# CubeHack Design Report

**R. C. S. Rathnage, H. M. T. N. Herath, R. A. J. R. Perera, K. R. P. N. S. Ranaweera**

Wayamba University of Sri Lanka
chandimarathnage@gmail.com
thisarahhm@gmail.com
jinaliperera98@gmail.com
poorninadeema96@gmail.com

***Abstract-*** This report includes the details of the CubeSat designed by the team Spectrum for the CubeHack competition. The main purpose of this satellite design is to gather information on weather conditions; humidity, temperature and biometric pressure. The satellite will also give details on its orientation.
We have proposed a design of 1U CubeSat with a mass of 1kg. The main purpose of the structure subsystem of the CubeSat is to enclose and protect the satellite. So, Aluminium is used as the material for the structure subsystem of our CubeSat. On-Board Computer autonomously controls all other subsystems and resets certain systems. For our design, the proposed microcontroller is ATmega328p. We are planning to store all kinds of data, analyze them and prepare those data to transmit to the ground station. OBC helps to measure humidity, temperature and biometric pressure. Though the memory of the microcontroller is sufficient, we use a 32GB external SD card to be used in case of an emergency. And also, a Mini TF Card Adapter Reader Module is used to communicate between the memory card and the MCU. The Electrical Power Subsystem will generate power, store it and distribute power to other subsystems. In this subsystem, we use four 10cmx10cm solar panels of 5V in a parallel configuration. Considering many reasons, we use a Lithium-ion rechargeable battery to store power. In the Communication Subsystem of our CubeSat, we use radio frequency to communicate. A 433MHz RF transmitter and receiver module is used for the subsystem. Sensors used as the payload in our CubeSat are ADXL335, DHT22, TM7711, LM35. From the data we get from these components, we can make predictions about the weather.
This design is proposed to complete this CubeSat at the lowest possible cost.

***Index Terms-*** Aluminium, Attitude Determination and Controls, Communication, CubeSat, cube satellite, Electrical Power Subsystem, Low Earth Orbit, miniaturized satellite, On Board Computer, Payloads, Polyimide, subsystems

## I. Introduction

Members of the team Spectrum of Wayamba University of Sri Lanka are R. C. S. Rathnage, H. M. T. N. Herath, R. A. J. R. Perera and K. R. P. N. S. Ranaweera. We were inspired to participate in CubeHack competition after the CubeSat workshop organized by the SEDS SL, SEDS Pera and IEEE MIT-S of University of Peradeniya. This is a detailed report of our proposed cube satellite design for this competition.

A CubeSat is a miniaturized satellite with specific criteria that control factors like shape, size and weight. A CubeSat unit is referred to as 1U with standard dimensions of 10cmx10cmx10cm and a mass of 1kg to 1.33kg. The most common variations of CubeSats include 2U, 3U, 6U and 12U. Cube satellites are commonly used in Low Earth Orbit(LEO) for numerous applications. The very specific standards for cube satellites help reduce costs. Because of the standard aspects of CubeSats, companies have tended to mass-produce components and offer off-the-shelf parts. As a result, CubeSats are getting priority over highly customized small satellites since engineering and development are less expensive. The standard measurements also reduce costs related to transporting and deploying these cube satellites into space. [1] A cube satellite is consisting of several subsystems which individually play specific roles in operation of the satellite. Structure Subsystem, On Board Computer(OBC), Attitude Determination and Controls(ADCs), Electrical Power Subsystem(EPS), Communication Subsystem and Payload are those significant subsystems of a cube satellite.

Each of these subsystems of the proposed design will be discussed in this report.

## II. Structure Subsystem (STR)

### A. *Role of the structure subsystem.*

The main purpose of the structure subsystem is to enclose, protect and support the other subsystems and to provide a mechanical interface with the launch vehicle.

### B. *Dimensions, Mass.*

Dimensions - 1U (10cmx10cmx10cm)
A nano CubeSat is designed to reduce the cost of entry into space, to reduce time to get into orbit and because the launch cost and development cost is very low.
Mass - 1kg
This overall mass is consisting of 25g of OBC, 23g of Payloads (Accelerometer-2g, Humidity sensor-3g, Pressure sensor-10g and Temperature sensor-8g), 550g of EPS (battery-50g and solar panels-500g), 100g of COMMS, 200g of STR, 100g of other materials (wire, clip, switch etc.) and 2g of tolerance.

### C. Proposed materials.

The proposed material for the structure of the design is Aluminium. It is lightweight, durable, strong and relatively cheap compared to other materials and also can be obtained easily.

