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Data Acquisition and Analysis for Evaluation of a Balloon based Low Cost CUBESAT Prototype

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Abstract: ***As a part of our initiative to launch a low-cost CUBESAT, first step was aimed to develop a proto model for environmental studies at higher altitude. In the first phase of evaluation a balloon launch is conducted with CUBESAT hardware with additional function of environmental monitoring. The aim of this task was to collect the weather parameters such as pressure, temperature, humidity varying at higher altitudes. In addition, it was also aimed to collect data like position, UV index, IR and Visible light index. The entire data is obtained and stored by the method of Data Logging. The data thus collected is then analyzed at the ground station using MATLAB software.***
In this paper, the methodology used to build the proto model, its capability of measuring various environmental parameters and real time transfer of data through UHF data link is discussed. The paper will also highlight the results obtained and analysis that is carried out for system evaluation.
Keywords: CUBESAT, environmental studies, balloon launch, data logging, MATLAB, pollution, UHF.

I. INTRODUCTION

Satellite technology has established as one of the most promising technology of present and future. This technology is able to meet several primary needs with respect to the communication network, area surveillance and imaging etc. which has been helpful to every sector of techno logical development. Satellite technology has also largely involved student community to acquire experience of multi technology and also study various unexplored areas of space and earth science. Student satellites are mostly referred to 'SMALLSAT'

The task is identified as realization 1U (1 unit) i.e. 10cm x 10cm x 10cm cube satellite that consists of all the necessary sensors, microcontroller battery etc is embedded within. In the first phase, a balloon launch is proposed with emulated CUBESAT hardware with additional function of environment monitoring. Subsequently CUBESAT design development and launch activity will be taken up. The state of atmosphere is generally assessed by its weather condition. It is the criterion which gives the information regarding the atmosphere at a given point of time and place [1].

Weather occurs due to the constant motion of atmosphere. The determining factors of the weather are pressure, temperature, humidity, precipitation, wind etc. The study of these weather conditions is known as meteorology and meteorologists are the people who study this data and forecast weather. It is important to analyze the state of atmosphere at a certain altitude in a particular region so as to take necessary steps or actions to determine the causes for air pollution and other things that disrupts the condition of the environment which leads to unnatural seasonal changes. There is a need for collecting the meteorological data from a remote location and store it at a central place so as to evaluate and analyze the possible atmospheric conditions.

The Indian Meteorological department has been working on measuring the practical weather conditions at a particular region with the help of hydrogen balloons to which the sensor embedded system will be attached and that monitors the various parameters of the weather at lower layers of the atmosphere in a particular region [2]. In order to do so, the Indian Meteorological Department releases hydrogen balloons equipped with the embedded system for every 4 hours to a certain altitude.

II. PAYLOAD DESCRIPTION

The payload is designed to have 4 layers in it and the processing unit used here is ARDUINO UNO. The four layered payload consists of sensors, GPS, transmitter, two data logging units and two Arduino UNO units, Power board, some switches, cables and LED's that indicated the functioning of the system.

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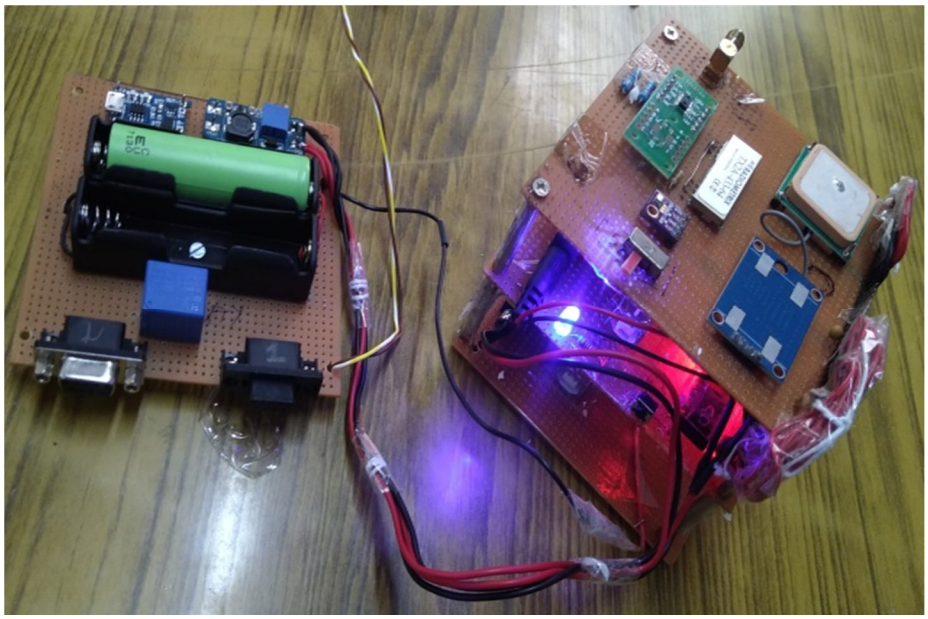

