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Design and Development of a Nanosatellite for Atmospheric Analysis

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Abstract- The compact Nanosatellite was designed and developed to carry out Atmospheric analysis by creating a step forward to enhance low-cost CubeSat platforms for Environmental monitoring. The modular 6u CubeSat prototype was designed by considering size and weight constraints for my Nanosatellite (weighs <10kg) application. The standard dimensions for 6u CubeSat are 20x10x34.05 in cm. This work focuses on conducting atmospheric analysis by measuring critical parameters such as temperature, pressure, humidity, air quality, and many other factors, which offers many insights into Environmental Research and Atmospheric conditions. The subsystems involved, i.e., The Arduino R4 Wi-Fi, a Microcontroller, and Raspberry Pi 5, a Microprocessor, worked together as on-board computer subsystems to retrieve data from multiple Sensors and scientific instruments, which are integrated into the payload region of CubeSat. The Lora WAN development module operating in the 865-868 MHz frequency range is equipped to engage telemetry and communication subsystem, paired with a custom-designed turnstile antenna deployment system, which allows reliable long-range communication for CubeSat to communicate with the ground station. The CubeSat is structured using lightweight PETG material, with components manufactured through 3D printing, and also equipped with deployed solar panels, which play a vital role in the electronic power supply subsystem to ensure continuous power supply to the CubeSat. Integrating all these subsystems into 6u CubeSat, i.e., a compact nanosatellite that provides a facilitated platform for Atmospheric Research and Remote sensing Applications, will contribute to more innovations in Earth and Space science Applications.

Keywords: Nanosatellite, 6U CubeSat, Atmospheric Analysis, Environmental Monitoring, Remote Sensing, Low-Cost CubeSat Platform.

I. INTRODUCTION

The rapid advancements in CubeSat technology have opened new theme for addressing mini space mission challenges, particularly in earth Observations from lower earth orbit. Nano satellites include CubeSats which are compact in size, low cost, and versatile to achieve mini space missions. Not only space missions but also to study earth atmosphere at higher altitude, CubeSats had become a preferred choice not only for scientific but also for commercial applications due to their modular design, size & weight constraints and also contains ability to integrate multiple components in payload.

This project aims to tackle the study of atmospheric conditions through a 6U CubeSat, a nano satellite specifically designed and developed for atmospheric analysis. By measuring various parameters such as temperature, pressure, humidity, air quality, and to conduct environmental research through remote sensing applications. The modular 6u CubeSat is developed to provide crucial data for understanding atmospheric conditions and to enhance environmental studies. These insights are more essential for environmental studies, and atmospheric monitoring.

The modular 6U configuration ensures a compact design and balanced payload capacity and subsystems complexity in process of making it ideal for integrating advanced sensors and scientific modules. To achieve reliable data transmission between satellite and ground station the satellite is introduced with LoRa technology that operates in free licensed frequency range of India i.e. 865-867 MHz, supported by a customized turnstile antenna deployment mechanism. The use of 3D-printed PETG material for structural components will remain CubeSat with light in weight and also enhances the CubeSat's efficiency and affordability.

This project documented with the progress made in the design and development of the 6U CubeSat, also detailing the components used, equipped subsystems, and fabrication. Through this project, we aim to contribute to the developing body that works in satellite-based atmospheric research and emphasizes the potential of CubeSats as preferred platforms for Earth atmospheric observations and scientific explorations.

Nanosatellites are small satellites that usually weigh between 1 kg and 10 kg. They are popular for space missions because they are small, cheap, and can-do specific jobs. The idea of small satellites started with space exploration, which began when Sputnik 1 was launched in 1957.

The idea of making smaller satellites came about to save money and time compared to building big satellites. In the 1980s and 1990s, universities and research centres began looking into small satellites for educational projects and science experiments.

This design meant that nanosatellites could be made in standard sizes (1U = 10x10x10 cm). This helped in making, launching, and combining them with other satellites. CubeSats were first made for schools, giving students and researchers the chance to design, build, and run their own satellites.

