Weather Forecasting CubeSat

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Abstract- Weather is the state of atmosphere at a particular time and place with regard to temperature, moisture, air pressure, precipitation etc. Bio organisms need to adapt with the changing atmospheric conditions. It is therefore important to know the atmospheric condition for different applications. The interest is to design an autonomous small cube satellite which can provide the information of weather from anywhere without using Network. Here a hardware model has been designed and implemented. It is possible to provide instant weather report which can be used to compare the data of a place with some different altitude as well as for different time instant. In meteorology, the main objective is to know accurate weather conditions with less human efforts, reliable and efficient data. As the weather varies from place to place and with the altitude, it is difficult to get accurate weather for a particular location. With the advancement of technology, specially embedded system & data acquisition systems, the problem of large set up area and cost has been reduced significantly. Cube–Sat can be setup at home as well as in atmosphere

Keywords- Internet Of Things, Autodesk, Google Collaboratory, C++ and Python.

I) Introduction-

Here I am going to create one weather forecasting cubeSat. So why weather ?

Weather is the state of atmosphere at a particular time and place with regard to temperature, moisture, air pressure, precipitation etc. Bio organisms need to adapt with the changing atmospheric conditions. It is therefore important to know the atmospheric condition for different applications. The interest is to design an autonomous small cube satellite which can provide the information of weather from anywhere without using Network. Here a hardware model has been designed and implemented. It is possible to provide instant weather report which can be used to compare the data of a place with some different altitude as well as for different time instant. In meteorology, the main objective is to know accurate weather conditions with less human efforts, reliable and efficient data. As the weather varies from place to place and with the altitude, it is difficult to get accurate weather for a particular location. With the advancement of technology, specially embedded system & data acquisition systems, the problem of large set up area and cost has been reduced significantly. Cube–Sat can be set up at home as well as in atmosphere or in space which can provide accurate weather report. We are committed to providing high-quality weather forecasting report that are accessible to everyone. We hope you find our tool a valuable resource in your study journey and invite you to explore all it has to offer. People since nineteenth century became able to predict the environmental conditions. The only difference between the primitive and the modern system is that the advancement of technology. The measuring instrument has become miniaturized, efficient, reliable and more accurate to provide instant weather report without manpower. Weather being a natural phenomenon always change with the change of different atmospheric parameters. Still, the average or mean condition can be predicted which ultimately gives the climate of a geographical area fora long-time consideration. The most important parameters that affect the atmospheric conditions are air pressure, temperature and humidity. All these parameters are subject to change with change of altitude, day length (intensity of sunlight changes), environmental components (tropical zone, or temperate zone etc.), sun angle at particular spot etc. In modern system of weather forecasting, the environmental data are sent to a computer-based system through a Data Acquisition Systems (DAS).

In this system, data from various sensors is collected and processed to estimate the surrounding environment. Sensors collect data at different points and then reuse this data to facilitate the data transfer process. The multiplexed data is sent to the computer through a channel, and the entire system relies on satellite communications for wireless data transmission.

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II) Related work:

The application of CubeSats in weather forecasting has emerged as a promising avenue for advancing our understanding of atmospheric dynamics. Notably, the Tempest-D mission, initiated by NASA, has demonstrated the feasibility of utilizing CubeSats for atmospheric data collection. This mission showcased the potential benefits of employing small satellite platforms to enhance weather observation capabilities. Furthermore, the RainCube experiment, conducted by NASA's Jet Propulsion Laboratory, has highlighted the effectiveness of CubeSats in radar-based precipitation measurement, providing valuable insights into improving precipitation forecasting.

In addition to these agency-led endeavors, university-led initiatives have explored diverse techniques, including radio occultation and multispectral imaging, to leverage CubeSats for enhanced meteorological understanding. These projects underscore the collaborative efforts of the international scientific community to harness CubeSats for comprehensive and global weather forecasting solutions.

