separated numbers for acceleration (axe, ay, az) and gyroscope (gx, gy, gz) in real-time, allowing visualization of sensor data changes.

By extracting real-time compass data from Yaw readings, this project provides an innovative approach to enhancing the capabilities of the MPU-6050. The technique necessitates the use of the Digital Motion Processor (DMP) to compute the precise Yaw angle. Using a proprietary function, these Yaw angles are translated into compass directions, providing accurate heading information. This transformative process makes the most of the MPU-6050's motion tracking capabilities to offer compass data, boosting its usefulness for navigation systems and environmental monitoring. Future research might focus on enhancing sensor fusion methods to enhance compass accuracy, exhibiting the MPU-6050's adaptability and promise for bigger applications.

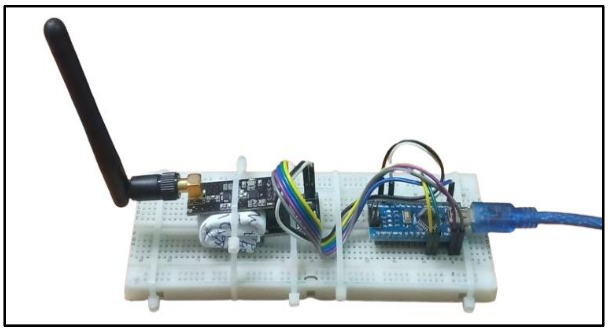

Figure 6: Satellite Ground Station

The provided connections seem to be associated with a wireless communication module, possibly NRF24L01, which is commonly used for short-range communication between devices. Here's the theoretical explanation for the connections: The CE (Chip Enable) pin is used to enable or disable the communication module. Connect this pin to a digital output pin on your microcontroller, in this case, to D7. The CSN (Chip Select Not) pin is used to enable or disable the SPI (Serial Peripheral Interface) communication. Connect this pin to a digital output pin on your microcontroller, in this case, to D8. The SCK (Serial Clock) pin is the clock signal for SPI communication. Connect this pin to the clock (SCK) pin on your microcontroller, typically labeled as D13 on Arduino boards. The MOSI (Master Out Slave In) pin is used for sending data from the microcontroller to the communication module. Connect this pin to the MOSI or Master Out Slave In pin on your microcontroller, typically labeled as D11 on Arduino boards. The MISO (Master In Slave Out) pin is used for sending data from the communication module to the microcontroller. Connect this pin to the MISO or Master In Slave Out pin on your microcontroller, typically labeled as D12 on Arduino boards. The VCC (Voltage Common Collector) pin is the power supply pin. Connect this pin to the 3.3V output of your microcontroller or a separate 3.3V power supply. The GND (Ground) pin is the ground or common reference voltage. Connect this pin to the ground (GND) of your microcontroller or the ground of your power supply, ensuring a common ground for the circuit.

Additionally, if an NRF24L01 Wireless Adapter Module is available: Connect the VCC pin on the NRF24L01 Wireless Adapter Module to a power source that provides a voltage between 5V and 12V.Connect the GND pin on the NRF24L01 Wireless Adapter Module to the ground (GND) of your power supply. This configuration allows the NRF24L01 module to communicate wirelessly while being powered appropriately.

V. DEPLOYMENT AND PARACHURTE LANDING

Parachutes play a pivotal role in decelerating CanSat, ensuring a safe and controlled descent. This section delves into the intricacies of parachute deployment mechanisms for small CanSat, focusing on design considerations and the mathematical framework governing their functionality.

When designing a parachute, we must consider:

1. The type of material we are using – we must use a material which is lightweight and durable, in our case we are using nylon.

2. The type of chord – choosing a lightweight yet strong chord for joining the parachute to the CanSat.

3. Appropriate deployment mechanisms – we are using a rubber band release method to deploy the parachute after the CanSat reaches a certain altitude.

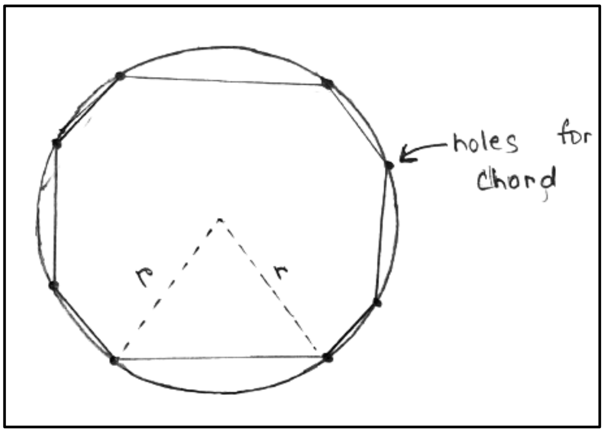

Figure 7: Parachute Cutting Model

The parachute was made with nylon fabric in an octagonal geometry inscribed inside a circle which has a diameter of 40cm and 8 strings of length 30cm. To provide stability to the parachute during the vertical descent, we cut a small hole of 5.5 cm in the center. Successful deployment of the parachute depends on several factors including the desired descent rate, atmospheric conditions, and the specific design of the parachute. The parachute size influences the amount of air resistance or drag it creates which in turn affects the descent rate.

