International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Design and Development of the Satellite Structure and the Antenna Deployment for the 1u CubeSat

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Abstract

Whenever we think of satellite the first thing that comes to our mind is big in size, requires a lot of fuel etc which is very true. But if I tell you there are satellites whose size is just like a 3x3 rubik's cube and can help in remote sensing, communications and many more. These small satellites are known as CUBESAT. This Paper presents the design of internal and external components of 1U CUBESAT.

This Paper also provides critique on the insufficient data present for lunar exploration. Finally the external design of CUBESAT has been implemented on Fusion 360 with dimensions of 10cm*10cm*10cm and Static stress, Vibration and Thermal analysis has been done in Simulation section of Fusion 360.Whenever we think of satellites, the first thing that comes to mind is that they are large, require a lot of fuel, etc., which is very true. But if I tell you, there are satellites whose size is similar to a 3x3 Rubik's cube and can help in remote sensing, communications, and many more things. These small satellites are known as CUBESAT. This Paper presents the design of internal and external components of the 1U CUBESAT in a systematic manner, and to better understand the configuration of the satellite, sensors like the MPU6050 and LIDAR have been integrated into the CUBESAT to get the orientation and surface examination, respectively. This Paper also provides a critique of the insufficient data present for lunar exploration. Finally, the external design of CUBESAT has been implemented on Fusion 360 with dimensions of 10 cm by 10 cm by 10 cm, and Static stress, Vibration, and Thermal analysis have been done in the simulation section of Fusion 360.

Keywords: Aerospace engineering, Aeronautical Engineering, Satellite and Antenna Deployment

1. Introduction:

CubeSats are tiny box shaped satellites that are mainly launched into low earth orbit to observe Earth, test new communication technology, or perform miniature experiments. CubeSat's began as collaborative effort in 1999 between Jordi Puig-Suari, a professor at polytechnic state university (Cal poly) and Bob Twiggs, a professor at Stanford University's space systems development laboratory (SSDL) they came up with a set of specifications for a small inexpensive satellite that their space engineering students could learn how to design, make, and send into space. The basic CubeSat design is a cube 10cm x 10 cm x 11.3 cm in size and is called 1U (standing for 'one unit'). It is similar in size to a standard Rubik's Cube. The mass of 1U is not allowed to be greater than 1.33kg. They can be 1U, 2U, 3U, or 6U in size, and typically weigh less than 1.33 kg (3 lbs)per U.

