CANSAT 2022-23 CRITICAL DESIGN REVIEW (CDR)

TEAM ID: 2022ASI-002

TEAM NAME: ASTROPEEP

Astropeep

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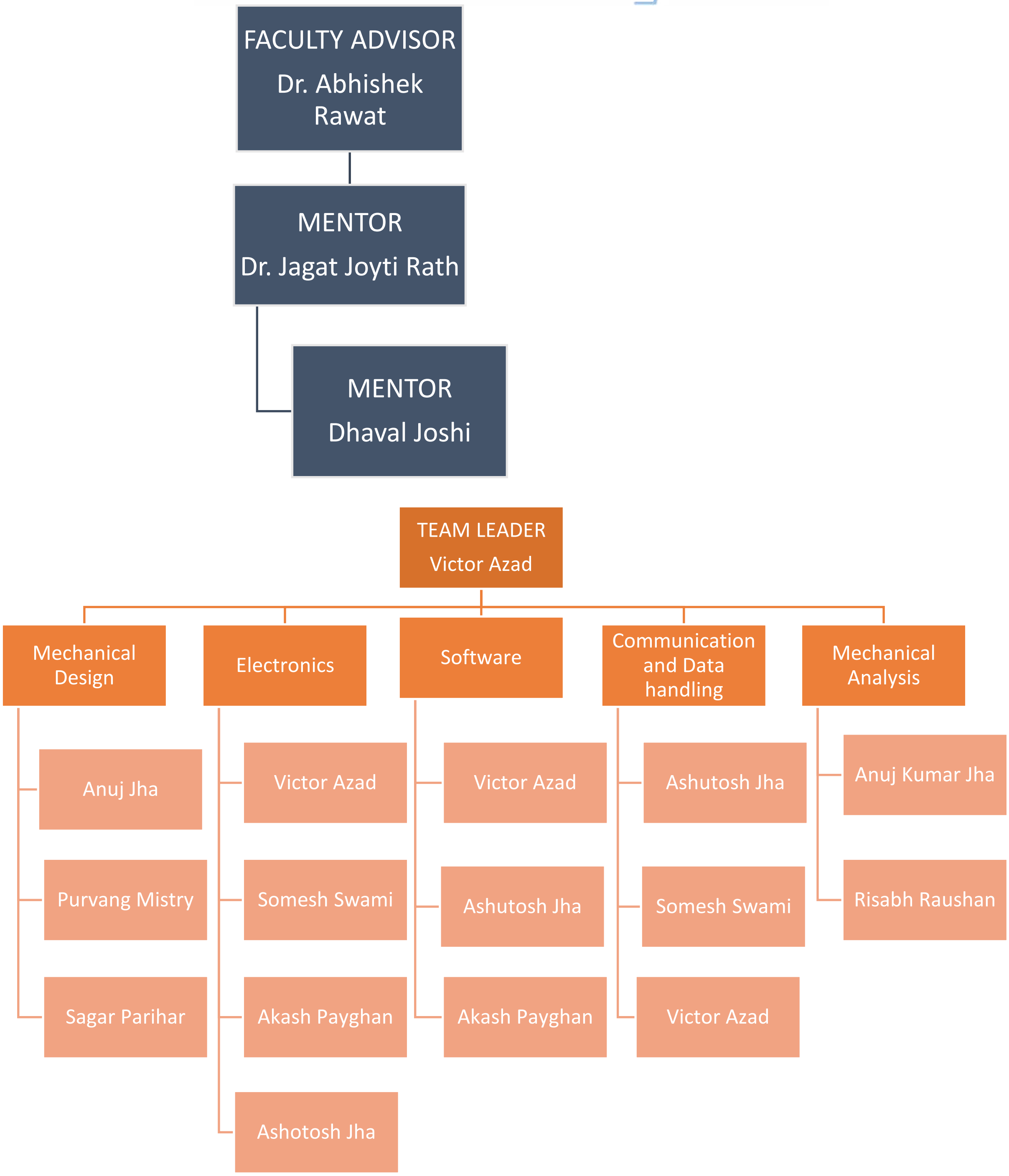
Team Description



Sponsorship to CANSAT

We as Team Astropeep have received the sponsorship from different organisation and institutions, in form of money and in the form of goods.

List of sponsors are as mentioned below:

1. *Institute of Infrastructure Technology Research and Management, Ahmedabad*
2. *Centre of Advanced Defence Technologies, IITRAM, Ahmedabad*
3. *Indian Studytech Services Pvt. Ltd., Dholpur, Rajasthan*
4. *Rudrabots Pvt. Ltd., Ahmedabad*

List of Acronyms

Acronyms	Meaning
3D	3-Dimensional
A	Analysis
cm	Centimeter
D	Demonstration
dB	Decibel
EPS	Electrical power Subsystem
FRR	Flight Readiness Review
FSW	Flight Software
GCS	Ground Control System
gm	Gram
GPS	Global Positioning System
GS	Ground Station
GUI	Graphical User Interface
Hz	Hertz

I	***Inspection***
I2C	***Inter-Integrated Circuit***
IC	***Integrated Circuits***
LED	***Light Emitting Diode***
PC	***Personal Computer***
QHA	***Quasi Harmonic Function***
RTC	***Real Time Clock***
T	***Test***
VM	***Verification Method***
GHz	***Giga Hertz***
s	***Second***
csv	***Comma separated values***
hrs	***Hours***
PCB	***Printed Circuit Board***
mAh	***Milli ampere hour***
m	***Meter***
V	***Volts***
FSS	***Flight Software State***

System Overview

MISSION SUMMARY

- ***Innovative Mechanical Gyro-control system that shall demonstrate the descent control of the CANSAT.***
- ***CANSAT descent control system that shall open at an altitude of 500 m.***

CANSATs will be launched to an altitude of 800.0 m to 900.0 m from the ground level and above the launch site & deployed near the peak altitude. During the ejection from the rocket orientation of the CANSAT is not controlled. The CANSAT must remain intact during the course of the entire mission and send the data to the ground station through a telemetry link.

Sr.no.	Requirement	Priority	Fulfillment	VM			
				A	I	T	D
1	Total mass of the CANSAT shall be under 0.700 kg (+/- 0.050 kg)	High	Mass of Cansat is within limits.	x			X
2	CANSAT shall fit in a cylindrical body of 0.125 m diameter x 0.310 m height. Tolerances are to be included to facilitate container deployment from the rocket fairing.	High	Cansat is designed with appropriate dimensions.	X			X
3	Any sharp edges on the container body shall be avoided as it can cause interfere during the CANSAT ejection from the rocket.	High	No sharp Edges are present.	X			X

4	*Color of the CANSAT body shall be fluorescent i.e., pink, red or orange, and shall embody the Indian flag.*	*High*	*Color will be fluorescent and will embody Indian Flag.*				*X*
5	*The CANSAT shall consist of necessary sensors to provide the following mandatory Real-time datasets: Position data, altitude, pressure, temperature, orientation data, power data & system status.*	*High*	*Cansat has necessary sensors required for measuring mandatory data.*	*X*			*X*
6	*Each data field shall be displayed in real-time on the ground station user interface/software.*	*High*	*GUI will be developed for displaying Data.*				
7	*CANSAT shall also record the data and save it into an onboard SD card in case of telemetry connection loss.*	*High*	*The data shall be recorded in SD Card.*				
8	*All electronics shall be enclosed and shielded from the environment. No electronics can be exposed except for sensors. There must be a structural enclosure.*	*High*	*No Electronics is exposed.*	*x*			*X*
9	*CANSAT structure shall be built to survive 15 Gs of launch acceleration & 30 Gs of shock.*	*High*	*CANSAT will survive required shock.*				*X*
10	*The CANSAT shall have an external power switch with an indicator light or sound for being turned on or off, in order to avoid the de-assembling of CANSATs on the launch pad.*	*High*	*CANSAT has an external power switch.*	*x*			*X*
11	*The CANSAT shall contain a total of 2 descent control mechanisms, to be used at different stages while descent.*	*High*	*has 2-descent control mechanism.*				*x*

12	***CANSAT shall immediately deploy the first parachute after ejection from the rocket.***	***High***	***1st parachute will be immediately deployed after ejection.***				***X***

Sensor Systems Summary and Test results

Selected Component	Type	Function	Interface
Adafruit BMP 280	*Pressure and temperature sensor*	*Measures air pressure and temperature both in the payload and the container*	*I2C*
Matek SAM M8Q	*GPS*	*Gets payload coordinates (latitude and longitude), GPS time, and GPS satellite*	*Serial*
Voltage divider	*Voltage Sensor*	*Measures voltage of the payload's battery*	*ADC*
MPU6050	*Acceleration and Orientation Sensor*	*Orientation and Acceleration Measurement*	*ADC*

Sensor	Model	Function
Altimeter Sensor	*BMP280*	*Altitude Measurement*
Air Pressure and Air Temperature Sensor	*BMP280*	*Pressure and Temperature Measurement*
Acceleration and Orientation Sensor	*MPU6050*	*Orientation and Acceleration Measurement*
GPS Receiver Sensor	*Matek SAM M8Q*	*Latitude, Longitude, Altitude, Time, Satellites number Measurement*

Voltage Sensor	***Voltage Divider , CPU's ADC Converter***	***Power Status***

Payload Air Pressure Sensor Summary (1 of 2)

Sensor-Adafruit BMP 280

Pressure Range (hPa)	*Operating Voltage (V)*	*Weight (g) / Dimension (mm)*	*Current Consumption (uA)*	*Resolution (Pa)*	*Accuracy (hPa)*	*Interface*	*Data Format*
300-1250	*1.65 – 3.6*	*1.2 21.6 x 16.6*	*2.7*	*0.016*	*±0.08*	*I2C, SPI*	*Float XXXXX. (Pa)*

Altitude above sea level can be calculated from Barometric Equation below. However, output from sensor is very noisy so that a kalman filter will be used to estimate the pressure value.

Barometric Equation

$$h = 44330 \times \left(1 - \left(\frac{P}{P_0}\right)^{\frac{1}{5.255}}\right)$$

h = calculated altitude [m]
P = sensed pressure [Pa]
Po = pressure at ground level [Pa]

Sample Output

```
pressure : 99697.86
pressure : 99698.62
pressure : 99701.95
pressure : 99699.18
pressure : 99698.55
pressure : 99698.00
```

Data Processing

```
bmp.performReading();
press = bmp.pressure;
readAlt = bmp.readAltitude(SEALEVELPRESSURE_HPA);

kalmanBarometer();

if (readAlt != 0 && millis() < 5000) {
  alt0 = readAlt;
}
if(readAlt<alt0){
  alt0=readAlt;
}
altitudeBMP = readAlt - alt0;
```

Kalman Filter

```
void kalmanBarometer() {
  baroKalman[0] = baroKalman[0] + baroKalman[1];
  baroKalman[3] = baroKalman[0] / (baroKalman[0] + baroKalman[2]);
  baroKalman[4] = baroKalman[4] + baroKalman[3] * (readAlt - baroKalman[4]);
  baroKalman[0] = (1 - baroKalman[3]) * baroKalman[0];
  readAlt = baroKalman[4];
}
```

Payload Air Pressure Sensor Summary (2 of 2)

Temperature data will be collected and processed with the help of

Sensor				Adafruit BMP 280			
Temperature Range (°C)	**Operating Voltage (V)**	**Weight (g) / Dimension (mm)**	**Current Consumption (uA)**	**Resolution (Pa)**	**Accuracy (hPa)**	**Interface**	**Data Format**
0 – 65	1.65 – 3.6	1.2 21.6 x 16.6	2,7	0.016	±0.08	I2C, SPI	Float XX.XX (C)

Adafruit_BMP3XX library. No further processing is needed as the reading is very stable.