$V = \sqrt{(2 \cdot W/\rho \cdot A \cdot Cd)}$ Where, V is the descent rate, W is the weight of the CanSat (1 kg), ρ is the air density, A is the parachute's effective cross-sectional area, Cd is the coefficient of drag.

We will also need to determine the size of our parachute using the formula: $A = 2 \cdot W/\rho \cdot A \cdot Cd$

The value of Cd depends on the design of parachute and in our project, we consider it to be 1.3. The value of ρ varies with altitude and atmospheric conditions and we are taking standard measurement of 1.225 kg/m³.

And for our project, we have chosen the shape of our parachute to be circular hence we will be using: $A=\pi r^2$, Where r = radius of parachute.

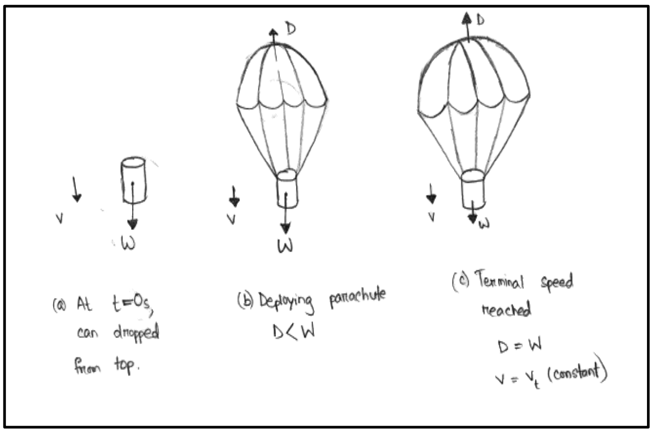

Figure 8: Parachute and Satellite weight ration

The primary objective of this is to achieve a gentle and secure landing, facilitated by the parachute's capacity to modulate the descent rate. The deployment of a parachute in CanSat is a carefully organized process aimed at ensuring a safe and controlled descent of the egg. Initially the parachute is stored compactly inside the CanSat which triggers the deployment mechanism at a certain altitude, descent rate or time to release the parachute for safe ascent of the egg. Once the parachute unfolds, the canopy catches the air which generates a drag force which is required to slow down the CanSat for a safe landing and prevents any damage to the egg. The process is meticulously organized in such a way so that the CanSat and its component can safely land.

VI. SIMULATION AND TESTING


Figure 9: Satellite testing

The CanSat system's simulation and testing phase was important in guaranteeing its operation and durability. The Arduino UNO R3 microcontrollers were thoroughly evaluated to determine their capacity to manage the refined network of sensors and communication modules. The robust performance of the microcontrollers in managing the coordinated operation of the MPU6050 gyroscope, BMP280 pressure and altitude module, and DHT11 temperature module was tested before launching.

Sensor calibration was a critical component of the testing phase. To achieve accurate alignment tracking of the MPU6050 gyroscope and precise readings of altitude, pressure, and temperature by the BMP280 and DHT11 sensors, careful methods were undertaken. Calibration aims to reduce mistakes, increasing the dependability of the obtained data.

The NRF24L01 radio modules, which are in charge of managing real-time wireless communication, have undergone thorough testing to ensure their effectiveness in transmitting data between the CanSat and the ground station. The modules' stability within the established 100-meter range was confirmed by simulated scenarios that included variable distances and potential interference.

The deployment mechanism, which is critical for a safe descent, was thoroughly simulated and tested. The rubber band release mechanism for parachute deployment was tested in a variety of scenarios to ensure reliability and consistency. Simulated scenarios proved the parachute's deployment accuracy, including variations in altitude leading to, fall rates, and timed releases.

The CanSat's ability to capture and transmit real-time data during its controlled descent was the focus of the overall performance investigation. To evaluate the accuracy of sensor readings, simulated data reflecting environmental factors was compared to expected values. This phase revealed potential difficulties, which helped to develop the CanSat system for maximum functionality.