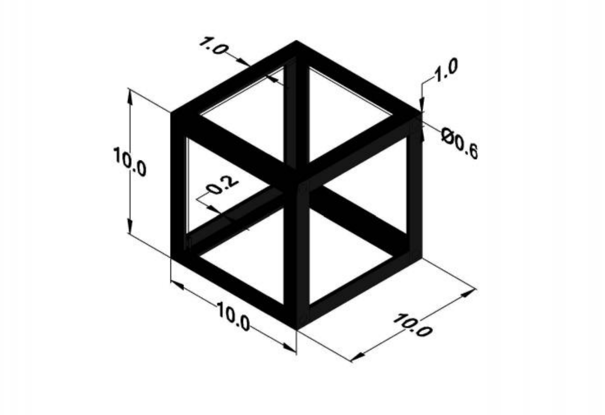


**Figure 1 : Aluminium frame with dimensions**

### D. Thermal Controls.

Polyimide is used to insulate the satellite in the form of aluminium polyimide. Polyimide side is used for the exterior while the aluminium side for the interior making insulated exterior and conductive interior. Polyimide has excellent resistance to heat and radiation and also gives a gold shine to the exterior. [2]

### E. Manufacturing costs, budget and feasibility.

The total cost of this proposed design will be around Rs.15130. The estimated rough budget is;
OBC – Rs.700
Payloads – Rs.1500
(Accelerometer - Rs.450, Humidity sensor - Rs.400, Pressure sensor - Rs.450, Temperature sensor – Rs.200)
EPS – Rs.4000
(Battery – Rs.2000, Solar panels – Rs.500*4= Rs.2000)
COMMS – Rs.2000
STR (Al strips)– Rs.1000
Other (wire, clip, switch, rivet, screws, lead) – Rs.2000
PCB's – Rs.2000
SD card (32GB) – Rs.1600
Card adapter – Rs.330
The feasibility of the design is high since the required materials can be easily found and the manufacturing cost is relatively low.

## III. On Board Computer (OBC)

### A. Role of the OBC.

OBC is the brain of the satellite. The primary role of the OBC is autonomous control of all subsystems of the satellite. The main functions are to communicate with other subsystems, change and control different modes like power saving mode, normal mode, transmit mode etc. On-board computer is specially designed to monitor and control the real-time operation of a satellite in real-time.

### B. Micro-controller proposed.

The microcontroller proposed for this design is ATmega328p. It is an 8-bit AVR microcontroller with 32KB In-System Programmable Flash Memory, 2KB internal SRAM, 1KB EEPROM, Programmable watchdog timer with a separate on-chip oscillator and an on-chip analog comparator. This is operated at 2.7V to 5.5V with an automotive temperature range of -40 to +125 degrees of Celsius. This has 23 programmable I/O lines. [3] High performance, low power consumption, low price and easiness in programming (high experience in C++ language) are considered in the selection of this microcontroller.

### C. Functions planning to perform with the OBC.

All the functions of the satellite design will be controlled by the OBC. It will store all kinds of data collected by the sensors and analyze and prepare them to be transmitted to the ground station through the RF module. The telecommand data sent by the ground station to the satellite will be processed in the OBC. The OBC will monitor all the subsystems and reset certain systems. The OBC helps to measure humidity, temperature, biometric pressure and orientation (roll, pitch and yaw) of the satellite.

### D. Attitude Determination and Controls (ADCs)

ADCs change the current orientation of the satellite to the desired orientation. In other words, the control system makes sure that the satellite is facing the direction that it is supposed to face during the mission. It is only needed if the satellite has pointing requirements. The reaction wheel is the commonly used attitude control actuator. Three reaction wheels are used to control the roll, pitch and yaw of the satellite. In our proposed design accelerometer is used to get the orientation of the satellite but an attitude control actuator is not used since it has no pointing requirement.

### E. Memory / EEPROM

The required memory is achieved by the on build memory of the microcontroller used. EEPROM is 1KB. An external SD card of 32GB is used to save data in case of a data transfer failure. For the communication between the memory card and the MCU a Mini TF Card Adapter Reader Module is used.