Data Processing

```
bmp.begin();
bmp.setTemperatureOversampling(BMP3_OVERSAMPLING_2X);
bmp.setPressureOversampling(BMP3_OVERSAMPLING_32X);
bmp.setIIRFilterCoeff(BMP3_IIR_FILTER_DISABLE);
bmp.performReading();
```

Sample Output

```
temp : 27.53
temp : 27.54
temp : 27.56
temp : 27.65
temp : 27.65
temp : 27.65
```

GPS Sensor Summary

Sensor Matek SAM M8Q + Compass

Tracking Sensitivity (dBm)	Operating Voltage (V)	Weight (g) / Size (mm)	Current Consumption (mA)	Channel	Accuracy (m)	Interface	Update Rate (Hz)	Data Format
-165	4-6	7 20 x 20 x 10	29	72	~2.5	UART	18	Float and Integer

Longitude, latitude, and the other data will be collected and processed with the help of Tiny GPS Plus library by Mikal Hart. This sensor can lock onto GPS satellite quickly.

Data Processing

```
while (gpsSerial.available() > 0) {
  if (gps.encode(gpsSerial.read())) {
    if (gps.location.isValid()) {
      latitude = gps.location.lat();
      longitude = gps.location.lng();
      altitudeGPS = gps.altitude.meters();
    }
    if (gps.time.isValid()) {
      jam = gps.time.hour();
      menit = gps.time.minute();
      detik = gps.time.second();
    }
    satellite = gps.satellites.value();
  }
}
```

Sample Output

```
14,12,13,-7.7711291,110.3733215,144.3,7.00
14,12,14,-7.7711148,110.3732986,141.3,9.00
14,12,15,-7.7710929,110.3733139,142.7,10.00
14,12,16,-7.7711000,110.3733139,138.9,10.00
14,12,17,-7.7711000,110.3733139,138.9,10.00
14,12,18,-7.7711091,110.3733063,145.7,11.00
14,12,18,-7.7711091,110.3733063,145.7,11.00
```

Left to right:
Hour, minute, second, latitude, longitude, altitude, satellite

Source:
https://github.com/mikalhart/TinyGPSPlus/blob/master/src/TinyGPS%2B%2B.h

Payload Voltage Sensor Summary

Name	Range (V)	Error rate (%)	Interface	Data Format
Processor Analog Pin (Voltage Divider)	0 - 5	0.03	ADC	Float X.XX (Volt)

Battery voltage is measured using the ADC port trough a voltage divider, the following resistors are used in the circuit.

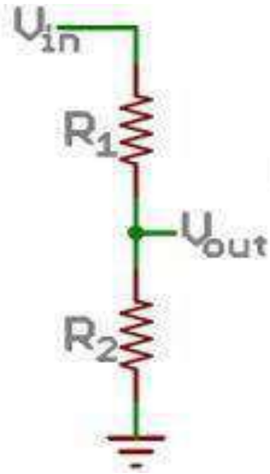
R1 = 1 MΩ

R2 = 100 kΩ

The ATSAMD Processor ADC has maximum resolution of 32-bit with 3.3 volt analog reference, but the resolution used is 16-bit resolution. So, the maximum accuracy of this on board voltage sensor is 50 uV..

Data Processing

```
static int R1 = 1000000; //1M ohm
static int R2 = 100000; // 100k ohm
analogReadResolution(16);
rawVoltage = (analogRead(voltagePin) * 3.3) / 65535.0;
teganganBaterai = rawVoltage * (R1 + R2) / R2;
```



Sample Output

```
batt : 3.99
batt : 3.99
batt : 3.99
batt : 3.99
batt : 3.99
batt : 3.99
batt : 3.99
batt : 3.99
```

Gyroscope Sensor Selection Summary :

Sensor	Range (°/s)	Resolution (bit)	Accuracy (°/s)	Data Interface	Operating Voltage (V)	Cost (Rs.)	Dimension (mm)	Weight (gm)
MPU6050	±250	16	1.9	I2C/IIC	3-5	120	4 X 4 X 0.9	3

Reason for selecting MPU6050 :

- Light weight, small size and Low Cost.
- Using same sensor for acceleration and orientation measurement will reduce the cost and weight of Cansat.

Innovative Materials Selection:

Material Proposed as in PDR:

As in Preliminary Design Report (PDR) of our CANSAT had:

Serial No.	Component	Previous Material	Modified material
1.	Outer Body Panels	ABS Polycarbonate Sheets	ABS Polycarbonate Sheets
2.	Vertical Rods	2024 T3 Al Alloy	CFRP Z-100
3.	Horizontal Bases	2024 T3 Al Alloy	CFRP Z-100
4.	Circular Support Rings	--	CFRP Z-100
5.	Top Lid	Polyethene Film	Polyethene Film
6.	Parachute & Chords	Ripstop Nylon	Ripstop Nylon

Reason to Change Materials:

- The change in the material of the structure including the Vertical Rods, Horizontal bases and the circular ring support were previously proposed as to be made up of 2024 T3 Al Alloy which is replaced by Carbon Fiber Reinforced Plastic (CFRP) because of the following reasons:

1. **Stress-Strain Curve:**
   Lower yield point of the Aluminium in general which would have led to the increase in the deformation as compared to that of the CFRP. Also the ductility as a property in not needed for our use.

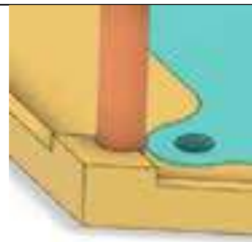
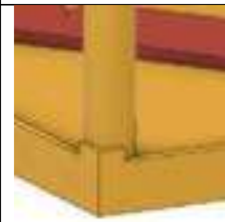
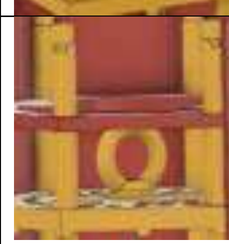
2. **Availability:**
   Market availability of the Aluminium and it's alloy is very rare due to the import and export restrictions and also due to the scarcity in the global market and so is not the case with the CFRP Z-100 as the spools, sheets, rods, and plates all are available in the local market.

3. **Economics:**
   The cost of Aluminum is too high and cannot fit in the budget constrain of CANSAT whereas cost of CFRP is relatively lower than 2024 T3 Al Alloy.

Material Acquisition:

- Material for prototype testing was received in early January 2023 but it was sample piece used to validate our own mathematical model as computed.
- Material to be used in the fabrication of the main structure have been ordered and are in process.
- We have received all our electronical components as ordered for the testing and analysis purposes.

Changes in Mechanical Design Dimensions

Changes Made	Previous Dimensions	Previous	New Dimensions	New
Increased Rod Diameter in Battery and Gyro Compartment	5 mm		7 mm	
Increased thickness of Base Plate and Parachute 2 Base Plate	2 mm		5 mm	
Increased Parachute 1 Base Plate thickness	2 mm		7 mm	
Added a support Plate to increase strength in Parachute 2 Container	0 mm		5 mm	
Added a hook to grab parachute	-		-	

PHYSICAL LAYOUT:

Fig. Home View For CANSAT

Fig. Home View of CANSAT without body panels

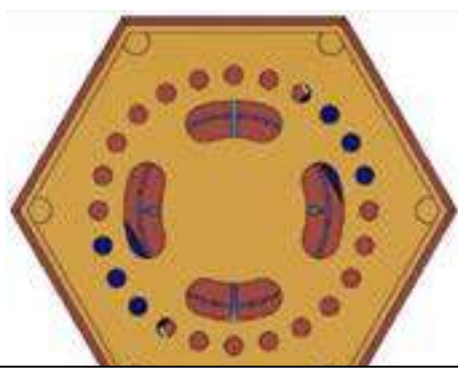


Fig. Top View of CANSAT

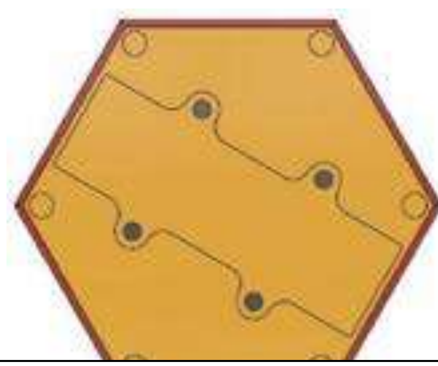


Fig. Bottom View of CANSAT

DAMPING

To deal with the vibration and shock due to thrust of launching vehicle. We have planned of adding up foam and carbon fiber shock dampers to the PCB plates, servo housing, battery setup, camera module and buzzer module.

All the components are a vital part of the CANSAT and for the proper data acquisition all of the components has to be damped against vibration.

Types of Damping Used:

- Shock Absorber for the PCB and Battery plates:

- Shock Absorbing Foam Padding being used for servo motors used for ejection mechanism and gyroscope control:

- Rubber Shock Absorber are being used for the screws which are being used to

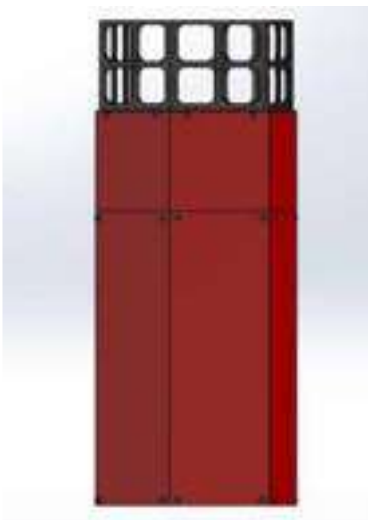
mount the Outer Body Panel on the CANSAT Frame:

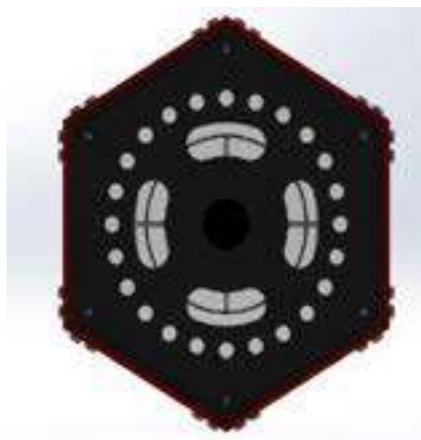
SYSTEM CONFIGURATION CONCEPTS:

Selected Design Concept of PDR:

As proposed in the **Preliminary Design Review (PDR)** round held in the September 2022. We have the following design concept proposed:

Fig. Concept 1 Design Proposed





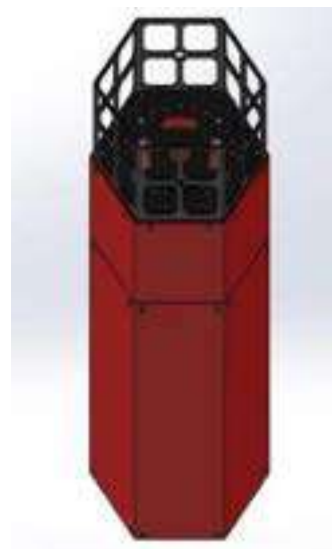


Fig. Concept 1 Design Dimensions

Design Analysis:

All the below mentioned results were analyzed to simulate the

- Total Deformation:

  This is to check deformation along the yaw, pitch & roll caused due to the axial loadings.