III) Literature Review:

Numerous organizations and researchers around the world are constantly working to collect and store data for accurate weather forecasts. Numerous attempts have been made by various researchers to predict the weather conditions using various techniques. But due to the nonlinear nature of Weather, prediction accuracy obtained by these techniques is still below the satisfactory level. Ali, Lin etc [1] developed an ANN technique to estimate tropical cyclone heat potential (TCHP) for estimating the Cyclone and Intensity prediction. They estimated TCHP by 1) an ANN technique, 2) a two-layer reduced gravity model, and 3) a multiple regression technique and compared the estimations with the in-situ observations. Out of the three methods, they found that ANN approach has given the best results. The results suggest the utility of the ANN technique in estimating TCHP with better accuracy in the North Indian Ocean that certainly, in turn, helps in improving the cyclone track and intensity predictions. Sarma, Konwar, Das etc [2] showed that Artificial Neural Network (ANN) can also be combined with different methods. A neural network model for rainfall retrieval over ocean from remotely sensed microwave (MW) brightness temperature (BT) is described. They Proposed, a soft computing approach for rainfall prateestimation over ocean using online feature selection, clustering, and hybrid neural network. In this study, they applied an online feature selection (FS) algorithm to the BT dataset obtained fromTMI. The nine-channel BT data are the input feature to this feature selection algorithm. It selects the most relevant channels both vertical as well as horizontal. A k-means clustering algorithm is then applied to the dataset of selected features. Separate multilayer perceptron (MLP) neural networks are trained for each of the clustered data. These trained MLPs are then combined to form a hybrid network. The results showed that hybrid network ANN-Hyb provided better instantaneous rain fall rate estimation compared to ANN alone. Chaudhuri & Chattopadhyay [3] designed a Feed forward multi-layered artificial neural network model to estimate the maximum surface temperature and relative humidity needed for the genesis of severe thunderstorms over Calcutta. Prediction error is computed and compared for single layer network and one hidden layer artificial neural network. Result reveals the efficiency of the one hidden layer ANN. The performance of the model is found to be good and showed that the neural network technique is of great use in forecasting the occurrence of high frequency small-scale weather systems. As part of the weather forecast, a comparison was made of the results of the single-layer neural network forecasts and the second-order autoregressive process. The analysis revealed that the single-layer neural network consistently outperformed the second-order autoregressive process in terms of prediction accuracy. In addition, experiments involving both single-layer and single-hidden-layer artificial neural networks showed promising results, underscoring the effectiveness of single-hidden-layer neural networks for accurate weather forecasting. Specifically, these networks have been shown to be able to estimate maximum surface temperature and maximum relative humidity with remarkable accuracy. Such estimates helps to aid in forecasting the conditions of an approaching storm and provide valuable forecast information with a lead time of up to 24 hours.

IV) METHODOLOGIES:

The various methods used in forecasting the weather are as follows:

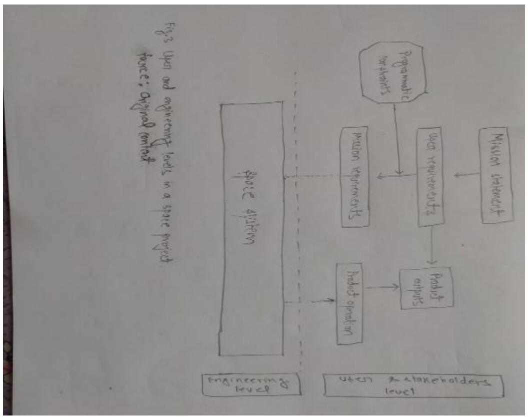
(1) Synoptic weather forecasting
(2) Numerical methods
(3) Statistical methods.

1) **Synoptic weather forecasting**: The first method is the traditional approach in weather prediction. This primary method continued to be in use until the late 1950s. Synoptic" means that the observation of different weather elements refers to a specific time of observation. Thus, a at a given time is a synoptic chart to a meteorologist. In order to have an average view of the changing pattern of weather, a meteorological centre prepares a series of synoptic charts every day. Such synoptic charts form the very basis of weather forecasts.

