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Development of *a Novel Cubesat Platform Instrument for The In-Situ Continuous Measurement of Vertical Weather Profile*

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Abstract- This paper presents the design and development of a novel CubeSat platform monitor for the measurement of vertical weather profile for the continous evaluation of the state of the atmosphere variables of temperature, humidity and barometric pressure. .Vertical weather profile data is not easy to obtain, current practice in Africa and most developing societies in other continents employs labour intensive and inefficient ground based instruments The nanosatellite was designed, developed, calibrated, standardized and field tested using mostly locally sourced resources. The performance of the weather monitoring CubeSat was assessed in the laboratory and on the field, the in-situ weather profile measurements were stored in the microSD card over the time allowed for verification The platform was found to be robust, suitable and parameters of Temperature and Pressure were observed to reduce with increasing altitudes while the Humidity increases with increasing altitudes the results are comparable with those obtained with standard instruments.

Indexed Terms- Weather Profile, Cubesat Platform, Countinous, Evaluation, Atmospheric Variable, Temperature, Humidity, Barometric Pressure

I. INTRODUCTION

Weather monitoring is a periodic or continuous surveillance or analysis of the state of the atmosphere and climate, by measurement of variables such as temperature, moisture, wind velocity, humidity and barometric pressure. Current practice in Africa and other developing societies in other continents employ mostly ground based instruments to acquire this data at highly prohibitive cost and with limited coverage owing to topographic limitations and other natural barriers. Attempts were sometimes made to employ scanning strategy to reconstruct estimates to provide a vertical ‘‘slice’’ of the atmosphere which are often of poor quality and not suitable for the determination of the fine scale atmospheric features within precipitation

However in situ vertical weather profile measurement with satellite provides better data for scientific evaluation of meteorological condition of the atmosphere. It provides valuable information about the state of the Earth-atmosphere system and its components in a continuous and area-wide scale. It is used for monitoring of the near-Earth space weather conditions, precipitation and global warming, human activities including the radiation environment hazardous to spacecraft, crews of high-altitude aircraft, astronauts and the ionosphere environment.

Results from weather monitoring can help national agricultural planning on efficient and profitable farming practice by providing continuous information about rainfall, evaporation rates, and soil moisture levels conditions that can influence the quantity and quality of crop yields.

Osinowo *et al.*(2022) and Adepoju *et al.*(2020) design a low cost weather station for automatic data collection device with Arduino microcontroller. The collections were done with microSD card by Osinowo *et al.* 2022 with removable third party software for downloading the data. Graphical interface unit was developed by Adepoju *et al.* (2020) using Matlab base GIU interface for the obtained data. Kedia 2016, Ukhureber 2017, Dada *et al.* (2018) designed weather station with standalone logger and display unit. They employed newer version of off-the-self atmospheric sensors. The developed weather station do not involved internet of things interface, which make it cost effective. Many weather station developed by commercial manufacturers are highly expensive and not easy to repair when faulty. Also, commercial manufacturers constantly phase-out the previous weather station and replace with new design without notice.

This research is to complement the work done by researchers that have developed weather station for in-situ measurements of vertical weather profile data is not easy to obtain. Many established station employed tower and radar, a method which is very expensive. A system is developed using Drone deployed weather CubeSat to house the weather station and effectively used for vertical profiler.

II. METHODOLOGY

The system comprises of two main units: the first unit is molding of the CubeSat unit using aluminum alloy metal; and the second unit is developed weather ground station. The Figure 1 is basic block layout of the developed weather station for vertical weather profiler consisting of Arduino mega Microcontroller, BME 280, Power Supply Unit, with graphic display unit and system operational software.

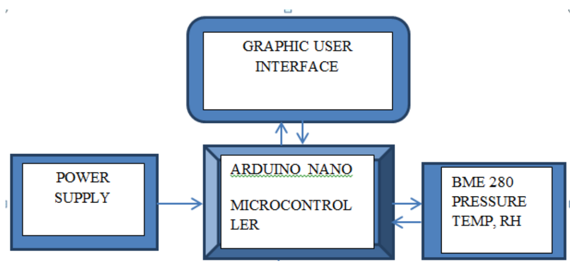

Figure 1 Block Diagram of Weather Monitoring Unit

III. I THE CUBESAT STRUCTURE DESIGN AND FABRICATION

The fabrication of the structure involved 5 steps as follows:

STEP 1. FABRICATION OF SQUARE END PLATES

The two Square end plates were cut from solid flat 12 mm thick aluminum plate to 10 cm by 10 cm The Square internal slot was achieved by chain drilling and manually filling to size 8 cm by 8 cm as shown in Figure 2

The recesses and undercuts to 8.8 cm by 8.8 cm by 2 cm to accommodate and flush fit of the face plates (deeper to accommodate solar panels) were also done on the shaping machine. The next operation was to mark out the position of fastening holes and holes drilling. These were drilled on a pedestal drilling machine and threads are tapped with a tap on bench vice

Figure 2: CubeSat Structure Under Fabrication

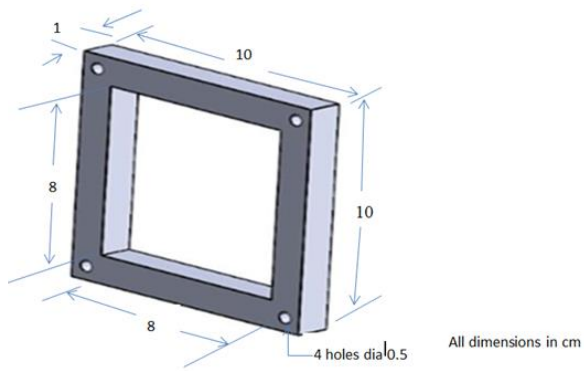

Figure 3: Fabricated Face Plate of CubeSat

This is closely followed by the cutting of the 4 square connecting rods to 10 mm by 10 mm by 8 cm as shown in Figure 4.

Step 2 The Cutting and machining of square shape rods

The machining to square shape rods was done on the shaping machine the four frame members were cut to their respective lengths and shapes using bench tools and shaping machine.

STEP 3 FABRICATIONS OF 36 PIECES OF 4 MM SCREWS

A non-magnetic material, Aluminum was used to fabricate the fastening screws to reduce magnetic interference on the magnetic sensors. Thirty six (36) pieces of the 4 mm screws for joining of the frame sections and face plates were produced, using lathe machine and screw cutting, with a 4 mm die nut on a bench vice. A sample of the fabricated screws is presented in Figure 5.

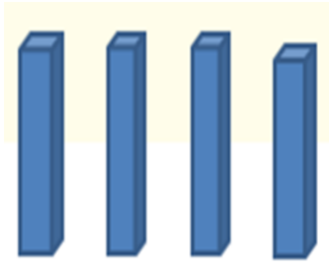

Figure 4: Fabricated 4 square shaped connecting rods

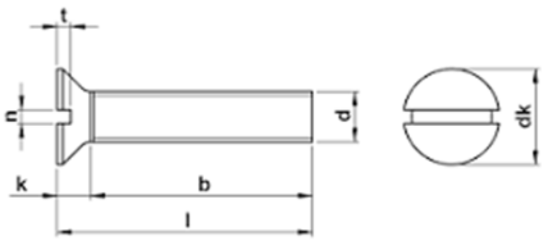

Figure 5: Fabricated Screw for Assembly of CubeSat

STEP 4 FABRICATIONS OF THE SIX SKIN PANEL FACE PLATES FACES

The face covers produced are six in number, one for each face of the CubeSat. The Plate were mark out to the dimension of their various length and breadth and cut to size from the 1mm thick aluminum sheet with a guillotine cutting machine, the sharp edges were removed. The marking operation for the positions of the holes was done and drilling was done on the drilling machine. Figure 6 (a) is the sample of the tin face plate.

STEP 5 ASSEMBLY OF THE CUBESAT STRUCTURE UNIT:

The Custom aluminum screws were used for the joining of the face covers onto the frame structure of the spacecraft. Figure 6 (b) shows the frame of the 1 U CubeSat while the assembled CubeSat is shown in Figure 6 (c)

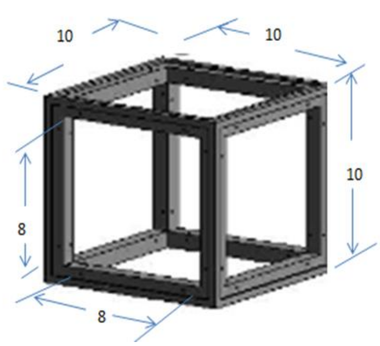

Figure 6 b: Fabricated Skin Face Plates (6 NOS)