## IV. Electrical Power Subsystem (EPS)

### A. Role of the EPS.

This system deals with the power generation, power utilization and power storage of the satellite. The power system is essential for the other CubeSat subsystems, to function. The design objectives of the power system are providing adequate power to the electrical subsystem, minimizing power drain from the batteries, ensuring efficient recharging of the batteries. And also, we have to consider minimizing the weight and volume of the CubeSat. [4] Solar cells are used to convert sunlight to electricity and then stored in rechargeable batteries to provide power during an eclipse as well as during peak load times. [5]

## B. *Solar cell selection and justifications.*

Four 10cmx10cm solar panels of 5V are used in this proposed design for the required power supply considering the efficiency.

## C. *Solar Array configuration*.

The solar panels will be body mounted to four sides of the satellite, in a parallel configuration.

## D. *Battery selection and justifications*.

A lithium-ion rechargeable battery is used since it is fast charging and is commonly used in CubeSats. The required power to charge the battery can be easily obtained by solar panels. Lithium-ion batteries has high energy-to-mass ratios, therefore they are suitable to use on mass-restricted spacecraft. Batteries sometimes come with heaters to prevent the battery from reaching dangerously low temperatures which could cause battery and mission failure. [5]

# V. COMMUNICATIONS SUBSYSTEM (COMMS)

## A. *Role of the COMMS.*

The Communication subsystem is used to communicate with the ground stations. This consists of three segments as telemetry, tele-command and payload. Telemetry data is the data sent from the satellite to the ground station such as housekeeping data, health parameters of the satellite while tele-command data is the data sent from the ground station to the satellite to control the satellite. Payload data is the data obtained from the payload.

## B. *Types of communications proposed.*

Radio Frequency is used in communicating in the proposed CubeSat design. A 433MHz RF transmitter and receiver module is used considering the required parameters of the satellite. The transmitter is one of the very low-cost power effective modules and can be used to interface with almost every microcontroller. This transmitter module has an operating voltage at a range of 3V to 12V and it is the operating voltage of most of the microcontrollers and boards. The Transmitter offers only one-way communication at a 1Kb data rate. This receiver is one of the popular and cheapest receivers and has low power consumption. The maximum operating voltage range of the receiver module is 5V. The typical sensitivity of both transmitter and receiver is 105 dBm. [6].

## C. *Link Budget Analysis.*

It is the most important factor in satellite communication. It helps to identify if the transmitted data can be received or not by the receiver. Basically it is the gains and losses of the system, calculated by the equation; Received power(dB)=Transmitted power(dB)+Gains(dB)-Losses(dB). Received power should be greater than the sensitivity of the receiver to receive data from the satellite.

## D. *Regulations applicable when communicating with the satellite and reserving the frequency.*

Signals beyond 900MHz frequency are not used in the communication of satellites. Data is encrypted since it can be received by any other receiver on the ground since antennas used in satellites are omnidirectional (send data in all directions). In case of communication loss, the gain of the antenna can be increased to receive signals or can communicate through another satellite.

# VI. PAYLOAD AND MISSION

## A. *Type of the payload.*

Sensors capable of obtaining data related to weather conditions are used as the payload in this proposed design.

## B. *Components planning to use.*

The components planning to use as payload are ADXL335 Accelerometer Sensor, DHT22 Humidity Sensor, TM7711 Pressure Sensor and LM35 Temperature Sensor.

ADXL335 Accelerometer Sensor - An accelerometer is a device to measure acceleration forces. It shows acceleration due to gravity in the g unit. The ADXL335 measures acceleration within a range of ±3 g in the x, y and z-axis. The output is given as analog voltages at the output X, Y and Z pins proportional to the acceleration in respective directions. The angle of inclination or tilt can be calculated by using X, Y, Z’s value and also Roll, Pitch and Yaw angles. [7]

DHT22 Humidity Sensor – This device is a basic, digital temperature and humidity sensor with a capacitive humidity sensor and a thermistor used to measure the atmosphere. Then it emits a digital signal on the data pin. Although it is relatively simple to use, it takes careful time to retrieve data. DHT22 sensor is more accurate and works in a larger range of temperature/humidity compared to the DHT11. The required power is 3V to 5V. This sensor is suitable for 0-100% humidity readings with 2-5% accuracy and also for -40 to 80°C temperature readings with ±0.5°C accuracy. This has a sampling rate of 0.5Hz (once every two seconds). Low cost is considered when selecting this sensor. [8]

TM7711 Pressure Sensor - The TM7711 is an analog-to-digital converter used to measure resistance changes. Some applications this module is commonly used are load cell and air pressure sensors. This is a highly accurate, quality and cost-effective module. The module power supply is 3.3-5 V. [13] Extremely low power consumption and low cost is considered when selecting this sensor. [9]