- Equivalent stress:

  According to the Von-mises Theory, the Equivalent Stress or Von-mises Stress, is most used criteria for checking yield conditions for any structure.

- Stress Intensity:

  This is to check the magnitude of the stress generated in a particular component in the CANSAT.

- Shear Stress:

  It is the stress generated at the edge of the structure of CANSAT parallel to the vertical axis i.e. the roll axis of the CANSAT.

CANSAT PDR Proposed Design:-

This is the structure considered for the design analysis of the CANSAT which includes the vertical solid rods and hexagonal plates which all are in a single piece as they are 3-D printed using the Carbon Fibre Spool with a re-inforced packing.

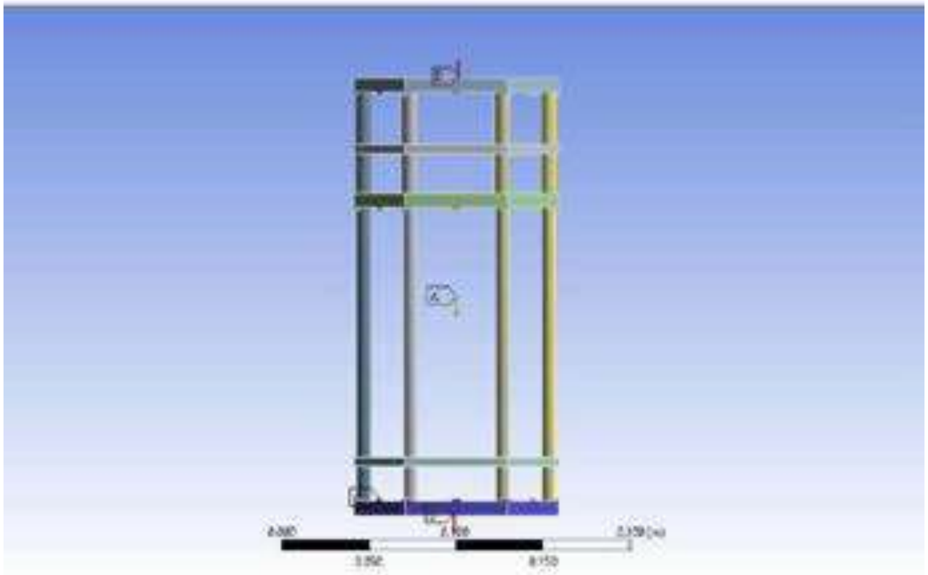
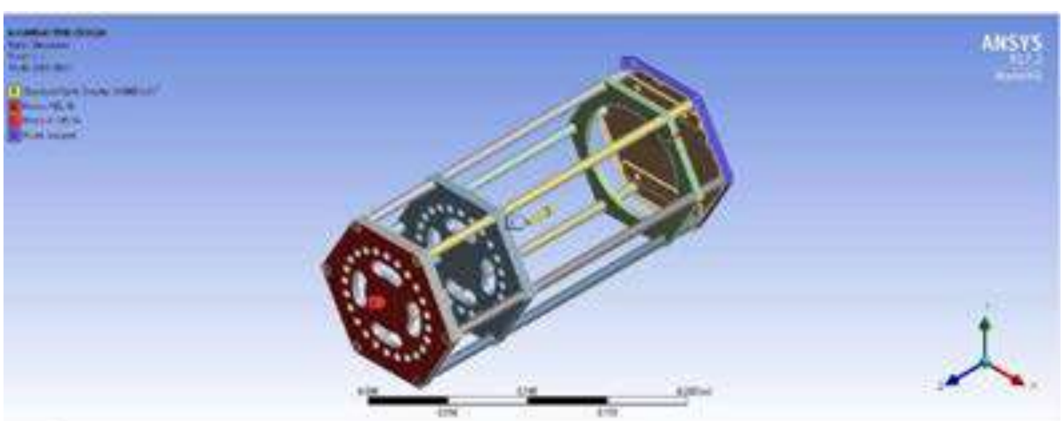


Fig. Structure considered for the analysis.

The meshing for the structure is considered of 0.0008 m (meters) with a Path Conforming Tetrahedron mesh elements. The mesh wash fully programme controlled.

The forces are assumed to act in the center of top and bottom plates as the there is a hook in the center of the Top Plate for tying the Parachute Chords to it. Also, we have considered the force due to acceleration of gravity at the center of the CANSAT.



For the same meshed structure, the solution goes as follows:

1. Total Deformation:

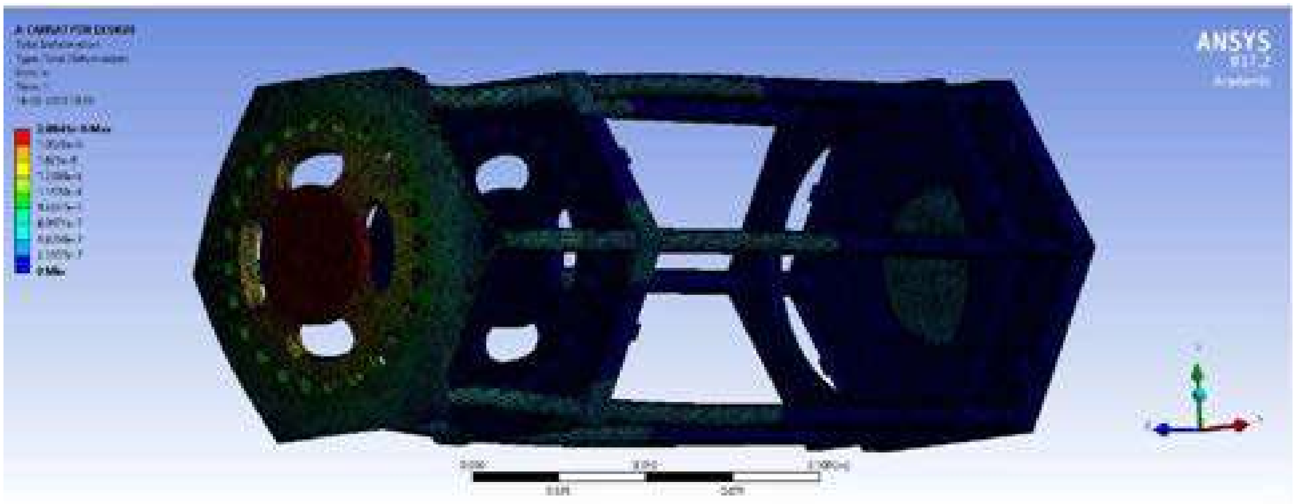


Fig. Total Deformation/Distortion in the CANSAT

2. Equivalent Stress:

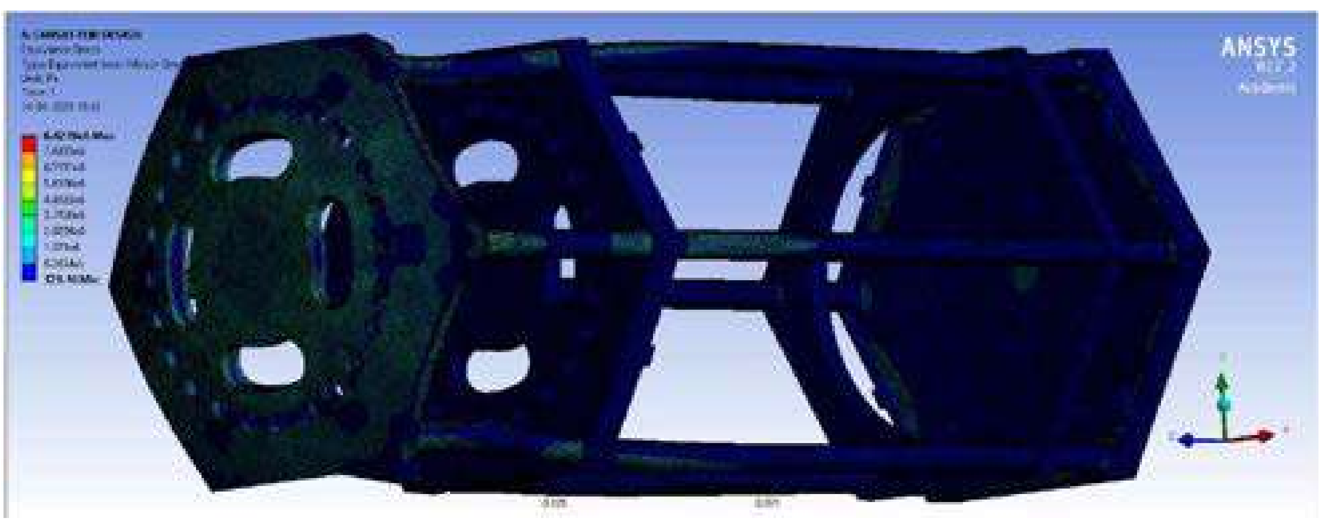


Fig. Window Showing Equivalent Stress in

3. Stress Intensity:

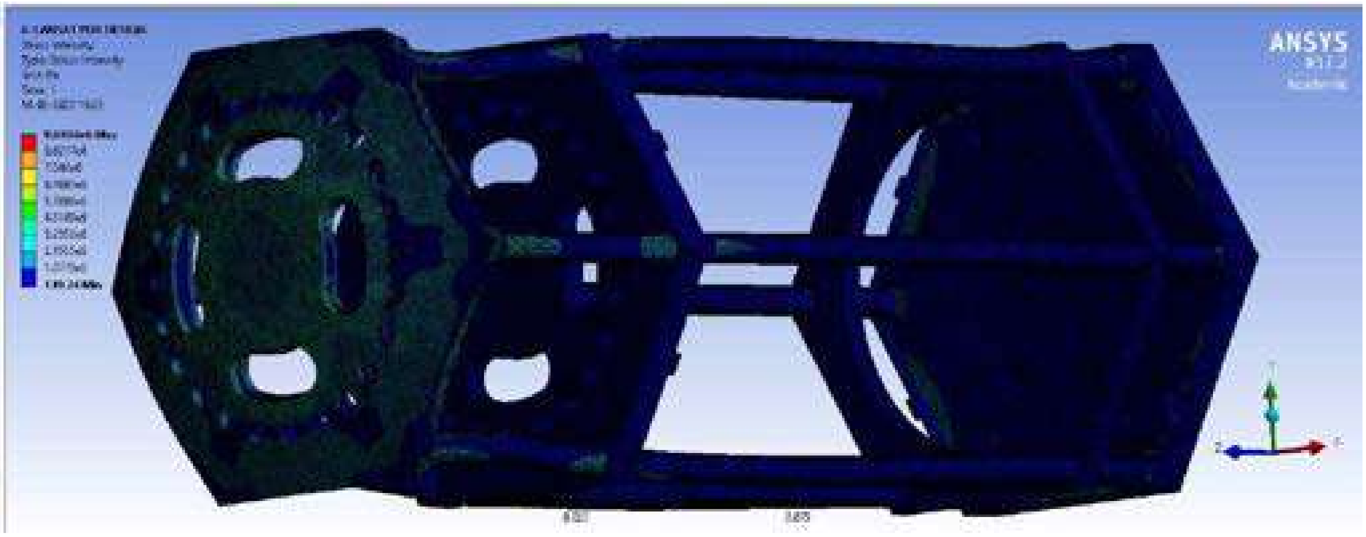


Fig. Stress Intensity in different components of CANSAT

4. Shear Stress:

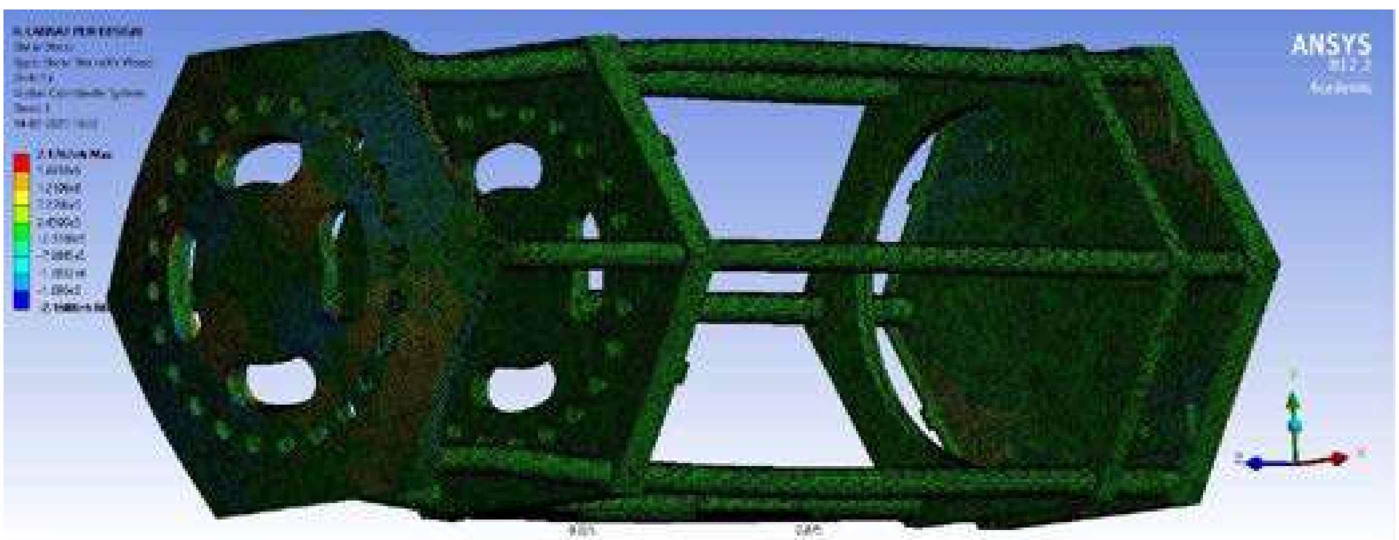


Fig. Shear Stress generated in the CANSAT.

As it can be seen, the structure has failed the loading of 265 N i.e. the value for 30g's of launch force and considering the safety and multiplying this by the safety factor of 1.5.

Observation:

Looking to the simulation results achieved and as discussed about the change in the material, we have found out that the structure fails if constructed out of normal **Carbon Fiber** spool with this amount of loading.

Conclusion:

To avoid any such failure during the launch or ascent we then decided to go with the **Carbon Fiber Reinforced Polymer.** And adding up a extra horizontal support to the structure and replacing the hollow hexagonal faced pipes with the solid circular faced rods.

Solution Derived:

For the same three different design versions were prepared and analyzed. The changes to the CANSAT were as follows:

1. Increasing the Diameter of the Vertical Rods
2. Adding Up a circular ring to the compartment deforming
3. Increased Diameter of rods with a circular ring added to the deforming compartment.

Out of all these the 3rd design alteration gave us the best possible results which is as follows:

CANSAT Improved Design & Analysis:

The design proposed after the alteration is as follows:

The solution to the analysis with the same constraint as of the previous one is as follows:

1. Total Deformation: (Negligible Distortion was observed)

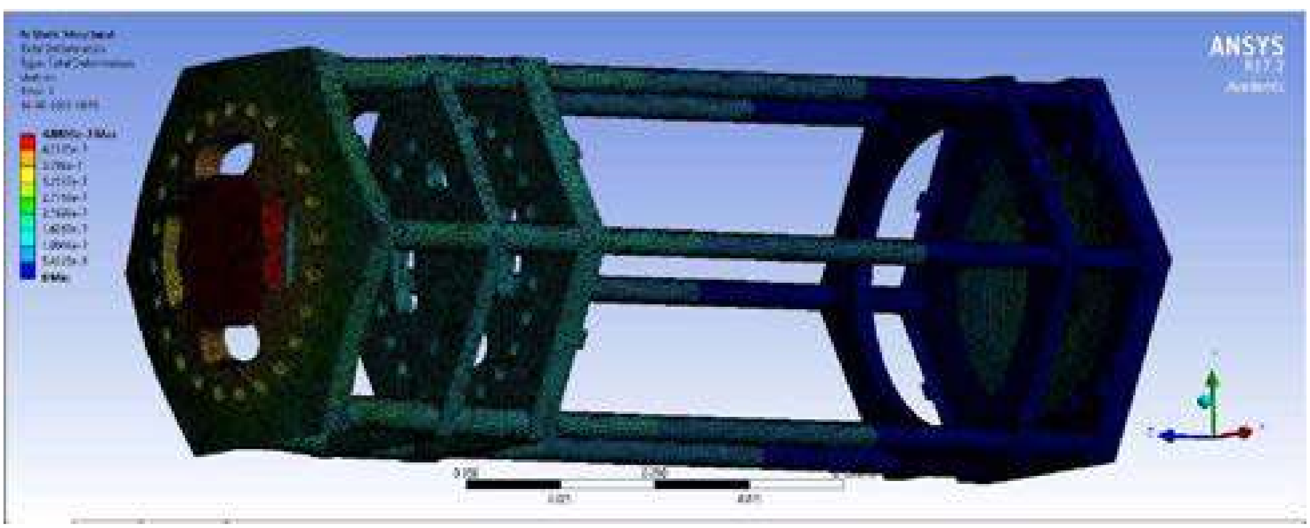


Fig. No / Negligible Deformation Observed

2. Equivalent Stress:

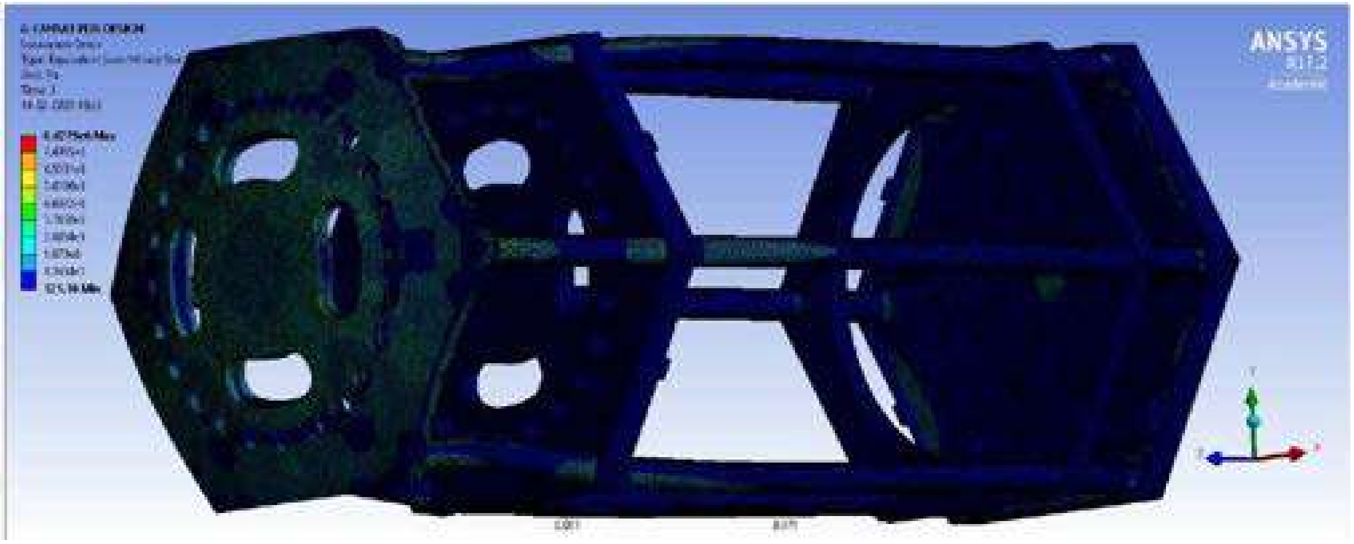


Fig. Reduction In the Equivalent(Von-Mises) Stress of the CANSAT

3. Stress Intensity:

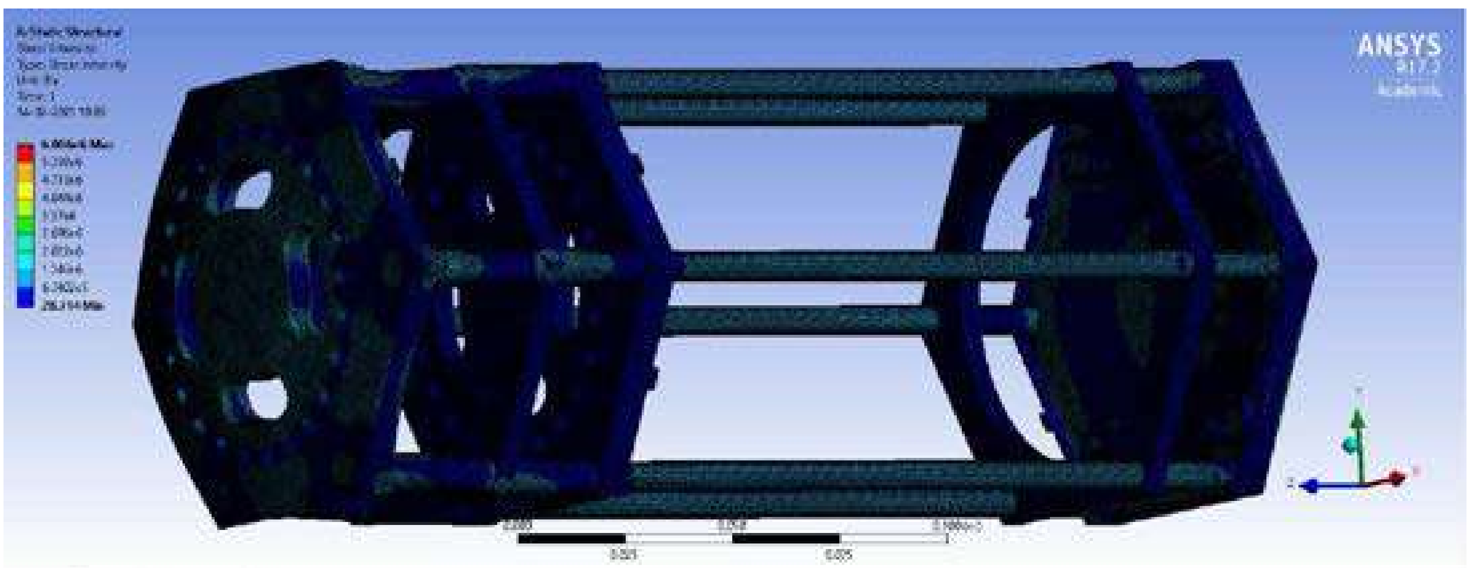


Fig. Reduction in the Stress Intensity generated in the components.