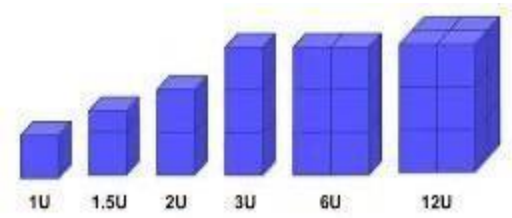


Fig 1 Various dimensions of Cubesat

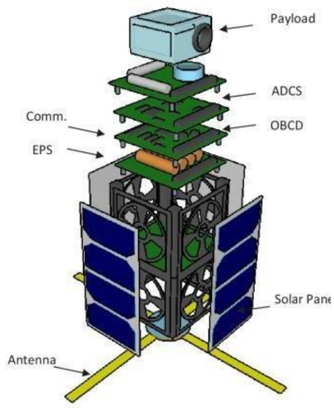


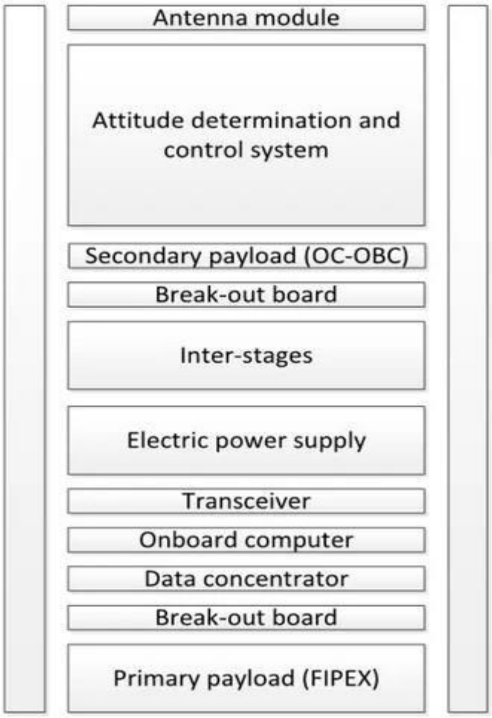
Fig 2 Structure of cubesat

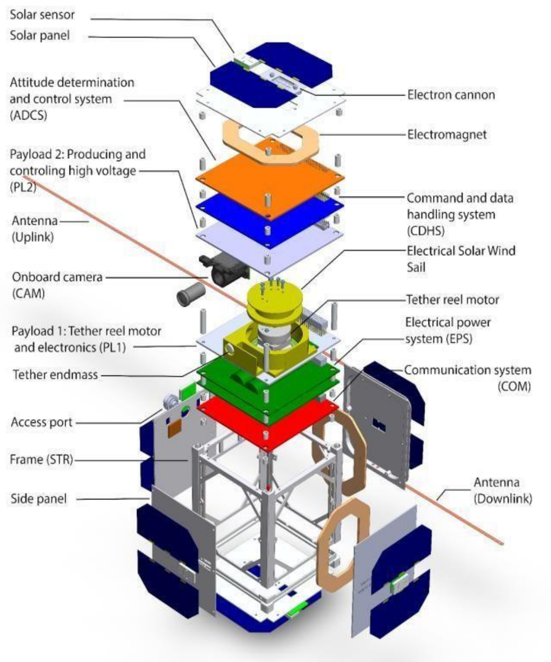
Modern CubeSats are a special class of nano satellite. The size of one-unit (1U) CubeSat is 10cm x 10 cm x 11.3 cm. CubeSats can be composed as made in several combinations of the 1U to form up to 6U (Fig. 1), or even more. Universities, governments and manufacturers are progressively turning to CubeSats as ready-to-build systems able to deliver low-cost and rapid entree to space aimed at research and development along with operative missions such as earth observations, deep space and asteroid captures. Nevertheless, the market of components and hardware for small satellites, mainly CubeSats, still drops small of providing the essential capabilities required by continually growing mission tasks. Diverse CubeSat components are commercially available as off-the-shelf standard components delivered by a restricted quantity of suppliers. A way to overcome this issue is to improve the capacity to adapt each micro-satellite. With the adoption of advanced manufacturing (3D-printing) techniques such as additive manufacturing, some mission specific capabilities can be effortlessly fabricated into a system that commercial off-the-shelf components may not be able to provide, in terms of affordable optimized method.

- **Power Supply:** The electrical power system (EPS) consists of solar panels and batteries. Solar panels hold solar cells that convert the solar light from the sun into electricity. Having deployable panels adds solar cell area but also extra mechanical complexity. For the panels to deploy, they need a burn wire release mechanism.
- **Communication System:** CubeSats use radio-communication systems. The satellite uses an antenna, usually deployed once in orbit, to help with communication. Antennas range from commercial measuring tapes to more complicated inflatable dish antennas. A burn wire release mechanism can be employed to deploy antennas too
- **On-Board Computers OBCs:** This is the brain of the satellite, responsible for processing mission commands and coordinating all other subsystems, including the payload.
- **Attitude Determination and Control System:** The attitude determination and control system (ADCS) controls the orientation of the CubeSat concerning an inertial frame of reference and includes reaction wheels, magnetometers, thrusters, star trackers, sun and earth sensors, angular rate sensors, and GPS receivers and antennas

- **Payload:** Depending on the kind of mission, the CubeSat's payload or purpose can vary. The examples range from testing a flight control system to collecting data for some sort of biological experiment.