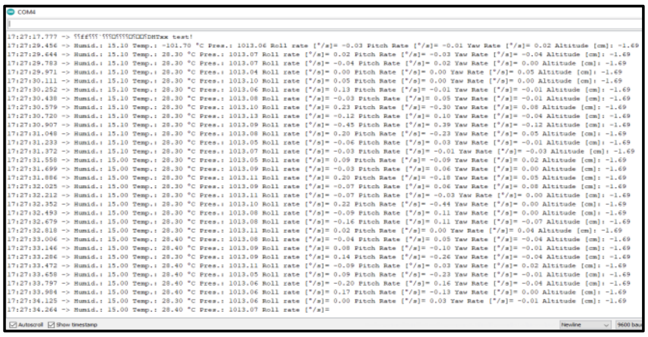

Figure 30: Total data collected from Satellite

This is the data collected and sent to another Arduino sitting on the ground via NRF24L01.

VIII. Component List

Sl	Item Name	Quantity
1.	Arduino UNO	1
2.	Arduino NANO	1
3.	BMP180	1
4.	DHT 11	1
5.	MPU 6050	1
6.	NRF24l01 with Antenna	2
7.	NRF24l01 power adapter	2
8.	Breadboard	1
9.	2 Cell Holder	1
10.	Battery	2
11.	Charger	1
12.	Jumper Wires	Undefined

Analyzing the pricing list for the components of the Cheap Affordable Nano Satellite project, it appears to be a cost-effective setup. The usage of Arduino UNO and Arduino NANO as the main control units provides a low-cost foundation for the project, with the UNO being somewhat more expensive but providing more functionalities. The BMP180 and DHT11 sensors, each priced at 150 takas, add to environmental data collecting, while the MPU6050, priced at 200 takas, improves the satellite's motion detecting capabilities. The introduction of NRF24L01 wireless communication modules, along with antennas and power adapters, offers connectivity features for data transfer; nevertheless, the cost of these components, particularly when purchasing two sets, may be a significant amount of the budget.

The remaining components, including the breadboard, 2-cell holder, and batteries, are reasonably priced and contribute to the satellite's total performance. When compared to other CanSat projects, this configuration appears to be competitively priced, providing a combination of functionality and affordability, making it an appealing alternative for those looking for a cost-effective solution for nano-satellite projects.

IX. FUTURE DEVELOPMENT

It is possible to minimize the size of the satellite without sacrificing performance by investigating cutting-edge materials and manufacturing technologies. To reduce size and weight, nanotechnology or creative engineering techniques will be used. To enhance power generation and prevent waste, researchers can look at more efficient solar panels, energy storage options such as supercapacitors or improved batteries, and energy harvesting systems.

Investigating cutting-edge sensors or developing custom ones can help the satellite capture more data reliably and over a wider range. This may entail the installation of new instrument types, the updating of environmental sensors, or the upgrading of cameras.

To improve data transmission rates and dependability, novel communication protocols, higher-frequency bands, or more communication channels will be tested. To achieve quicker data transfer rates, methods such as laser communication can be investigated.

The satellite will be able to react to changing situations without human involvement if autonomous operations are enabled by merging artificial intelligence and more advanced algorithms. Replace aging processors with new ones or install specialized gear for faster onboard data processing and analysis. This can speed up decision-making by removing the need for constant communication with ground stations.

To ensure the satellite's longevity, more resilient materials and components can be tested and included to withstand radiation, extreme temperatures, and other space-related challenges. Taking into consideration new research pursuits, educational projects, or technology demonstrations that capitalize on the satellite's capabilities can be done, possibly in collaboration with other satellites or missions for a greater impact.

The feasibility of building constellations or swarms of picosatellites to perform complex tasks or cover a broader region for data collection will be investigated. To reduce overall costs, cost-effective manufacturing methods, the utilization of commercially accessible parts, and the possibility of combined launches or tagging along with larger missions can be investigated.

Novel materials and designs for the satellite's structure will be investigated to improve endurance, survive harsh environments, and control thermal loads more effectively. By focusing on these specific elements in future versions of pico-satellites, significant gains in functionality, efficiency, and mission capabilities can be achieved.

X. CONCLUSION

The simulation and testing steps were critical in confirming the CanSat system's performance. The data acquired, which was wirelessly communicated during controlled descents, illustrates the project's successful execution as well as its potential as a teaching tool.

The hardware components, which include Arduino microcontrollers, sensors such as the MPU6050, BMP180, and DHT11, and communication modules such as the NRF24L01, work together to enhance the CanSat's capability. The parachute deployment system, which has been precisely constructed with material, chord type, and deployment processes in mind, enables a safe and controlled descent, meeting the important parameter of preserving an egg during landing.

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