LM35 Temperature Sensor - LM35 is a device to measure temperature with an analog output voltage proportional to the temperature. This output voltage is provided in Celsius. Any external calibration circuitry is needed for this. The sensitivity of LM35 is 10 mV/degree Celsius. Output voltage increases as temperature increases. Surrounding temperatures ranging from -55 °C to 150 °C can be measured using this sensor. The temperature output from LM35 is more precise than thermistor output. [10] Low-output impedance, a linear output, low self-heating and lower cost are considered when selecting this sensor. [11]

### *C. Data Processing*

Temperature, humidity and pressure in the atmosphere can be obtained using the payload data and they can be analyzed to predict further details on the weather.

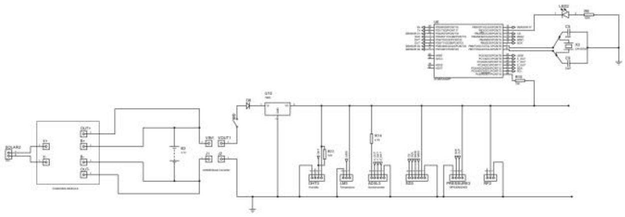

**Figure 2 : PCB design**

## CONCLUSION

This design is proposed to be designed feasibly at a low cost, to obtain details on humidity, temperature and biometric pressure of the atmosphere.

## ACKNOWLEDGMENT

Our team is extremely grateful to everyone who has contributed to make this task a success and we would like to express our sincere thanks to them.
This task would have been impossible if it was not for the cube satellite workshop organized by the SEDS SL, SEDS Pera and IEEE MIT-S of the University of Peradeniya. Our heartiest gratitude goes to the organizers and the speakers for the immense knowledge that was provided to us from the workshop.
We also acknowledge our parents and fellow batch mates for guiding us during the past few days and for the constructive criticism provided.

## REFERENCES

[1] NASA CubeSat Launch Initiative, CubeSat101 Basic Concepts and Processes for First-Time CubeSat Developers, For Public Release – Revision Dated October 2017.

[2] Aluminum Polyimide Film https://www.cgstape.com/product/aluminum-polyimide-film/ (accessed date 25/07/2021)

[3] 8-bit AVR Microcontroller with 32K Bytes In-System Programmable Flash DATASHEET, https://datasheetspdf.com/pdf/1469778/ATMEL/ATmega328P/1 (accessed date 31/07/2021)

[4] Power Subsystem, http://www.ae.utexas.edu/courses/ase463q/design_pages/spring03/cubesat/web/Paper%20Sections/5.0%20Power%20Subsystem.pdf (accessed date 30/07/2021)

[5] CubeSat, https://en.m.wikipedia.org/wiki/CubeSat (accessed date 30/07/2021)

[6] 433 MHz RF Transmitter and Receiver module pinout, features & working, https://www.etechnophiles.com/433-mhz-rf-transmitter-and-receiver-module-pinout-features-working/ (accessed date 28/07/2021)

[7] ADXL335 Acclerometer Module, https://www.electronicwings.com/sensors-modules/adxl335-accelerometer-module (accessed date 03/08/2021)

[8] DHT22 Temperature-Humidity Sensor + Extras, https://www.adafruit.com/product/385 (accessed date 01/08/2021)

[9] TM7711 24-bit Pressure Sensor Module, https://electropeak.com/tm7711-electronic-weighing-sensor-24-bit-ad-module (accessed date 01/08/2021)

[10] LM35 Temperature Sensor, https://www.electronicwings.com/components/lm35-temperature-sensor#:~:text=LM35%20is%20a%20temperature%20measuring,is%2010%20mV%2Fdegree%20Celsius. (accessed date 30/07/2021)

[11] Texas instruments, LM35 Precision Centigrade Temperature Sensors, https://www.ti.com/lit/ds/symlink/lm35.pdf (accessed date 30/07/2021)

## LIST OF FIGURES



## AUHORS

Mr. R. C. S. Rathnage, Undergraduate, Wayamba University of Sri Lanka, chandimarathnage@gmail.com
Mr. H. M. T. N. Herath, Undergraduate, Wayamba University of Sri Lanka, thisarahhm@gmail.com
Ms. R. A. J. R. Perera, Undergraduate, Wayamba University of Sri Lanka, jinaliperera98@gmail.com
Ms. K. R. P. N. S. Ranaweera, Undergraduate, Wayamba University of Sri Lanka, poorninadeema96@gmail.com