Fig.1 Onboard system

The arrangement was made such that the sensors (BME280, Si1145), GPS module, transmitter was placed on the top which is the first layer. In the second layer, we have an Arduino and CH375B USB disk read-write module that stores the data collected by the sensors. In the third layer board, we have another Arduino board that is connected to the GPS module and an SD card module that stores the data collected by the GPS.

The entire circuit is powered using a Lithium ion rechargeable battery of 3.7V, 2600MAh.The fourth board which is the power board has the battery along with power booster module, charging module and a relay, two DSUB connecters. Battery mode operation is the final mode of operation, that is the entire system is supposed to be operating at battery mode during its journey. For the system to operate in battery mode, we have to connect only the shorting connector and remove all the other connections and ensure that the relay is in OFF state.

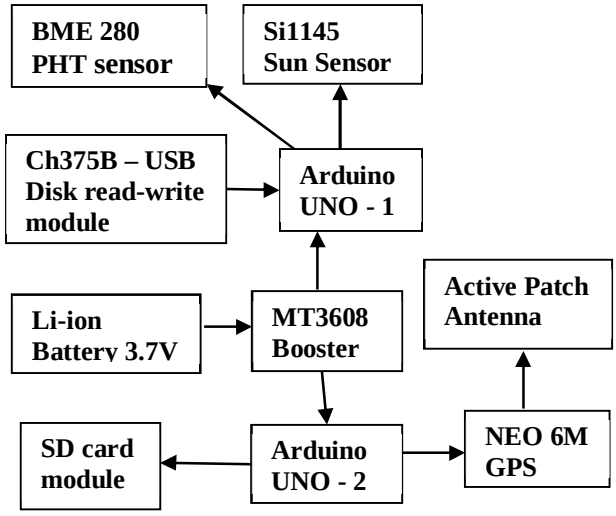

Fig.2 Payload Block Diagram

III. GROUND STATION

The ground station is the place where the received or collected data will be displayed, evaluated and analysed using some data representation techniques like plotting graphs using MATLAB.

IV. SENSORS

These are the devices that produce a measurable response to a change in a physical condition such as pressure, temperature, humidity etc. Sensors are the major components of the system that make in-situation measurements and responsible in converting some kind of physical phenomenon into a measurable quantity through data acquisition system.

V. BME 280 PHT SENSOR

The BME280 is as combined digital pressure, humidity and temperature sensor.
It delivers high performance in applications that requires humidity and pressure measurement. It has high accuracy and resolution over a wide range of temperature values and the integrated pressure sensor is an absolute barometric pressure sensor. Accuracy tolerance +-3% Relative humidity.

Fig.3 BME280 PHT Sensor

VI. SI1145 SUN SENSOR

The sun sensor used here measures the 3 things: UV index, visible and IR (infrared) light index. The Si1145 is a low-power, reflectance-based, infrared proximity, ultraviolet (UV) index, and ambient light sensor with I2C digital interface and programmable event interrupt output.