4. Shear Stress:

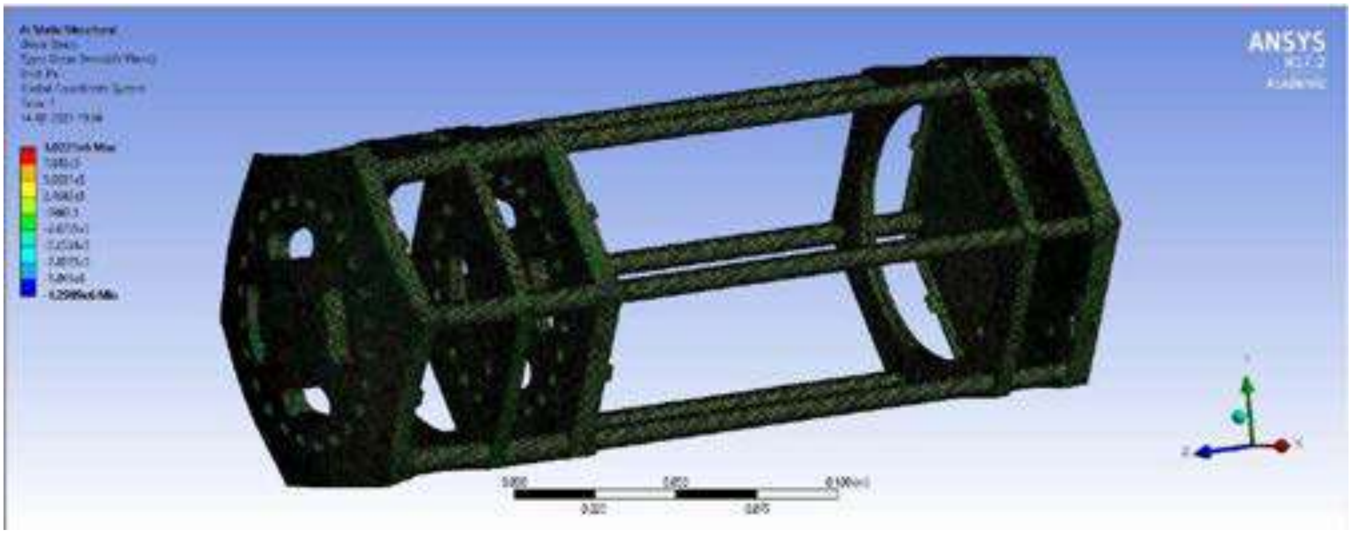


Fig. Decrement in the Shear Stresses around the CANSAT

Conclusion:

Looking to the results observed we hereby consider this particular design of structure of CANSAT to be the best fitted for our purpose.

POWER BUDGET:

We use a double cell Lithium-Ion battery to power the main system. The battery has a nominal voltage of 9v and maximum capacity of 600mAh each. Allows up to 2 hours of duration of operation. The Battery is lightweight and compact. Well known battery manufacturer.

Component	Power Consumption (Wh)
CPU (ATmega328)	0.238
Pressure Sensor (BMP 280)	0.007392
Acceleration and Gyro Sensor (MPU6050)	0.02574
GPS Module	0.792
XBEE	0.726
Servo Motor (Mechanical Gyro Control)	3.32
Servo Motor (Parachute Ejection)(x2)	12.24
Buzzer	0.792

In the above Budget Power Consumption is calculated for a period of 2 hrs on assumption that CanSat may be turned on for 2h, while the actual flight time might be less than that.

Total Power Drained from the Battery for 2 hrs operation = 5.369772 Wh.

Changes Made After PDR:

Battery configuration used to power our CANSAT has been changed from Series to 'Parallel'. This enables us for proper stepping down of voltage according to the requirements using the voltage divider system.

MASS BUDGET:

Method of correction:

In case any error occurs the lower part will be equipped with extra space for increasing weight with screws and nuts. Initially it will include 6 screws that can be detached if the structure is too heavy.

Margin = 500 – 497.1 = 2.9g

Part	Mass Contributed (in g)
PC ABS Panels	43.79 ± 0.2
Aluminium Rods	61.33 ± 0.2
Base Plate	22 ± 0.2
Parachute 1 CF Container	54.84 ± 0.2
Parachutes	90 ± 0.2
Shackle	10 ± 0.2
Carbon Fiber tube	30.28 ± 0.2
Dampers and Foam	30 ± 0.5
Screws, Washers and nuts	20.25 ± 0.2
Servos	27 ± 0.2
Other 3-D printed parts	20 ± 0.2
PCB 1	75 ± 0.5
Camera	20 ± 0.2
PCB 2	40 ± 0.5
Gyroscope	22 ± 0.2
Wiring	25 ± 0.5
Batteries	105 ± 0.2

TOTAL MASS = 696.49 ± 4.6 g = 701.09 g

ALLOWED LIMIT = 700 ± 50 g = 750 g

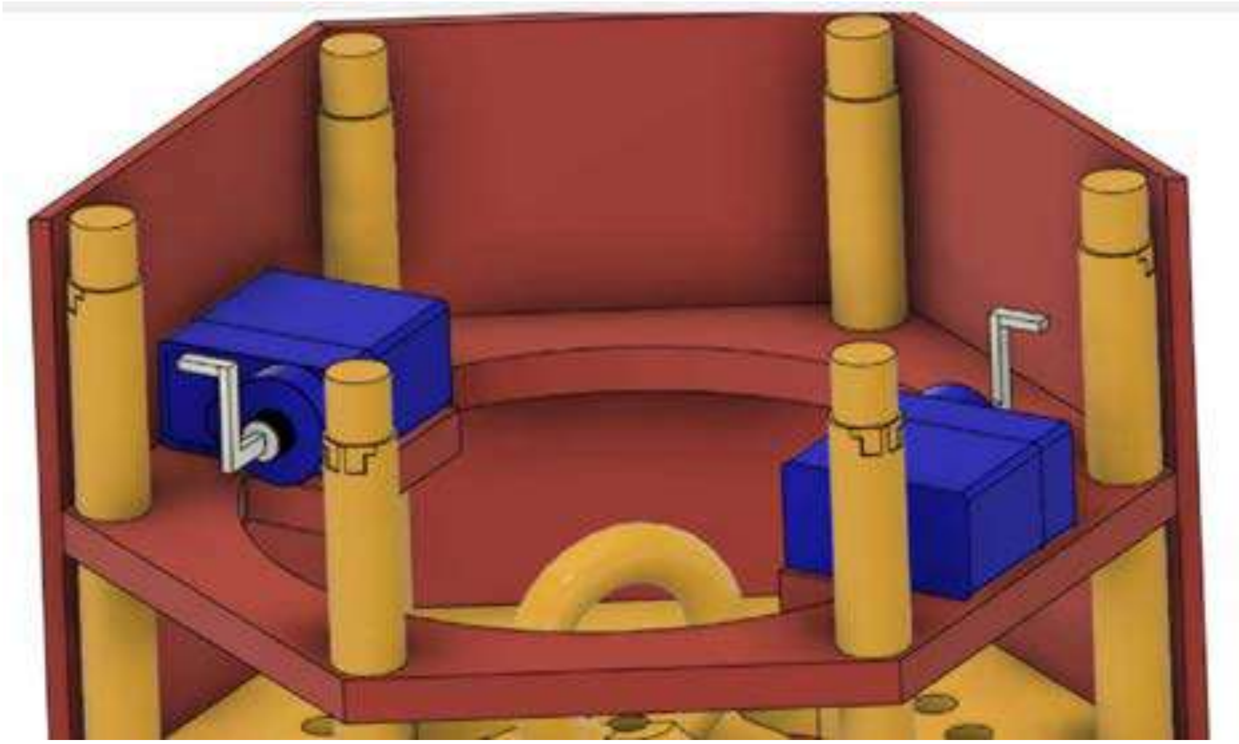
Changes Made After PDR:

Minor revisions were made in the mass calculations.

Actuator Design:

As proposed in the previous design concept of PDR we were having a setup of Pogo Pins to release the Parachute 2 after achieving a height of 500m. But due to guidelines and mission requirements prohibiting the usage of spring in the CANSAT, we decided to find a substitute parachute deployment system.

After further consideration we are using the following configuration, pair of servo motors



and actuators system.

Fig. Placement and Alignment of Servo Motors Acting as the driving element of Actuator Design of Ejection Mechanism

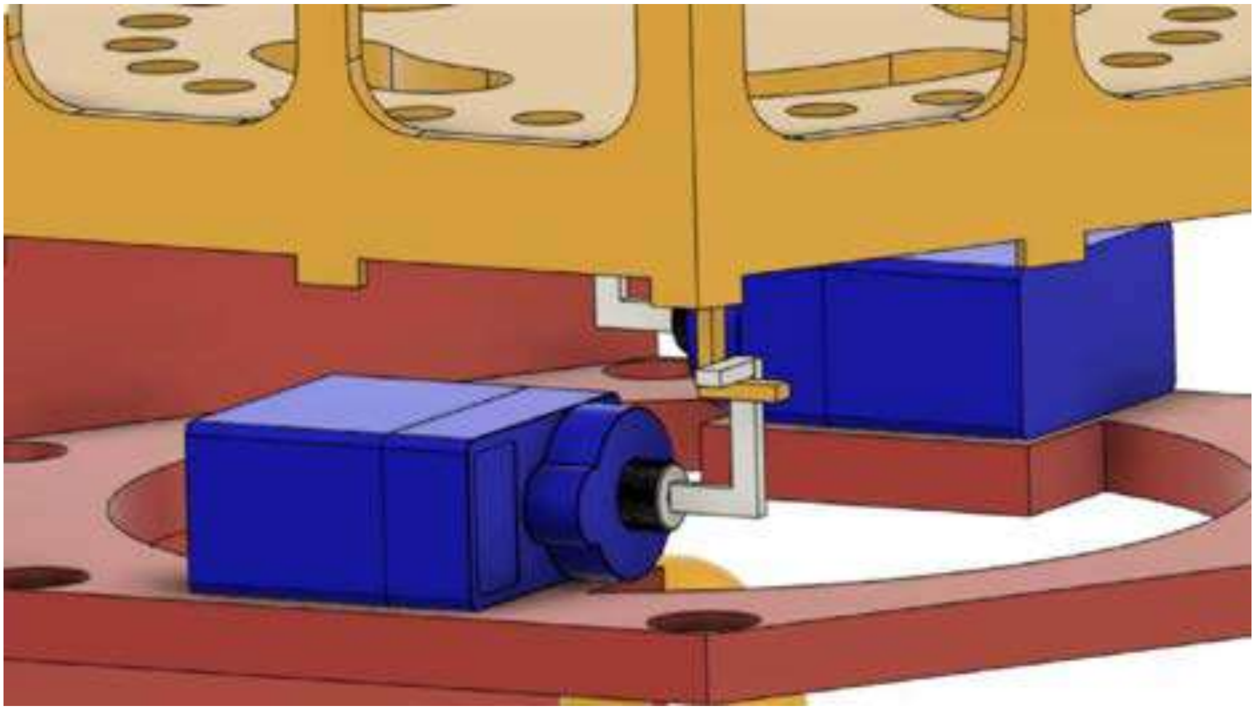
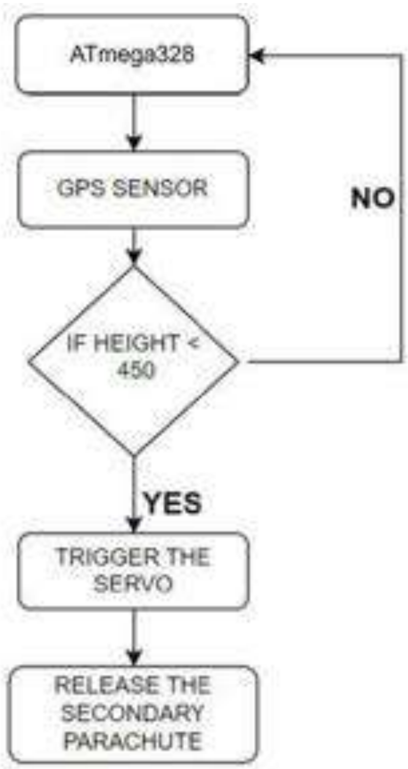