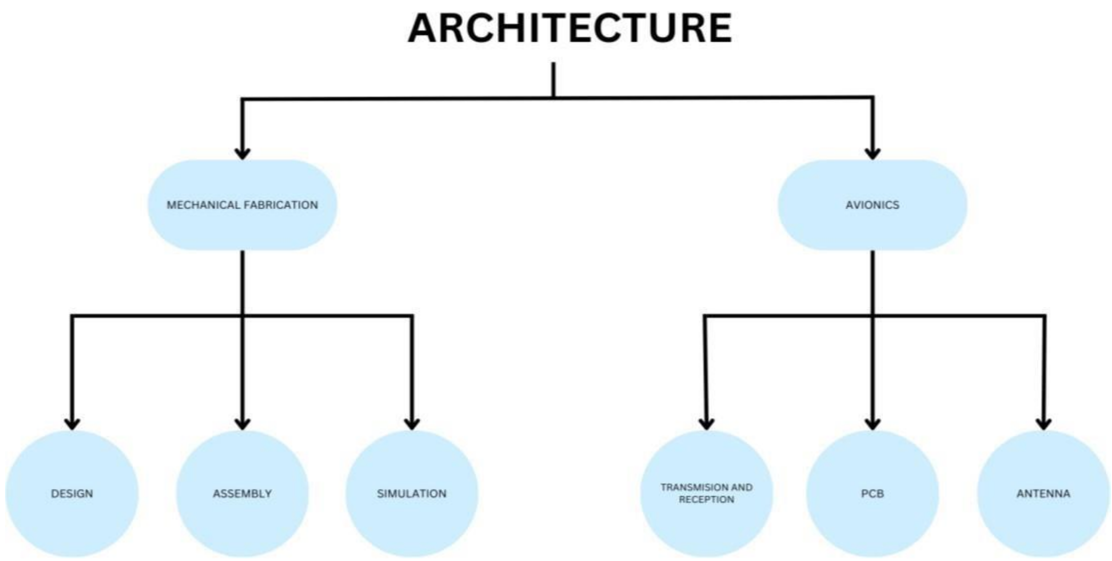
Thermal Control: To have the temperature of the CubeSat maintained to a set parameter and to detect and avoid temperature fluctuations, a thermal control system is required





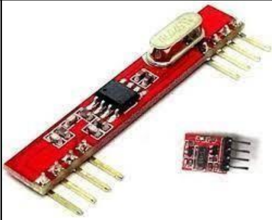
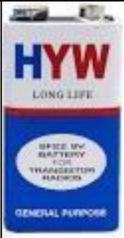
The structure of cubesat ESTCube-1

Architecture:-



List of Basic Components and Software Required Components:-

Component Name	**Component Image**	**Functioning**
Arduino uno		Microcontroller connected to receiver o the ground station
Arduino Nano		The Microcontroller connected to th transmitter in the satellite
MPU6050		3-Axis Gyroscope,3-Axis Acceleromete and Digital Motion processor; 1c com munication; -bit and 16-bit register ac cess modes
Transmitter		Transmitter is an electronic componer used for transmitting data from satellit to ground station. We used 433MH Transmitter in our CubeSat

Mofset		A three-terminal device having source gat and drain; controls the voltage an current the voltage and current flov between the source and drain termi- nal
434MHz Transmitter an Receiver		To Transmit data from the cube sat to th ground station
MINIATURE PUSH BUTTON		In our CubeSat we used 2 SPDT switches One for MOSFET and another fo switch- ing on and off of Arduino Nano
9V BATTERY		Used to supply power to Arduino Nano an other components
Lithium-iron battery		Lithium ion battery used to supply powe to mosfet for burning of steel wool wire

Softwares:-

- FUSION 360:-Fusion 360 is used for model designing and analysis of it.
- Eagle:- Eagle is used for making schematic diagram of PCB with connections of different compo- nent used in CubeSat.
- Arduino IDE:-Arduino IDE is used for coding the circuit used and how it will transfer data and re- ceive it at ground station
- CST STUDIO:- CST Studio is used for antenna designing and analysis of it. It is also used for calcu- lating range of Antennas.