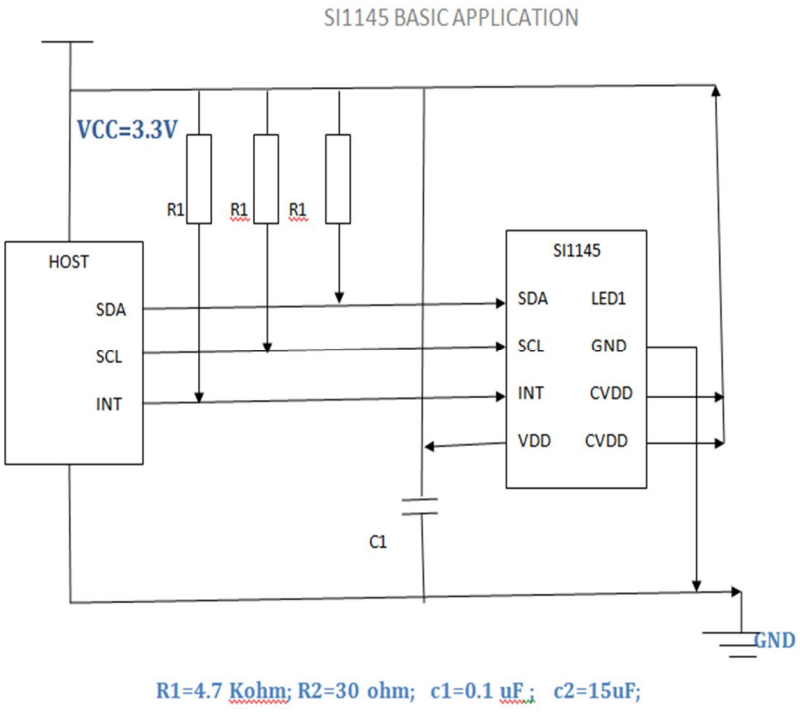

Fig.4 Si1145 Sun Sensor module

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VII. NEO-6M GPS MODULE

Global Positioning System (GPS) is one of the most widely used method to determine one's own location on the earth anytime in any weather, any place. It is a satellite-based radio navigation system owned by US government. It provides the geo location and time information to a GPS receiver anywhere on or near earth where there is a path without any obstruction providing Line of Sight (LOS) to 4 or more GPS satellites. The module simply checks its location on earth and provides output data which is longitude and latitude of its position. It is from a family of stand-alone GPS receivers featuring the high-performance U-BLOX 6 positioning engine.

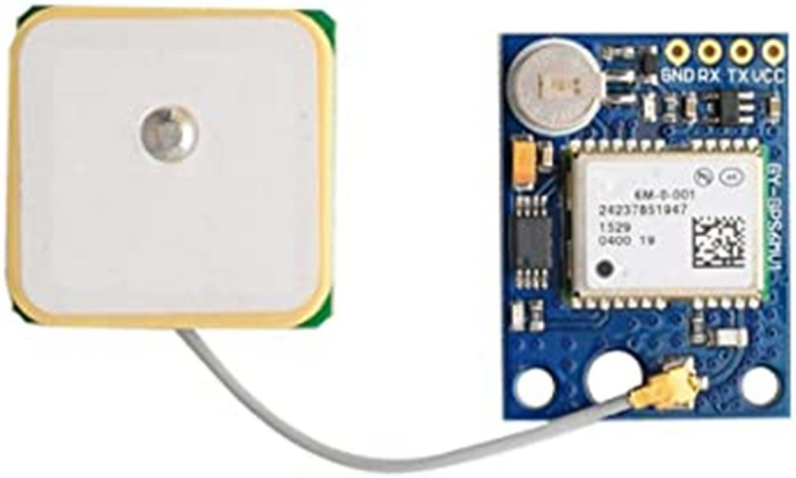

Fig.5 NEO-6M GPS Module

VIII. DATA LOGGING

Data Logging is a process of recording data based on time or an event. Data Logging was one of the major tasks of this project, where the data from various sensors is stored into a module which is equipped with a pen drive or SD card such that the entire data collected from the sensors is stored safely and can be retrieved back easily. We have used two data logging modules in this project, where one is CH375B USB disk read write module and the other one is a SD card module. CH375B module was used to store the data retrieved from the environmental sensors, whereas the SD card module was used to store the data retrieved from GPS.