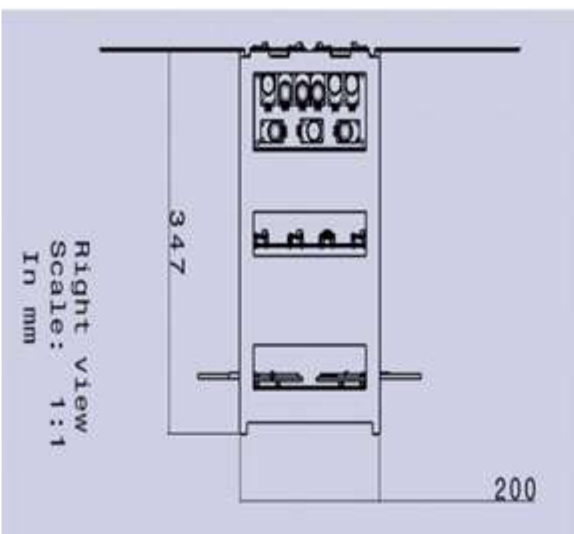

Fig1:2D Sketch of Nanosatellite

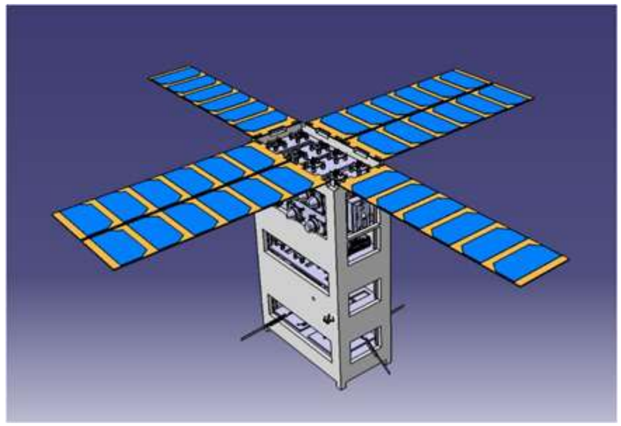

Fig 2: 3d Model of Nanosatellite

Atmospheric analysis:

Nanosatellites plays crucial role in monitoring earth atmospheric conditions. They will probably work more efficiently like bigger satellites like micro, mini and large satellites.

Build global partnerships to share information and avoid doing the same missions over again. Create standard designs for nanosatellites so they can work well together. Create smaller and more sensitive sensors to get more accurate measurements. Use sensors that can capture different light spectra to gather varied data. Use artificial intelligence and machine learning to analyse data right on the satellite. This way, we don’t have to send back a lot of information and can quickly spot unusual events. Send out groups of nanosatellites to get clearer pictures and more frequent updates. Work together with many nanosatellites to keep an eye on things all the time. Use nanosatellites alongside bigger satellites or flying devices like drones and balloons to collect different types of data effectively. Make solar panels and batteries that work better to power the advanced tools. Look into lighter materials for storing energy.

Build global partnerships to share information and avoid doing the same missions over again. Create standard designs for nanosatellites so they can work well together. Concentrate on problems, like air pollution in cities or ozone issues in the poles, by customizing the tools for specific areas or challenges.

Atmospheric Research with CubeSats:
Nanosatellites are tiny and inexpensive satellites made to study the air and environment around Earth. They have special tools that can detect gases such as carbon dioxide, methane, and ozone. They also check things like air quality, temperature, humidity, and weather changes. These satellites help keep an eye on dust storms, rain, and other environmental issues, giving us useful information about climate change, pollution, and weather patterns in real time with help of nanosatellites.

II. OVERVIEW OF A NANO SATELLITE

Nano Satellites, or Nanosats, weigh between 1kg and 10kg. Their small size makes them ideal for mini space missions and to observe atmosphere and also for weather forecast updates in real time. Satellites are grouped by their weight into different categories. Here are the types:

1) Small Satellites: (i) Pico Satellites – 0.1kg to 1kg
(ii) Nano Satellites – 1kg to 10kg
(iii) Micro Satellites – 10kg to 100kg

2) Medium Satellites:
(i) Mini Satellites – 100kg to 500kg

3) Large Satellites:
(i) Standard Satellites – 1000kg to 10,000kg
(ii) Heavy Satellites – over 10,000kg

CubeSats are small satellites made to carry out specific jobs such as watching over the Earth, sending messages, or doing scientific studies. They can be sent into space alone or together with other satellites.

Traditional satellites tend to be big and cost a lot of money, but nanosatellites are easier to make and launch, which allows universities, small businesses, and research groups to get involved in space activities. Nanosatellites are tiny satellites that use different technologies to be effective, affordable, and able to do complex jobs.

Material & properties:
PETG (Polyethylene Terephthalate Glycol-modified) is tough, durable materials and easy to use. The strength of it make it able to be a suitable material for food packaging, the chemical non-reactiveness property make it the most important material in health care, used for orthopedic and prosthetic device.The study evaluated the effect of printing temperature on the mechanical performance of PETG polymer. A temperature range of 230°C to 270°C was tested, with a 10°C increment between each condition (230°C, 240°C, 250°C, 260°C, and 270°C). A total of 120 samples were printed, and four mechanical tests were conducted to assess the impact of printing temperature on the material's properties.