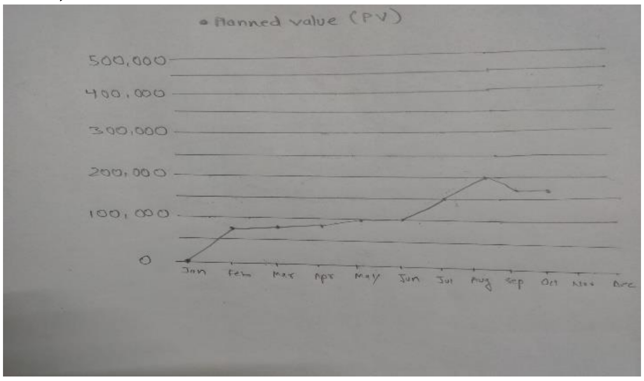
2) **Numerical Weather Prediction (NWP):-** Uses the power of computers to make a forecast. Complex computer programs, also known as forecast models, run on supercomputers and provide predictions on many atmospheric variables such as temperature, pressure, wind, and rainfall. A forecaster examines how the features predicted by the computer will interact to produce the day's weather. The NWP method is flawed in that the equations used by the models to simulate the atmosphere are not precise. If the initial state is not completely known, the computer's prediction of how that initial state will evolve will not be entirely accurate.

3) **Statistical methods:** are used along with the numerical weather prediction. This method often supplements the numerical method. Statistical methods use the past records of weather data on the assumption that future will be a repetition of the past weather. The main purpose of studying the past weather data is to find out those aspects of the weather that are good indicators of the future events. After establishing these relationships, correct data can be safely used to predict the future conditions. Only overall weather can be predicted in this way. It is particularly of use in projecting only one aspect of the weather at a time.

V) Flowchart:



VI) Estimated Costs:



VII) CONSTRAINT IDENTIFICATION:

As part of the development of a product weather Forecasting cubesat using Arduino Uno, Temperature Sensor, Pressor, Altitude sensor and display and control unit there a reversal constraints that need to be considered. These constraints include accessibility, constructability, and usability.

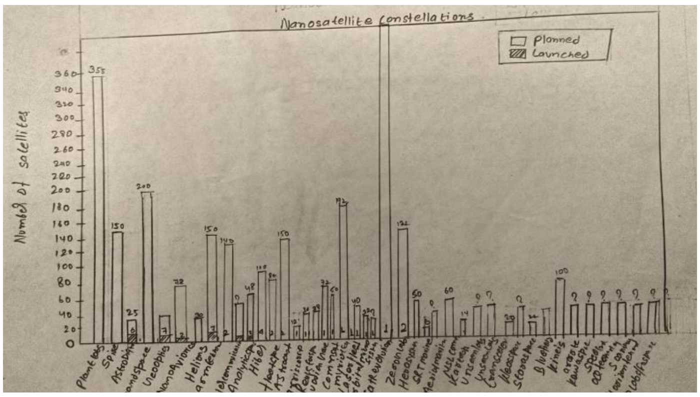
***VIII)* CONSTRAINT IDENTIFICATION:** This material is based upon work supported by the National Aeronautics and Space Administration through the Office of Biological and Physical Research (OBPR), the Exploration Systems Mission Directorate (ESMD), the Space Life and Physical Sciences Research and Applications (SLPSRA) division within the Human Exploration and Operations Mission Directorate (HEOMD), the Science Mission Directorate’s (SMD’s) Astrobiology Small Payloads Program, and HEOMD’s Advanced Exploration System Division. We gratefully acknowledge the contribution of the teams at NASA ARC and many Colleagues.

Several commercial concern, and multiple universities who made possible the spaceflight CubeSat missions described by these publications. LZ was supported by the National Aeronautics and space Administration under Grant No. 80NSSC18K1468 and Bio Serve Space Technologies.

IX)Working Principle:

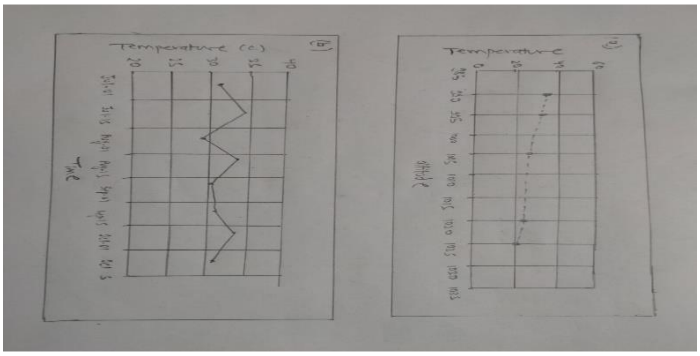
The data controlling unit is an embedded system platform. Here an Arduino Uno is used. It is powered by 9 V battery & programmed for the specific applications using Arduino open source software (Arduino 1.6.1). The temperature and humidity sensor DHT 11 is connected to Arduino Uno. Pin no. 1, 2 and 4 of DHT11 is connected with Pin no GND (ground), A0 and 5 V (supply) respectively. DHT11 collects environmental data and send it to the Arduino Uno for digitally processing analysis of data. The pressure sensor BMP085 takes the pressure data from the environment. The connection of BMP085 to the Arduino Uno is done as follows: Vcc to 3.3 V, SDA to A4, SDL to A5 and GND to GND. Accelerometer ADXL 335 is used. The connection of the accelerometer to the Arduino is done as follows; X to A1, Y to A2, Z to A3, pin 5 to Pin 5 (supply), GND to GND. All these modules are set into a cube box of small dimension. A transmitter & receiver module is also connected with the system. An RF transmitter-receiver module of 433 MHz is used for wireless data transmission. The cube-sat can be placed anywhere. The block diagram of the complete system is shown in Fig. 1.

Working prototype and model of the cube satellite.



X)Result and Discussion:

Pressure, humidity temperature against variation of altitude in Kolkata has been measured in the month of July, 2015. Table 1 shows the comparison of pressure, humidity and temperature with respect to the variation of altitude.



Among all these three parameters, temperature variation has the highest impact on industrial applications such as production, manufacturing etc. Data for the variation of temperature for four months have been recorded from July to October, 2015 in Kolkata. The recorded data is compared with the data from existing internet network-based data and weekly weather report of India Meteorological Department.

Weather Forecasting CubeSats have shown promising results in advancing our ability to monitor and predict weather patterns. Here, we discuss some of the key results and their implications:

Improved Data Collection: Weather Forecasting CubeSats have demonstrated their capacity to collect high-resolution data on various atmospheric parameters, including temperature, humidity, and cloud cover. This improved data collection has led to more accurate and detailed weather observations.

Localized Weather Monitoring: CubeSats can operate at lower altitudes and capture data in regions not covered by traditional weather satellites. This has allowed for more localized monitoring of weather phenomena, which is especially crucial for predicting and responding to microclimates and severe weather events.

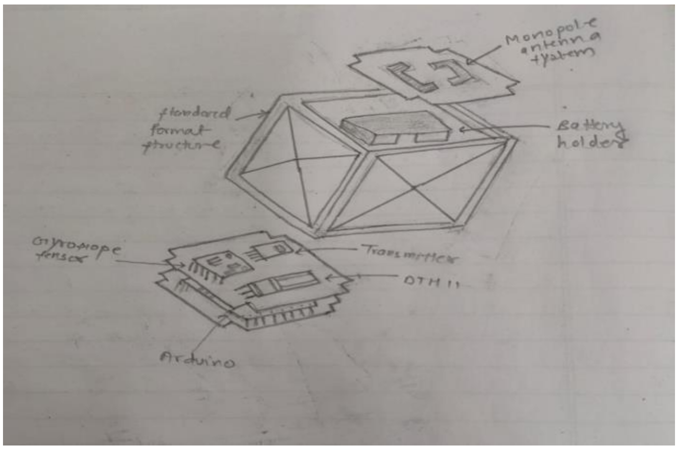
Enhanced Numerical Models: The data collected by CubeSats contribute to the improvement of numerical weather models. These models are fundamental to weather forecasting, and the higher-quality data from CubeSats enhances their accuracy. This leads to more reliable short-term and long-term weather predictions.