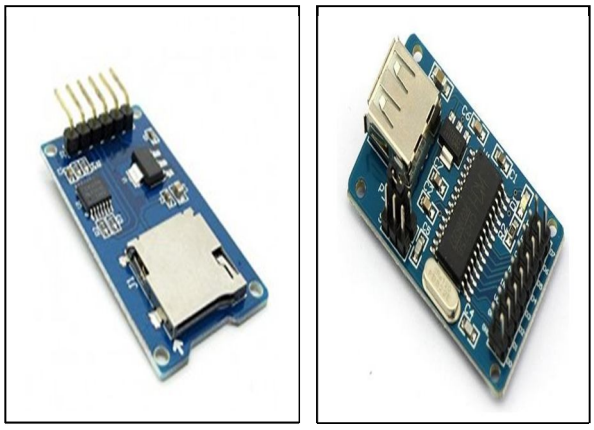

Fig.6 CH375B USB Disk Read-Write and SD Card Module

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IX. RESULTS

The payload designed was weighing about 400gms and was launched close to the start of ozone layers in a high-altitude balloon under the guidance of experts at TIFR.

Fig.7 Onboard System / Payload

The following graphs have been plotted showing the variation in pressure, temperature, humidity, battery voltage, UV light index, Visible and IR light index with respect to altitude using the MATLAB software. The following insights have been drawn from the plots.