The results indicated that the best mechanical performance was observed within the 250°C to 260°C range, which aligns with findings in the existing literature. However, higher temperatures did not always lead to improved mechanical performance, as demonstrated by the regressive trend in the combined yield stress graph. This study primarily aimed to understand the behavior of PETG filament in 3D printing conditions. Future work will involve further testing under varied conditions to provide more comprehensive insights and establish guidelines for selecting optimal printing parameters for specific applications.

Fig 3: OUTER CASE of Nanosatellite made with (PETG)

III. NANOSATELLITE SUBSYSTEMS AND COMPONENTS

Electrical Power System (EPS):
Electrical power system also referred as electronic power supply subsystem which was the heart of the Satellite that transmits continuous power supply to all subsystems and components in the satellite.
Components Equipped: (i) Solar power manager modules with 3.7v 14500 batteries

Fig 3: (EPS) electric power system

Onboard Computer (OBC):
On board computer subsystem, referred as Command and Data Handling system which plays crucial role in satellite, also known as brain of the Satellite.

Fig 4: On-board computer

This subsystem manages the satellite operations by processing the commands received from the ground station and operates the satellite to achieve its mission.

Components involved: 1) Arduino R4 WIFI
2) Raspberry pi 5

Telecommunication System
The Telecommunication subsystem also referred as Telemetry and Communication system, which plays crucial role in mission.

This subsystem acts as the bridge for the satellite to the ground station. It plays crucial role in mission by transmitting and receiving signals and commands from the ground station to satellite and also from satellite to ground station vice versa.

Telecommunication subsystems use Radio signals at different frequency bands and wavelengths to communicate between satellite and ground.

Signal Flow Pattern:
(i) Uplink: Signals will be transmitted from ground station to the satellite (Commands and Payload Data)
(ii) Downlink: Signals will be transmitted from satellite to ground station (Telemetry and Payload Data)
Components Equipped: (i) LoRa WAN Development Board
(iii) LoRa WAN Gateway module (in ground station)

Attitude Determination and Control System (ADCS)
Attitude Determination and Control system also referred as ADCS subsystem that ensures the satellite to maintain desired orientation.
The orientation, positioning and GPS are the important aspects that locates the satellite in 3-dimensional co-ordinate plane.

Fig 5: Lora WAN (Telecommunication)

Components equipped: (i) 3-axis digital Gyro meter
(ii) 3-axis digital Accelerometer
(iii) 3-axis Accelerometer
(iv) 3-axis digital compass
(v) GPS module

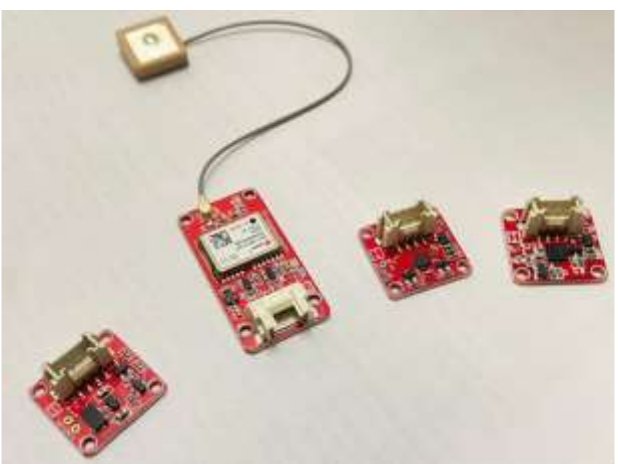

Fig 6: ADCS(Attitude Determination and Control System)

IV. PAYLOAD SYSTEM

The payload of a satellite consists of sensors, scientific instruments and equipment that perform mission operations of the satellite.

All the operations of a mission were conducted by payload system to collect scientific data using various sensors and scientific instruments.

In this project, the sensors and scientific instruments are installed in payload of our CubeSat. The payload designing is the biggest challenge in process of designing satellites and their components.