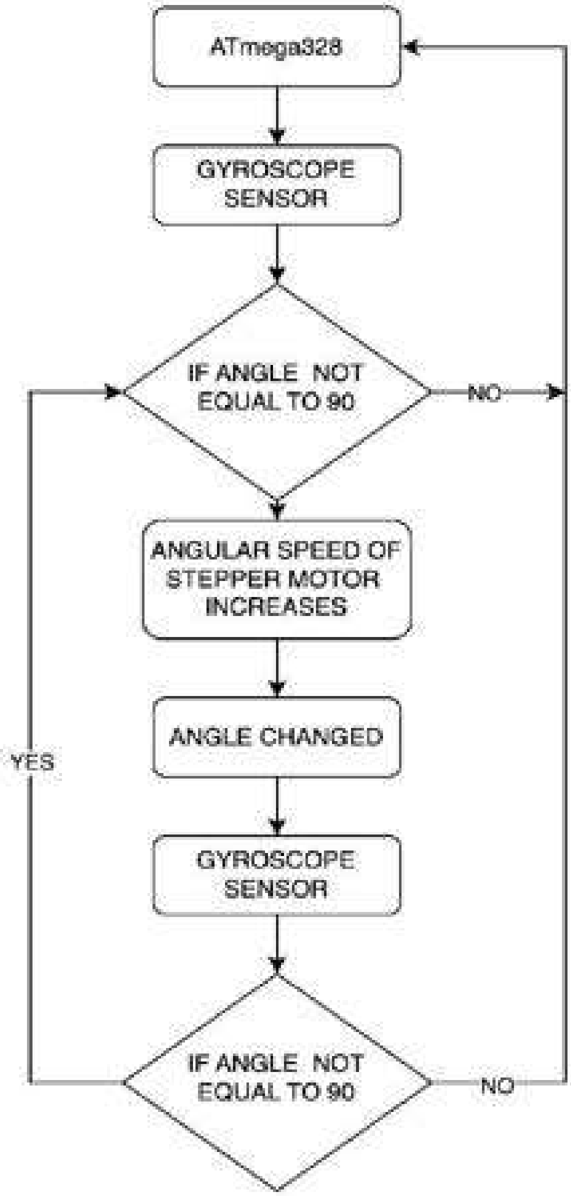
Fig2. Servo-actuator is holding the parachute 1 base plate until reaching 500m.

Block diagram for working of actuator system for parachute deployment,



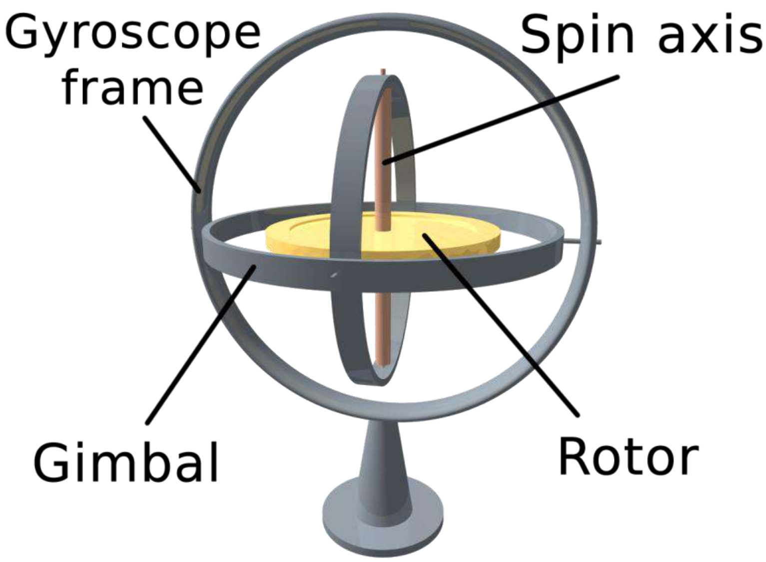
GPS sensor with the help of ATmega328 detect the position of our CANSAT from ground. When the height of our CANSAT goes below 450m, it triggers our servo motors and thus unlocked the upper chamber of our CANSAT, releasing the secondary parachute.

CONTROL MECHANISM OF GYROSCOPE



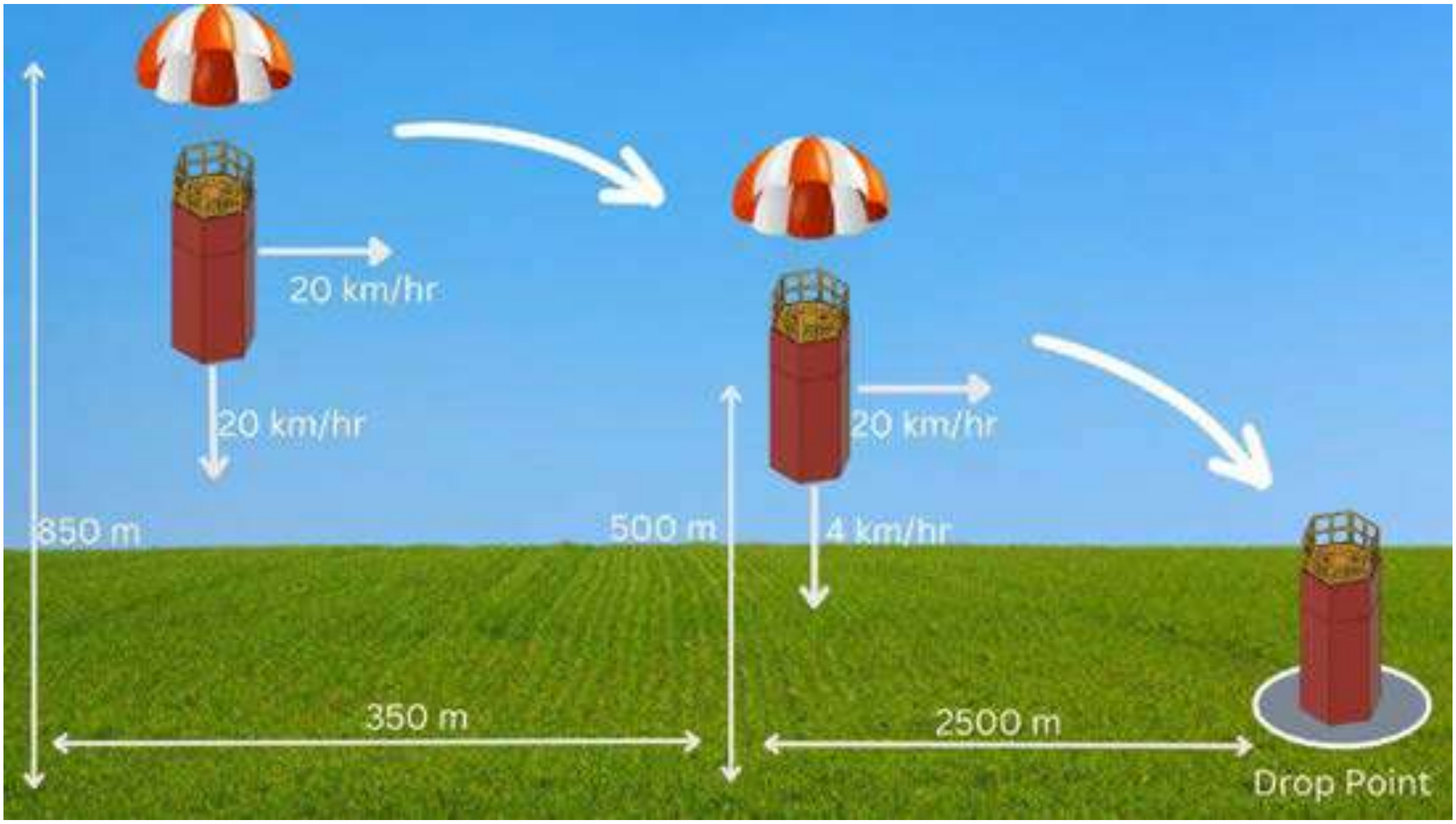
With the help of ATMEGA-328, gyroscope sensor detect the orientation of our CANSAT. If the angle detected by gyroscopic sensor is not equal to 90° i.e., our CANSAT is not perfectly straight then the angular speed of stepper motor attached to our gyroscope increases and thus our gyroscope applied force on the CANSAT to make it perpendicular. The angular speed increases uptill the CANSAT is not aligned perpendicularly.

Once our CANSAT is aligned perpendicularly the angular speed of stepper motor remains constant. Whenever an external force is applied to our CANSAT, accordingly the speed of stepper motor increases or decreases in order to align our CANSAT 90°.