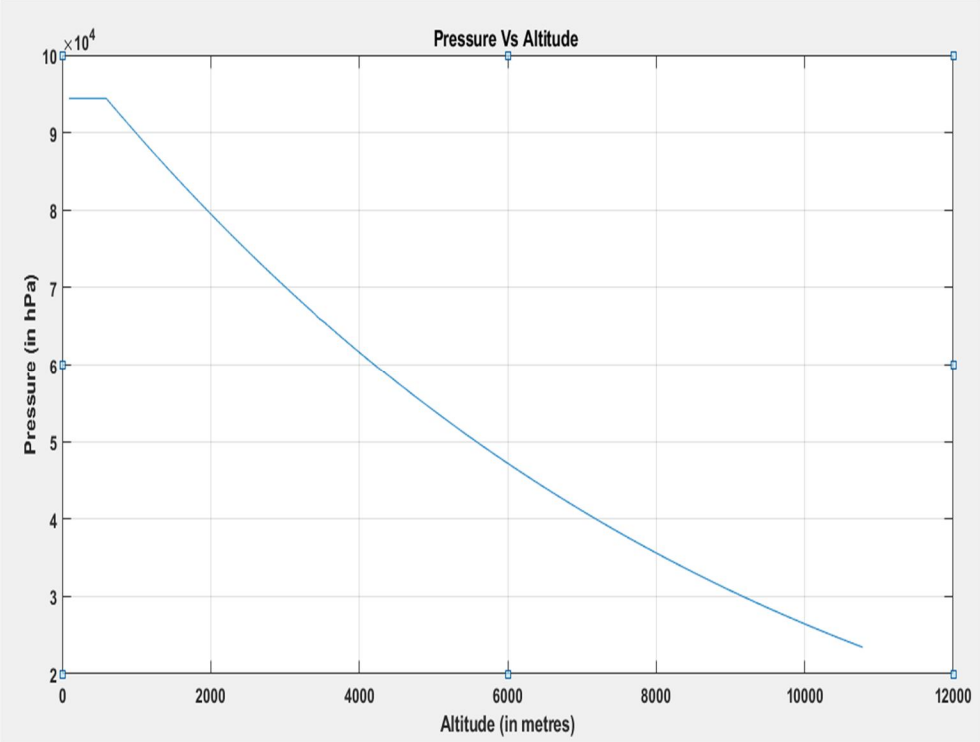

Fig.8 Pressure Vs Altitude

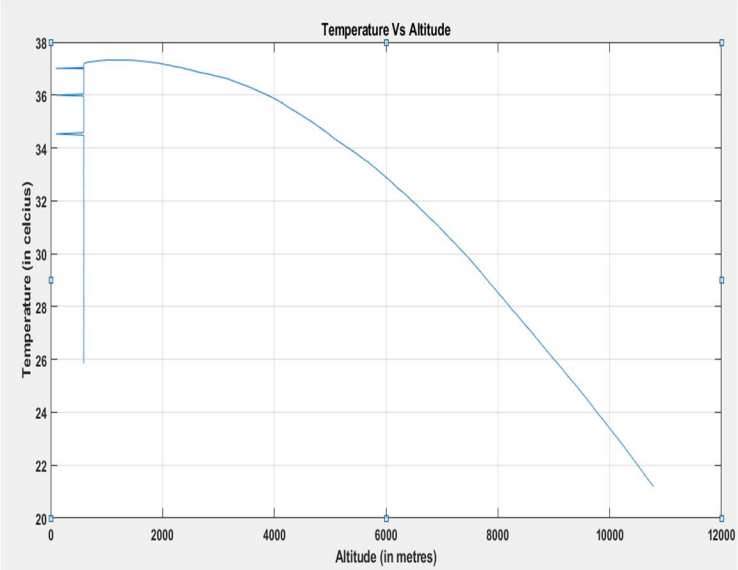

Fig.9 Temperature Vs Altitude

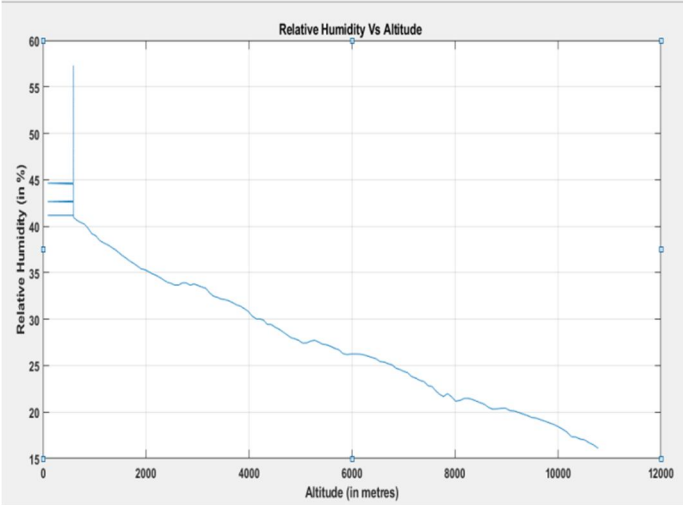

Fig.10 Relative Humidity Vs Altitude

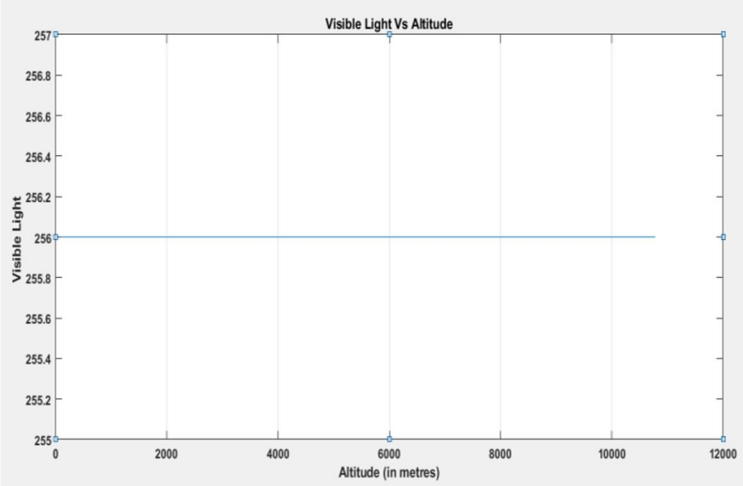

Fig.11 Visible Light Index Vs Altitude

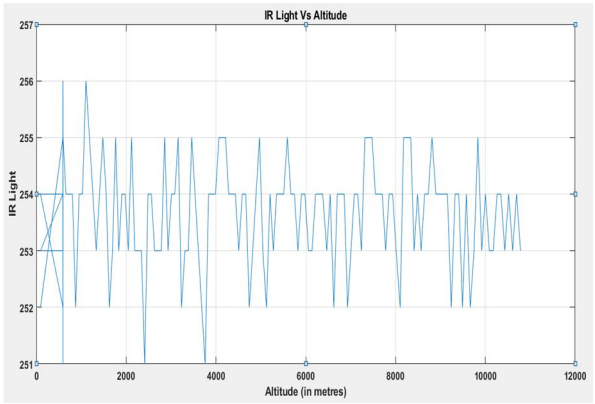

Fig.12 Infrared Light Index Vs Altitude

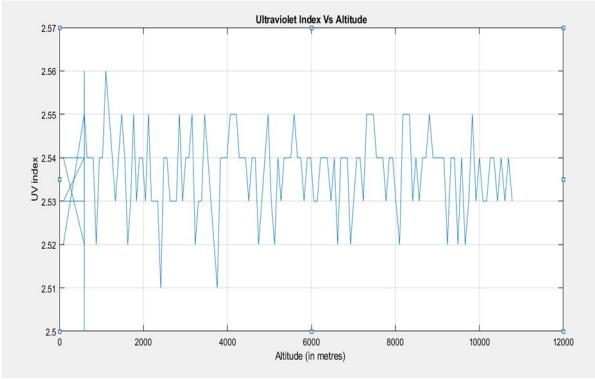

Fig.13 UV Index Vs Altitude

X. FLIGHT ANALYSIS & SUMMARY

Realization of a prototype for 1U CUBESAT was accomplished which also had an additional functionality of measuring various environmental parameters was made successful. The major focus was on to keeping the size, weight of the payload as minimum as possible, yet embedding it with all the necessary electronic equipment inside with proper positioning and functioning. The balloon reached an altitude of 18 km, floated for about 90 minutes and the flight was terminated once the mission was completed. The system was equipped with GPS, so we were able to monitor its position and could recover the payload and retain the data collected.

The results obtained were compared with the other databases, referred from various papers, who conducted similar experiments for environmental monitoring [3][4], to ensure that the procured values are reliable. A series of discussion was held with authorities of Telangana Environmental Board and TIFR (Tata Institute of Fundamental Research) balloon facility to finalize the configuration. A large support of TIFR balloon facility is extended to accomplish the task.

Fig14. Project Team at Launch Site

XI. CONCLUSION