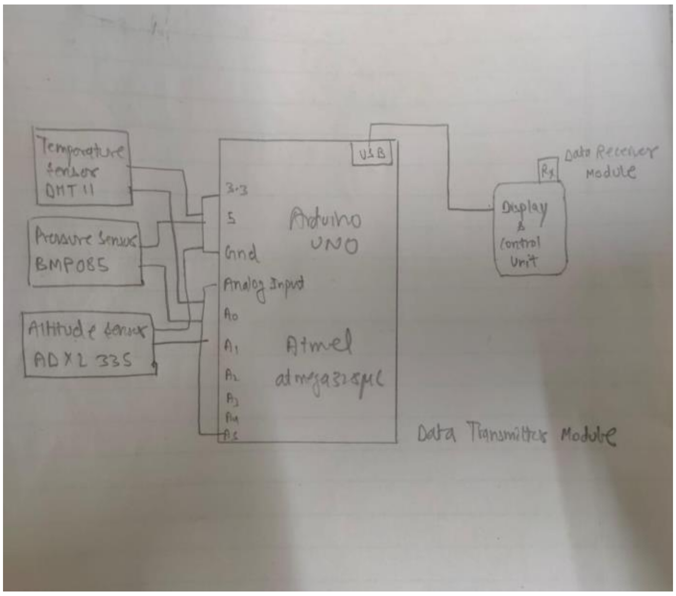
Climate Monitoring: Weather Forecasting CubeSats have played a vital role in climate monitoring. They provide consistent, long-term data that helps scientists track changes in the Earth's atmosphere over time. This information is essential for studying climate change and its potential impacts

Disaster Preparedness: CubeSats are instrumental in predicting extreme weather events, such as hurricanes, storms, and wildfires. Timely and accurate forecasts from CubeSats enable better disaster preparedness and response, potentially saving lives and minimizing damage.

Cost-Effective Solutions: CubeSats offer a cost-effective alternative to traditional weather satellites. They can be launched in constellations, providing more comprehensive coverage of the Earth's atmosphere without the high costs associated with larger satellites.

Research Opportunities: Weather Forecasting CubeSats have opened up new research opportunities in meteorology and atmospheric science. Scientists can use CubeSat data to study specific weather phenomena, validate models, and develop innovative forecasting techniques.