2. Procedure:

UNDERSTANDING:

Finalizing the design

1) To design the 1U CubeSat structure under 0.25 Kg
2) To design the structure which is easy to assemble and integrate with other subsystems
3) To design an Antenna deployment mechanism
4) To perform simulations to test the structural integrity of the CubeSat

To build a CubeSat, the first step is to finalize the external design of the CubeSat. A design that fulfills all the requirements of the problem statement. Before finalizing the design, we came across many design ideas that were good but were not able to fulfill the requirements of the problem statement. We came across a total of eight designs, but only five were placed in the conceptual design stage. After the decided the cube sat design mechanical team design the design of the cube sat and design of pcb cad design and the electronics team work on avionics system for the cube sat. Now the complete the cube sat design and avionics work.

DESIGNING:

1. ELECTRONICS AND ELECTRICAL SYSTEM

1.1 The Power system for the Cube sats here is a 9 volt battery along with a lithium-ion battery connected to the MOFSET, which is further used to deploy the burn wire release mechanism for the unfolding antennas

1.2 Programme all Sensors and components by coding and testing them by Placing them on a temporary breadboard with a microcontroller, checking for different values.

1.3 Communication system;- Transmission and Reception: The Transmission from the antenna will take place through the onboard computers, a transmitter connected to a microcontroller(Arduino Nano). The Microcontroller extracts data from sensors and transmits it through an antenna. The ground System will use a receiver connected to an Arduino Uno Microcontroller to receive the information transmitted. The Componnet have been programmed as such

Arduino Nano Algorithmes:-

#include <Wire.h>
 	
#include <MPU6050_tockn.h> #include
<VirtualWire.h>
const int MOSFET_SWITCH = 12; const int tx =
2;
struct { int X; int Y; int Z;
} DATA;
 	
MPU6050 mpu6050(Wire);
void setup() { pinMode(4, OUTPUT);
	mpu6050.calcGyroOffsets(true);
	vw_set_tx_pin(tx);
	vw_setup(4000);
	
	}
	void loop() { mpu6050.update();
	Serial.print("angleX : ");
	
	DATA.X = mpu6050.getAngleX();
	Serial.println(DATA.X);
	Serial.print("angleY : ");
	
	DATA.Y = mpu6050.getAngleY();
	Serial.println(DATA.Y);
	Serial.print("angleZ : ");
	
	DATA.Z= mpu6050.getAngleZ();

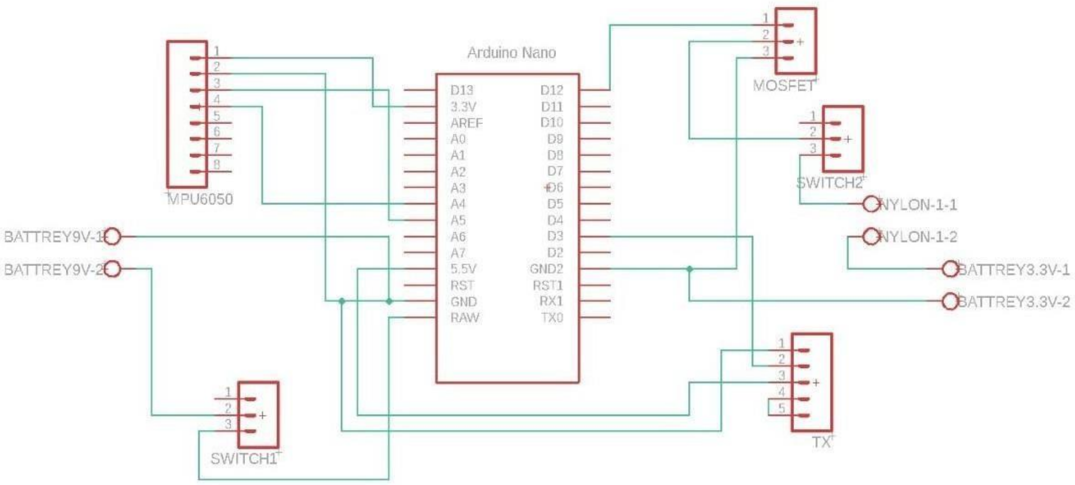
digitalWrite(4,LOW); delay(10000);
digitalWrite(4, HIGH); delay(500);
 	
digitalWrite(4, LOW); Serial.begin(9600);
Wire.begin();
mpu6050.begin();
	Serial.println(DATA.Z);
	
	vw_send((uint8_t*)&DATA, sizeof(DATA));
	vw_wait_tx();
	}

Arduino UNO:

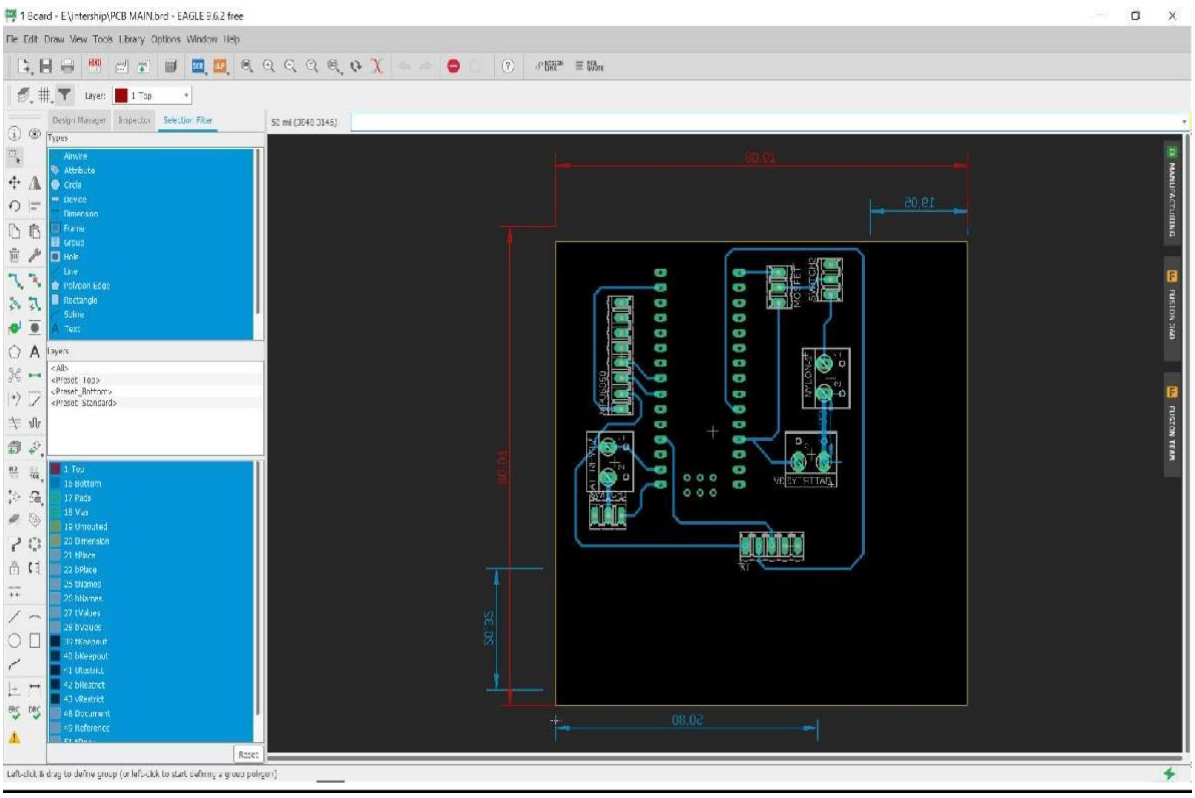
#include <VirtualWire.h> const int receive_pin=7
struct DATA{
int X; int Y; int Z;
};
 	
struct DATA *DataIn; void setup() { delay(1000);
Serial.begin(9600);
 	
Serial.println("setup");
 	
vw_set_rx_pin(receive_pin); vw_setup(4000);
vw_rx_start();
	Serial.print(' ');
	
	Serial.print("∠Y = ");
	
	Serial.print(DataIn->Y); Serial.print(",");
	Serial.print(' ');
	
	Serial.print("∠Z = ");
	