Satellite based communication system is one of the far-reaching domains in the wireless communication province which offers innumerable advantage for rapid and secure global communication. With the advent of balloon-based systems we are able to monitor huge amount of areas from higher altitudes which thus is a cost-effective approach. Existing environment monitoring systems are expensive and also require huge equipment and space. The need of cost effective and reliable environmental monitoring system is growing at a faster pace. Assessing the atmosphere at particular regions has become important so as to determine the status of the atmosphere and to predict the possible effects it can have on the environment. The data obtained is updated from time to time as per the weather changes.

XII. ONGOING WORK AND FUTURE SCOPE

Further enhancement can be done to the system by enabling it with few more environmental sensors like Gas sensor, to measure the amount of different gases present at higher altitudes. We are also working on to include the camera module for complete area surveillance using some image processing techniques and realization of UHF Data Link for establishing the communication link between the onboard system and the ground station, where the data that is collected will be transferred directly to the ground station and further analysis will be made out from the received data. This technique will thus help in eliminating the storage devices onboard.

According to a recent research, to reduce the amount of UV radiation falling on earth, scientists are planning to spray chalk powder (calcium carbonate component) at a certain altitude in the stratospheric region, to absorb these UV radiations. Past studies have shown found that the calcium carbonate exoskeletons of corals that make up reefs fluoresce under UV light, suggesting that they absorb UV rays. therefore, the coral acts as the sunscreen, that absorbs UV light and limiting the harm it inflicts on the reef's denizens [5].