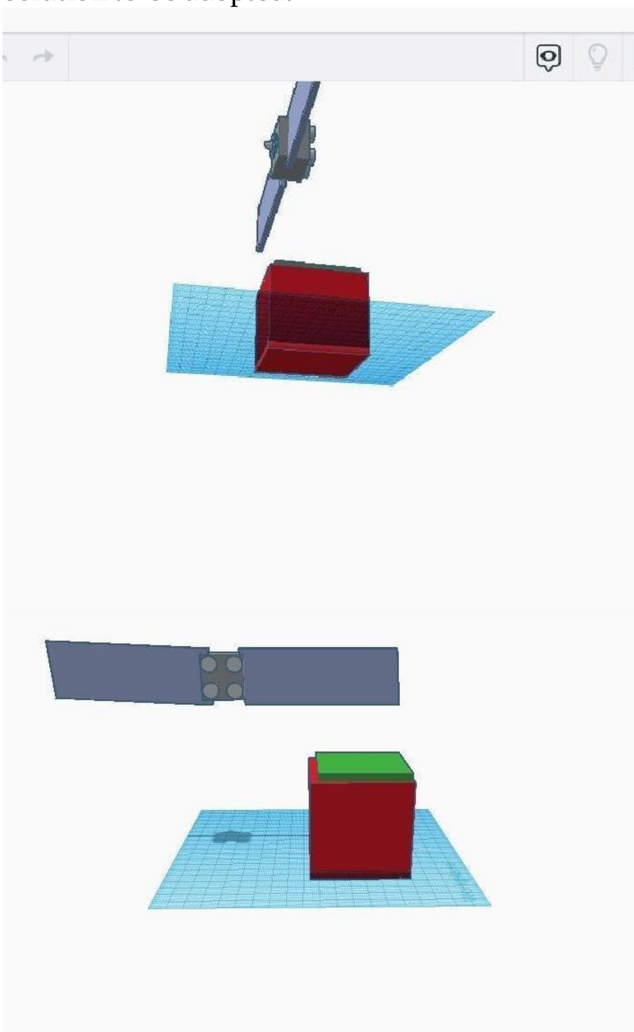


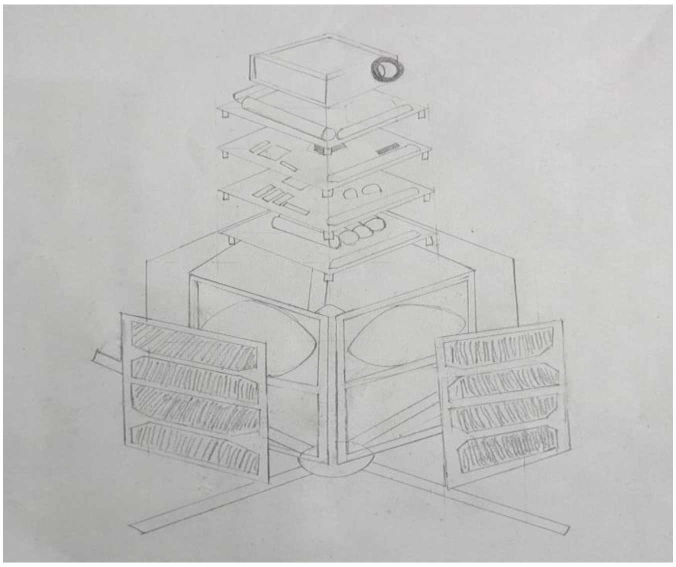


XI) Conclusion:

We have designed and implemented a cube-sat based weather monitoring system. The system is simple to construct, portable, cost efficient, less power consuming and reliable. We demonstrate the hardware design and the data acquisition system. The records of different weather parameters for 4 months with the variation altitude and time period have shown. As the system does not use internet network, data transmission has low cost which in terms provide large applications. It will have a positive impact on agriculture and production. There are some limitations such as the device may not communicate to a long distance without powerful transceivers section, the record of data in higher altitude with the help of gas balloon may be a problem. The components may be damaged by rain or long time use.

In this chapter an overview of best practices during the structural system design and manufacturing has been presented. In particular, attention has been focused on the definition of the requirements and how they affect the overall satellite design. Some aspects are strictly related to the mission itself and cannot be analyzed in detail, but the developer can use this chapter to analyze their particular case and find the best solution to be adopted.





XII) ACKNOWLEDGMENTS:

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XIII) References:

[1] F. Satoh and M. Itakura, Cloud-based Infrastructure for Managing and Analyzing Environmental Resources, SRII Global Conference, pp. 325–334, 2011.

[2] Q. Wei, N. Jin, X. Lou, R. Ma and J. Xu, SoftwareDesign for Water Environment Remote Monitoring System Based on Mobile Devices, Applied Mechanicsand Materials, pp. 2027–2032, (2011).

[3] Y. Zhengtong and Z. Wenfeng, The Research of Environmental Pollution Examination System Based on the Cloud Computing, International Conference on Communication Software and Networks, pp. 514–516,(2011).

[1] P. Kinney, ZigBee Technology: Wireless Control that Simply Works, Communications Design Conference Secretary of ZigBee BoDChair of ZigBee Building Automation Profile WG, 2 October (2003).

[2] Karthik Krishnamurthy, Suraj Thapa, Lokesh Kothari and Arun Prakash, Arduino Based Weather Monitoring System, International Journal of Engineering Research and General Science, vol. 3, issue 2, ISSN 2091-2730, March–April (2015).

[3] Columbia-Weather, Pegasus EX Portable Weather Station – Columbia Weather Systems, Inc. http://www.columbiaweather.com/Pegasus EX-Brochure.pdf, Accessed, 3 June (2010)

[4] M. Ibrahim and M. Youssef, Cell Sense: An Accurate Energy-Efficient GSM Positioning System,IEEE Transactions on Vehicular Technology, vol. 61, pp. 286–296, (2012).

[5] Weather and Environmental Monitoring Sensors, Springer US, pp. 496–523, (1994).

[6] N. Adam, V. Atluri, S. Yu and Y. Yesha, Efficient Storage and Management of Environmental Information, 10th NASA Goddard Conference on Mass StorageSystems and Technologies 19th IEEE Symposium on Mass Storage Systems, April 15–18, College Park, MA (2002).

[7] A. M. Langer EdD, Analysis and Design of Information System, 3rd Edition, Springer, (2008).

[8] C. E. A. Mulligan and M. Olsson, Architectural Implications of Smart City Business Models: An Evolutionary Perspective, IEEE Commun. Mag., IEEE, vol. 51, no. 6, pp. 80–85, (2013).

[9] Z. Machacek and V. Srovnal, Automated System for Data Measuring and Analyses from Embedded Systems, In 7th WSEAS International Conference on Automatic Control, Modeling and Simulation, Prague, Czech Republic, March 13–15, pp. 43–48 (2005).