	Serial.print(DataIn->Z); Serial.println(" ");
	}
	
	}

}
void loop() {
 	
char buf[VW_MAX_MESSAGE_LEN];
 	
uint8_t buflen = VW_MAX_MESSAGE_LEN;
 	
if(vw_get_message(buf, &buflen))
 	
{
DataIn = (struct DATA*)buf;
 	
Serial.print("∠X = ");
Serial.print(DataIn->X);
Serial.print(",");	

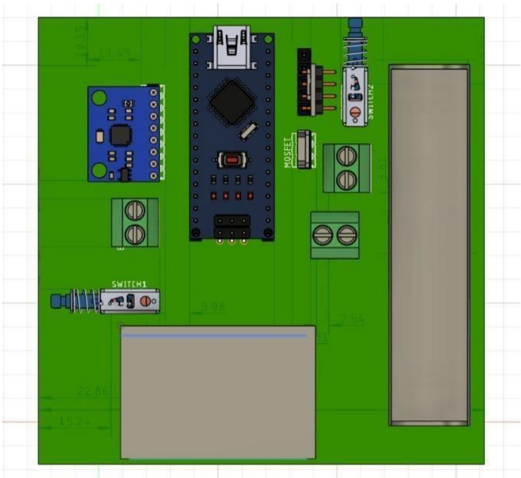
1.4 PCB:-The circuit has been made to occupancy all componenets while covering as little much area as possible, it comprise all the electricals components mentioned above. The schematics and cad models of the printed circuits board are:



Schematic View



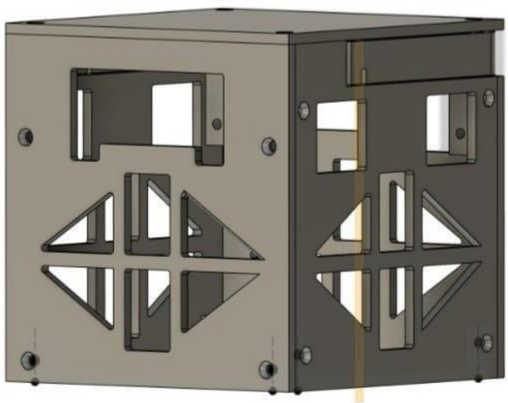
Board View



Cad design

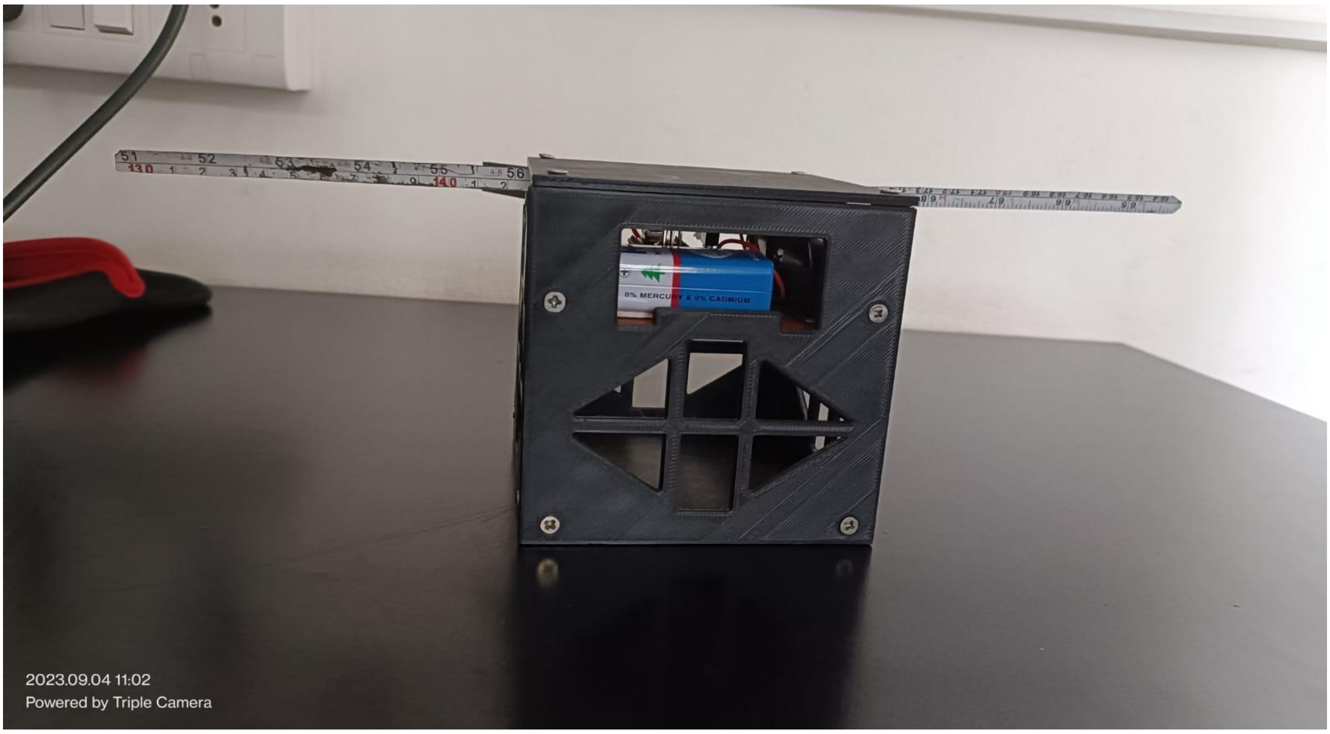
2. Mechanical Fabrication:

Designing cad models is the first step in the process of the mechanical fabrication. formulate the dimensions of each components, design, and apply constraints and force to check maximum the satellite can withstand.



After the assembly process create a motion study to get a brief idea about the motion; check for any interference.

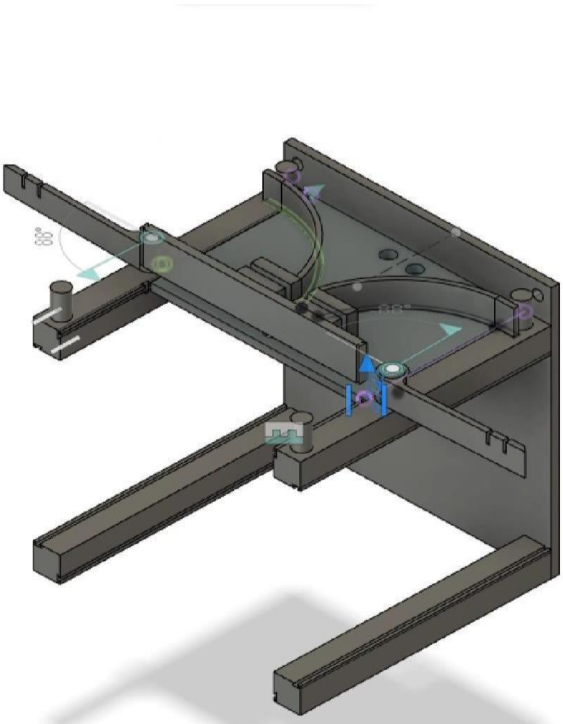
Now in accordance with pcb components, design the walls, the base, the lid. The following is the design and simulation for mission;