SUMMARY OF TRAJECTORY CONTROL:

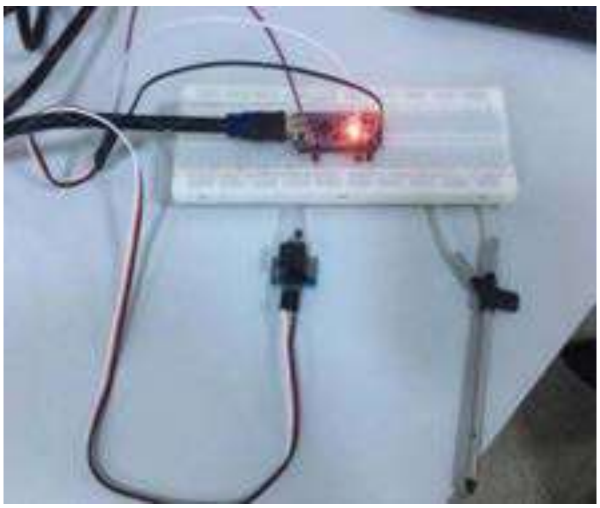
1. The average wind speed of DHOLERA is thy month of June is 20km/hr. that's why we consider the horizontal velocity of our CANSAT is to be 20km/hr.
2. In the first line of decent i.e. from 850 m to 500 m the vertical velocity of CANSAT is 20km/hr. Thus during this period of time our CANSAT travels the horizontal distance of 350 m.
3. In the second line of our decent i.e. from 500m to ground our CANSAT travels the speed of 4km/hr. thus the horizontal distance travel by our CANSAT is 2500 m
4. Thus when combining the horizontal distance travelled in the first as well as second line of decent is 2500m plus 350m is equal to 2850m i.e. 2.85 km
5. Thus we know how far our CANSAT can reach from our ground station, thus we know that we have to design antenna with the range of 3-4 km, so that we can communicate with our CANSAT when it reach to ground.



DESIGN OF PARACHUTE:

SENSORS TESTING PROCEDURE & SUMMARY

- Each of the sensors was tested on the breadboard with the use of the required software and the microcontroller. The accuracy of the data obtained from each sensor was checked.
- Then the sensor tests were carried out in a combined manner.

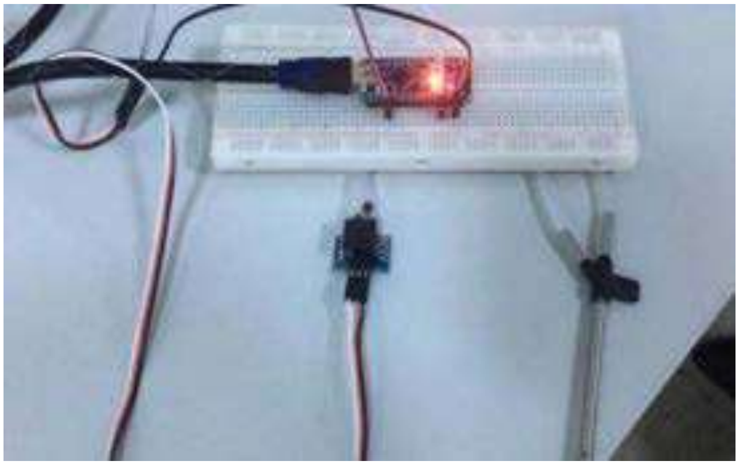


CDH

- The communication between the microcontroller and the sensors was tested.
- The communication between the receiver and transmitter XBee were tested using the XCTU Software for the competition distance requirements (600-800 meters).
- The gain test of the antenna was tested using the XCTU Software.
- The data transmission altitude requirement (750 meters) in competition will be tested via drone. Then, the data transmission speed and the accuracy of the data sent to the ground station will be checked.

EPS

Prototype circuit was installed on the perforated plate and breadboard. It was checked if it works with the required power supply.
The total current of the system was measured. Calculated and measured values were compared.
The melt of fishline circuit was installed and the break time of the melt was measured.
The MOSFET used in circuit was triggered with 3.3V to check its operation.
It will be checked whether there is a short circuit on the PCB.



Caption

Radio Communication

- The XBees setting was done over XCTU software. NETID/PANID and baud rate accuracy was checked.
- The XBee communicates in unicast mode. XBees do not broadcast, the XBees only communicate with each other.
- Data received from the sensors on the circuit will be transmitted to the ground station via XBee. The data will be checked from the ground station interface.
- The sufficiency of the computer battery was tested for 2 hours.
- We continue the tests as we have started at the PDR stage.

MECHANICAL

- Delta wing folding mechanism was tested (hinge, rotating joint, stretched fabric elastic and telescopic system).
- The sufficiency of the delta wings for descenting was tested at different altitudes.
- The CanSat's mechanical tests will be checked (separation, drop and fit check etc.).
- The payload release mechanism will be tested with FSW.
- The CanSat's subsystems durability before and after the test flights will be checked.
- The CanSat will be checked for the given environmental test requirements.
- Thanks to the folding mechanism designers in our team. It fits well into the container.
- The camera stabilization will be achieved by actively controlling payload with rudder and elevator using servo motors

Decent Control

- The installed electronic circuit will be placed in the payload and it will be tested at 450 meters via the drone.
- The payload's delta wings will be tested for gliding in a circular pattern with a radius of 250 meters from 450 meters to above 100 meters (actively controlled for one minute). Its aerodynamic suitability will also be checked during the test.
- Active control of the payload will be provided with rudder and elevator using the servo motors. The opening of the payload's parachute will be tested at an altitude above 100 meters.

FSW

- The accuracy of the data get from the each sensors were checked (particulate/dust, air speed, GPS location, temperature, pressure, etc.).
- Sub-systems were tested (release mechanisms, parachute opening, communication, etc.).
- Data recovery algorithms were tested in case of microcontroller reset.
- The sequence of the data transmission to the ground station will be checked for consistency in the appropriate order.

```
7840,10:47:47,325,1.53,96586.17,21.27,0.21,10:47:47,37.77,29.10,400.10,5,-9.53,3,0.00,-15104.00,-29952.00,-3073.00
7840,10:47:48,326,1.73,96583.89,21.26,0.15,10:47:48,37.77,29.10,400.40,5,-5.14,3,0.00,-11776.00,-29696.00,-2817.00
7840,10:47:49,327,1.66,96584.66,21.27,0.13,10:47:49,37.77,29.10,400.70,5,-17.19,3,0.00,-9728.00,-31744.00,-4353.00
7840,10:47:50,328,1.74,96583.72,21.27,0.14,10:47:50,37.77,29.10,400.90,5,11.95,3,0.00,-12288.00,-30208.00,-4353.00
7840,10:47:51,329,1.76,96583.45,21.30,0.21,10:47:51,37.77,29.10,401.30,5,-8.71,3,0.00,-12800.00,-29696.00,-4353.00
7840,10:47:52,330,1.93,96581.52,21.30,0.21,10:47:52,37.77,29.10,401.50,5,-6.30,3,0.00,-11520.00,-28928.00,-4097.00
7840,10:47:53,331,1.60,96585.31,21.33,0.23,10:47:53,37.77,29.10,401.60,5,-12.92,3,0.00,-11520.00,-29952.00,-3585.00
7840,10:47:54,332,1.66,96584.59,21.34,0.26,10:47:54,37.77,29.10,401.60,5,-15.55,3,0.00,-14080.00,-30976.00,-3073.00
7840,10:47:55,333,1.68,96587.09,21.31,0.21,10:47:55,37.77,29.10,401.80,5,-14.30,3,0.00,-11776.00,-28672.00,-3841.00
7840,10:47:56,334,1.70,96584.16,21.30,0.14,10:47:56,37.77,29.10,401.70,5,-8.23,3,0.00,-12544.00,-29440.00,-4097.00
7840,10:47:57,335,1.84,96582.56,21.28,0.12,10:47:57,37.77,29.10,401.70,5,5.02,3,0.00,-13824.00,-31232.00,-1793.00
7840,10:47:58,336,1.97,96581.05,21.27,0.16,10:47:58,37.77,29.10,401.80,5,-15.45,3,0.00,-11008.00,-30976.00,-3073.00
7840,10:47:59,337,1.82,96582.75,21.28,0.18,10:47:59,37.77,29.10,401.40,5,-15.06,3,0.00,-12544.00,-30464.00,-2049.00
7840,10:48:0,338,1.94,96581.36,21.26,0.21,10:48:0,37.77,29.10,401.10,5,-6.66,3,0.00,-12032.00,-30976.00,-3073.00
```

Sample of Data received

COMMUNICATION AND DATA HANDLING SUBSYSTEM DESIGN

Below is the communication Subsystem overview :

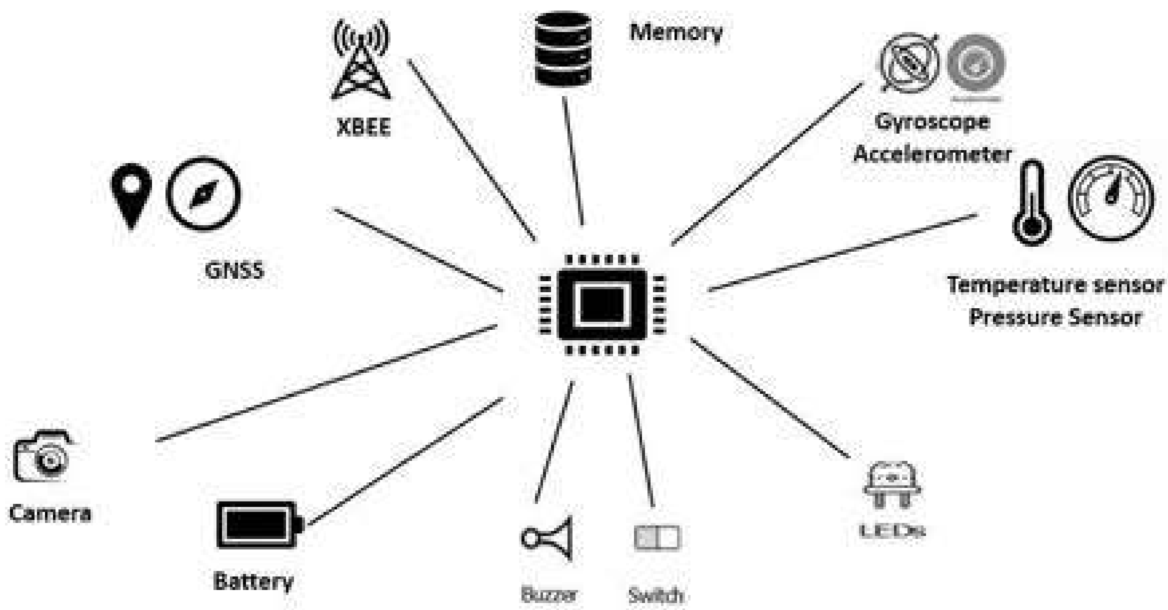


Fig. Communication and Data Handling Overview

Changes made after PDR in communication subsystem and data handling :

PDR	CDR	Rationale
Main processor was STM32F103	Main processor is changed to ATMega-328.	Due to problems faced in programming STM32F103 and because of previous experience of team in working with ATMega-328 and also meets all the requirements.