Sensors and Instruments equipped:

S.NO	NAME OF THE SENSOR	APPLICATION
1	Sound sensor	To measure environmental sound
2	UV sensor	To detect & measure UV light
3	Vibration sensor	To measure vibration in systems
4	Temperature sensor	To measure environmental temperature
5	Humidity sensor	To measure amount of humidity in air
6	Barometric sensor	To measure atmospheric pressure
7	Light sensor	To detect intensity of light
8	Raspi display	To show the basic information
9	Dust sensor	To measure dust intensity in air
10	Air quality sensor	To measure air quality
11	Gas sensor (MQ2)	Detection of LPG, methane, hydrogen
12	Gas sensor (MQ3)	Detection of Alcohol, ethanol, benzene
13	Gas sensor (MQ4)	Detection of methane, CNG
14	Gas sensor (MQ5)	Detection of LPG, natural gas, coal gas
15	Gas sensor (MQ7)	Detection of carbon monoxide
16	Gas sensor (MQ8)	Detection of hydrogen gases
17	Gas sensor (MQ9)	Detection of Co and methane

18	3 axis digital gyro	To measure angular velocity (rotation rate) attitude control and stabilization
19	3 axis digital compass	Provides orientation and heading data
20	3 axis accelerometers	To measure acceleration forces (static or dynamic)
21	Magnetometer	To measure magnetic field and to determine orientation
22	GPS	Provides real time location and time data
23	Lightning sensor	To detect electrical activity in atmosphere caused by lightning strikes

FIGURE : MQ2, MQ5, MQ3

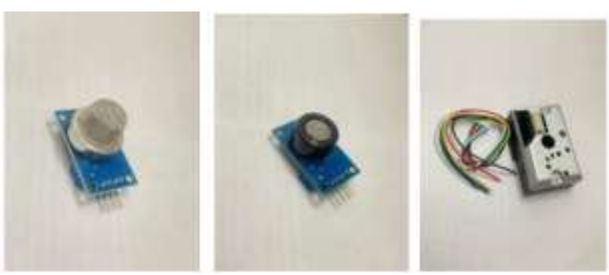

FIG: MQ7, MQ9, DUST SENSOR

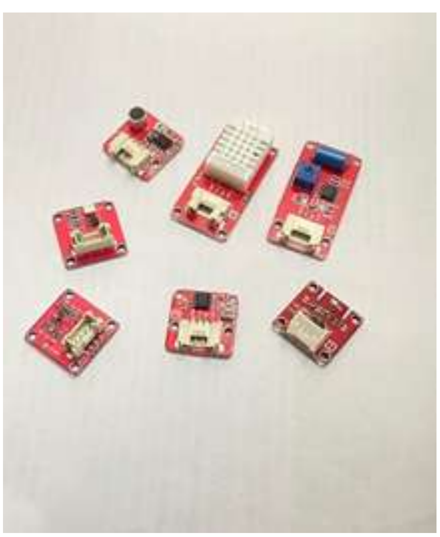

FIG: PAYLOAD SENSORS (Temp, pressure, humidity, vibration)

Working Process and Principle Of Nanosatellite: Arduino UNO R4 WIFI module is a microcontroller in our on-board subsystem and Raspberry pi 5 module works as a Microprocessor.

(Microcontroller)
(Microprocessor)

Fig: working mechanism by onboard computer

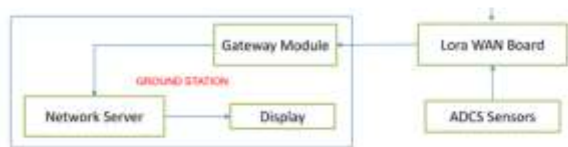

Fig: ground station protocol

The sensors equipped in the payload region transmits Analog and Digital outputs to HAT boards which will read by Arduino R4 WIFI and raspy 5 individually and performs different action i.e. to control, collect and process the data.

Arduino communicate with Raspberry pi by using UART communication protocol to send collected data to process it in raspberry pi.

Commands received from the ground station will get processed in raspberry pi and then controlled/performed by Arduino, as same Arduino data will be transmitted to raspberry pi and then get processed into data packs to send it to ground station vice versa.In this on-board computer subsystem, the command and data processing will be done by raspberry pi 5 microprocessor and the processed signal will be operated by Arduino R4 WIFI.

V. CONCLUSION

The nanosatellite designed for studying the atmosphere aims to offer an affordable way to keep track of atmospheric conditions from inner earth atmosphere. Instead of cameras or spectrometers, it uses sensors to gather important atmospheric data. Communication happens solely through Lora WAN, which allows for effective transmission of small amounts of data. To maintain precise sensor alignment, there's an attitude control system in place, and solar panels along with batteries provide the needed energy. Thanks to the progress in miniaturized technology, this nanosatellite is set to play a key role in tracking the environment and contributing important data for atmospheric studies.

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