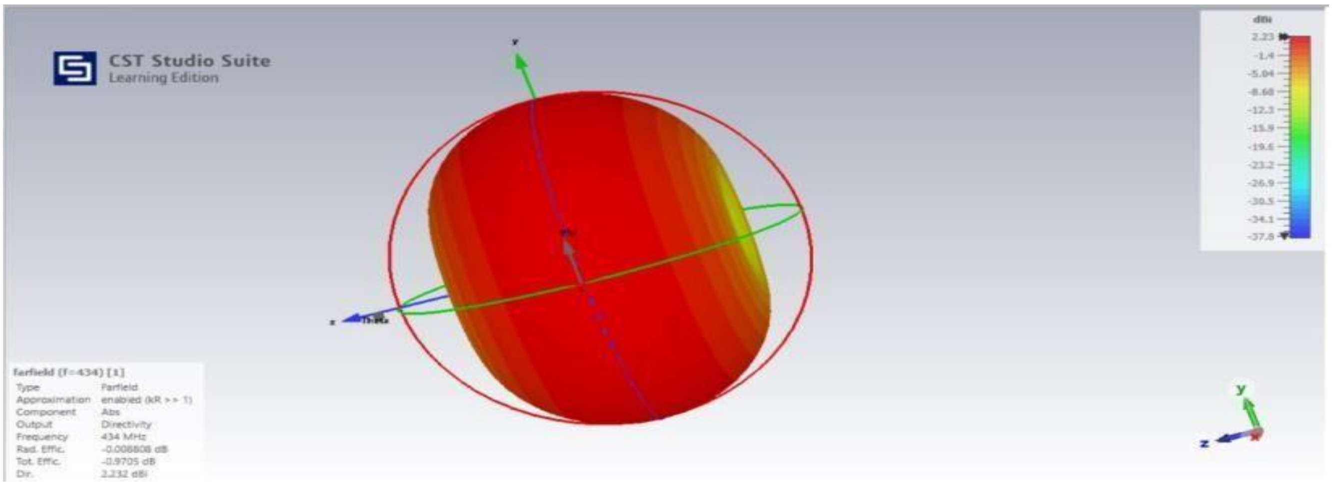
Now the final design of cube sat is printed in 3-D print. And after the printed the cubesat. And the avionics system place In 1u cube sat.

3. **AENTENNA DESIGN AND DEPLOYMENT**:

The antenna is tightly folded inside the door of the mechanism, and both doors are winded with the help of nylon wire, and a steel wool wire is winded to the nylon wire, so according to the Arduino nano code, when the mosfet switch is pressed after a delay of 10 seconds, the steel wool wire gets heated up, and due to this, the heat of the steel wool wire is transferred to the nylon wire, which breaks down, and the antenna which was tightly folded, gets deployed, and we start getting real-time data with the help of the transmitter, which is further received at the ground station.



Compute the length of the antenna with the given values and using the software cst Studio Suite simulate the signal waves.



CALCULATION AND DATA	
Frequency	433/434 MHz
C (speed of light)	299792458 m/s
Wavelength =speed of light/frequency	690.7660323 mm
Half Dipole =speed of light/frequency	345.3830161 mm
Length of Wire =Wavelength/4	172.6915081 mm
Radius of Wire =Wavelength/1000	0.6907660323 mm
Gap Length =Wavelength/400	1.726915081 mm
Range	640 m
Directivity	1.67

3. Observations:

Observation: The service module development occurred in several distinct phases:

1. Design Phase: We observed and participated in the design process, where detailed schematics and 3D models were created for the service module. This phase involved selecting components and ensuring compatibility with the Cube sat's payload.

2. Assembly Phase: During the assembly phase, we observed and actively contributed to the physical con- struction of the service module. This included soldering electronic components onto printed circuit boards (PCBs), integrating power distribution systems, and securing all components within the module.

3. Testing and Integration: Our observations extended to the testing and integration phase. We witnessed functional tests to ensure proper communication with the Cube sat's payload, power distribution checks, and thermal testing to verify the module's ability to withstand the harsh space environment.

4. Precautions:-

- Proper Safety should be taken while making of CubeSat.
- Proper handling should be done with all electrical components.
- While printing of PCB proper gear should be wore and toxic chemical should be handled with care.

5. Conclusion:

Have a solid theoretical background in all phenomena that occur in the mission and have identified all critical tradeoffs in the design.

Have finished designing all subsystems of the lU CubeSat- mechanical, electrical and software. After designing of various subsystems of lU CubeSat with our own circuit board design using Autodesk Eagle software, Fabrication of CubeSat using Autodesk Fusion 360 is completed successfully.

Algorithms of Arduino IDE have been implemented successfully for the sensors data analysis and have given positive outcomes. Prove, in first approach, Compliance to all requirements through Simulations using Fusion 360 simulation model

6. Refrences:

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