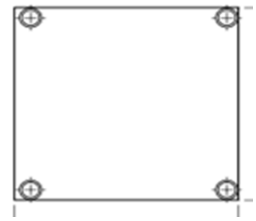

Figure 3.6 b: The 1U CubeSat Structure

Figure 6 c: Complete 1U CubeSat Structure Assembly

IV. THE HARDWARE OF CUBESAT

The microcontroller module employed is Arduino mega. The BME280 was used to measure pressure, temperature, and humidity. The module is easy to deal with as it requires no calibration. Moreover, the sensor can easily measure the pressure in range of 300 pa to 1100 pa. Further, the temperature range is from -40ºC to 80ºC. Also, it can measure the humidity from 0% to 100% with an accuracy rate of 3 percent. Also, the BME280 has the facility to measure altitude above the sea level in meters.

V. RESULT AND DISCUSSION

The system was tested first on 7th May, 2022 and subsequently to measure the temperature gradient along the tall Faculty of Science block c building of Obafemi Awolowo University (>15m) from around 5.10 pm, the result obtained were the temperature, pressure, humidity and orientation position of the system in space measured in three dimension by accelerometer. The various instruments successfully measured the parameters they were sent to capture and the sensors communicated there readings to the ground station, these were displayed dynamically on the graphic screen of the ground station Figures 7, 8, and 9 are the results of the temperature, humidity and pressure readings and the corresponding altitudes as captured by the instruments of the weather monitoring satellite around the science block c of the Faculty of science, ObafemiAwolowo University, Ile Ife. The Temperature and Pressure were observed to reduce with increasing altitudes while the Humidity increases with increasing altitudes

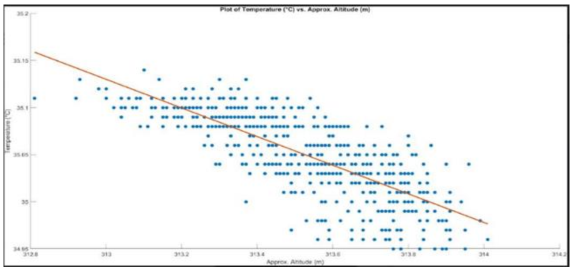

Figure. 7: Temperature and Attitude Plot

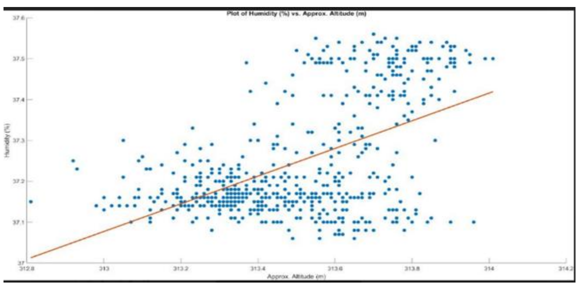

Figure. 8: Humidity and Attitude Plot

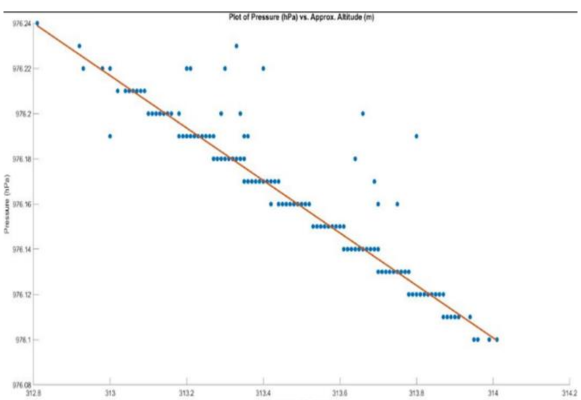

Figure. 9: Pressure and Attitude Plot

VI. CONCLUSION AND RECOMMENDATION

A prototype weather measuring standard 1U Cube Satellite that can simultaneously measure altitude, temperature and barometric pressure variations has been developed.. The nanosatellite was designed, developed, calibrated, standardized and field tested. The performance of the weather monitoring CubeSat was assessed in the laboratory and on the field mounted on a drone, the in-situ weather profile measuring instrument stored captured weather parameters in the microSD card over time allows for verification as shown on Figure 7, 8, and 9.

This present paper present the design and processes of fabrication of a tested vertical weather profile monitor that is cheap, scalable and accurate and easy to maintain suitable for tropical weather parameter capturing. The target parameters for capturing by this weather station first iteration are relative humidity, temperature and pressure and the results are comparable with those obtained with standard instruments.

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