We are also working on implementing the deployment of solar panels to act as source of power instead of a rechargeable lithium ion battery used in this project.

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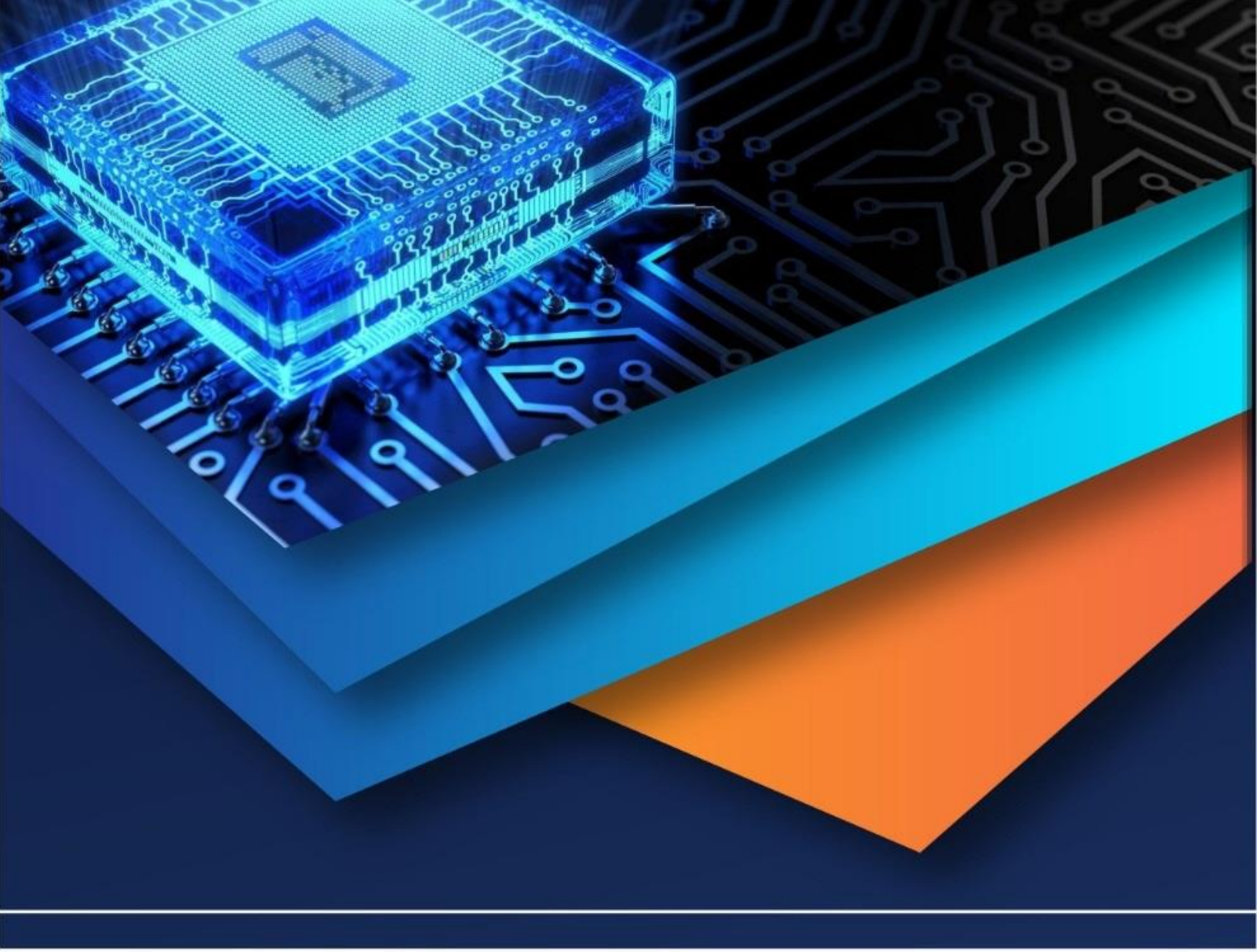

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