TELEMETRY

- Upon powering up, the CANSAT collects the required telemetry at a 1 Hz sample rate.
- The telemetry data is being transmitted with ASCII comma separated fields followed by a carriage return in the following format :
- <TEAMID>,<TIMESTAMPING>,<PACKETCOUNT>,<ALTITUDe>,<PRESSURE>,<TEMP>,<VOLTAGE>,<GPSTIME>,<GPS LATITUDE>,<GPS LONGITUDE>,<GPS ALTITUDE>,<GPS SATS>,<ACCELEROMETER DATA>, <GYRO SPIN RATE>, <FLIGHT SOFTWARE STATE>,<ANY OPTIONAL DATA>
- *The received telemetry for the entire mission will be saved on the ground station computer as a comma-separated value (.csv) file with name of file as 2022-ASI-002.csv*

The NET ID/PAN ID of the Xbee is set to team no. as per the requirements and its setting is shown below :

Fig. . Xbee 1 Setting for NET/PAN ID

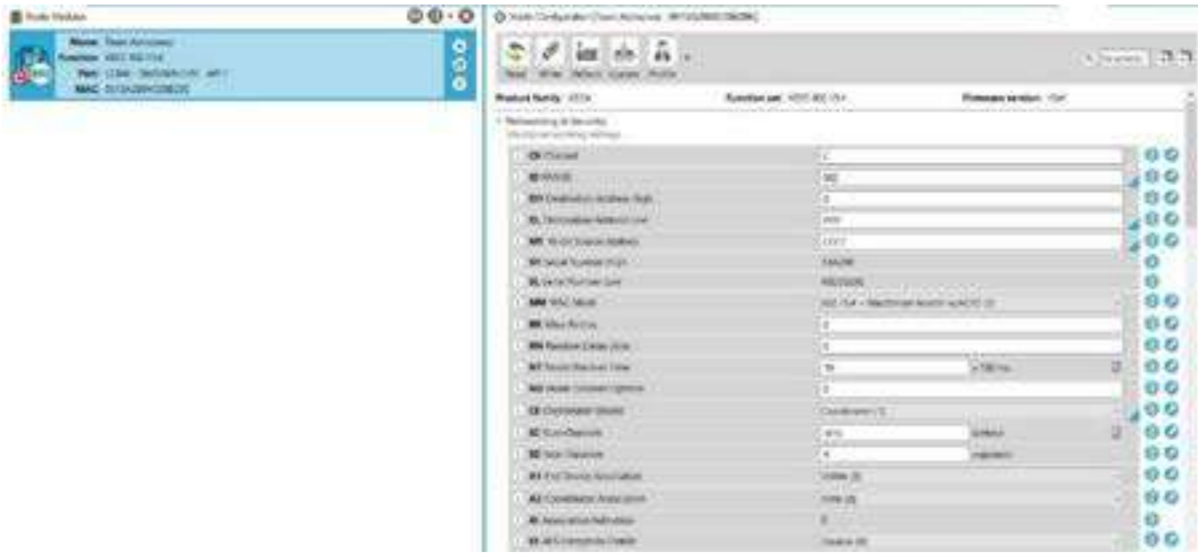


Fig. Xbee 2 Setting for NET/PAN ID

TELEMETRY DATA FORMAT

TM Parameter	Function	Resolution /Format
<TEAM ID>	Team Number	2022ASI-002
<TIME STAMPING>	Time since the initial power	Seconds
<PACKET COUNT>	Count of transmitted packets	Integer
<ALTITUDE>	Altitude in units of meters and must be relative to ground	0.1 meters
<PRESSURE>	Measurement of atmospheric pressure	1 pascal
<TEMP>	Temperature in Celsius	0.01°C
<VOLTAGE>	Voltage of the CANSAT power bus	0.01 Volts
<GPS TIME>	Time generated by the GPS receiver	Seconds
<GPS LATITUDE>	Latitude generated by the GPS receiver	0.0001 degrees
<GPS LONGITUDE>	Longitude generated by the GPS receiver	0.0001 degrees
<GPS ALTITUDE>	Altitude generated by the GPS receiver	0.1 meters

COMMUNICATION AND LINK BUDGET

Some changes are done in which we revisited the Gain calculation of receiving and transmitting antenna and we rectified accordingly as shown below.

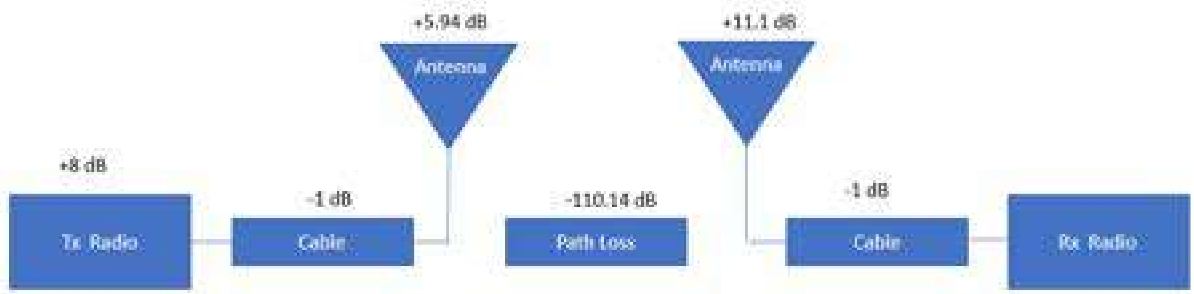


Fig. Communication and Link Budget

Calculation :

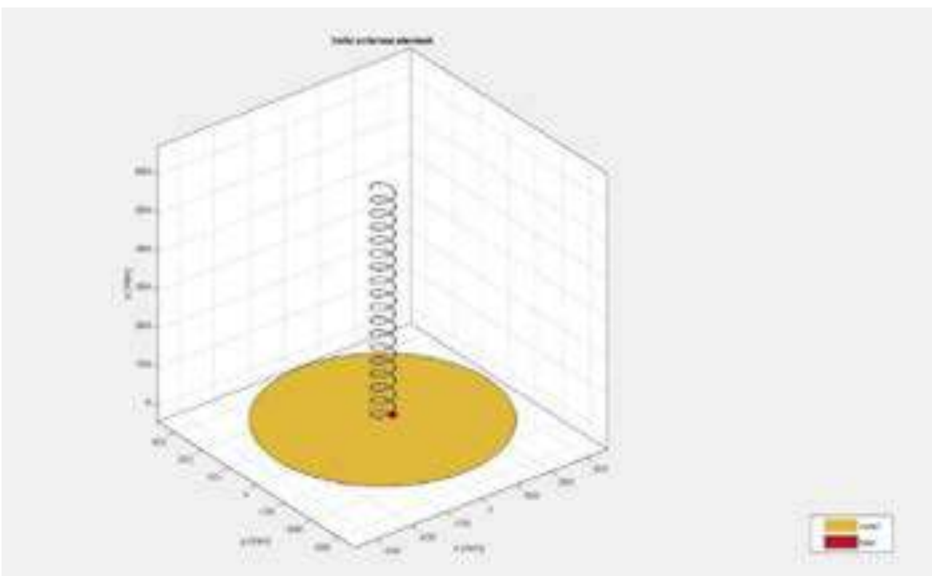
- Transmitted Power : 8 dB
- Transmitter Antenna Gain : 5.94 dB
- Transmitter Loss : 1 dB
- Free Space Loss : 110.14 dB
- Miscellaneous Loss : 1 dB
- Receiver Antenna Gain : 11.1 dB
- Receiver Loss : 1 dB
- Received Power : -84.14 dB
- Receiver Sensitivity : -101 dB
- Link Margin : 16.86 dB

ANTENNA SELECTION

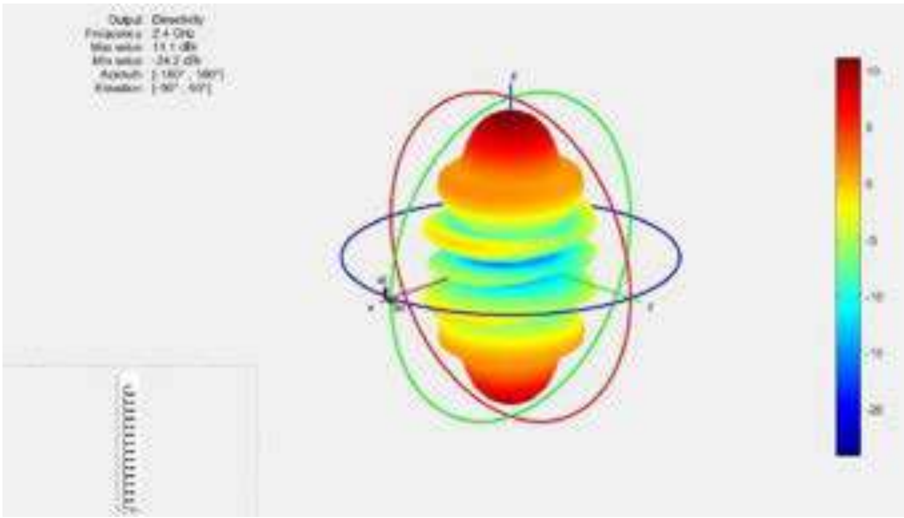
There is no changes since PDR just we simulated the radiation pattern of antennas and found the gains accordingly.

GCS Antenna

Antenna Design :



Antenna Radiation Pattern :

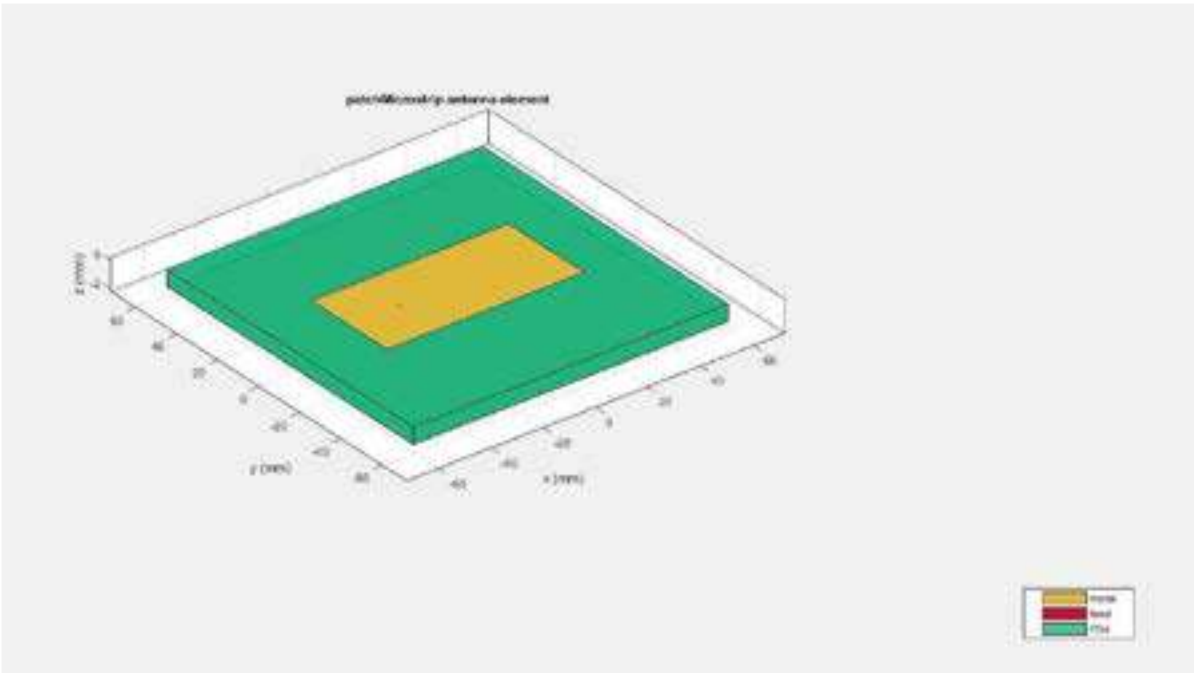


Antenna Design Code :

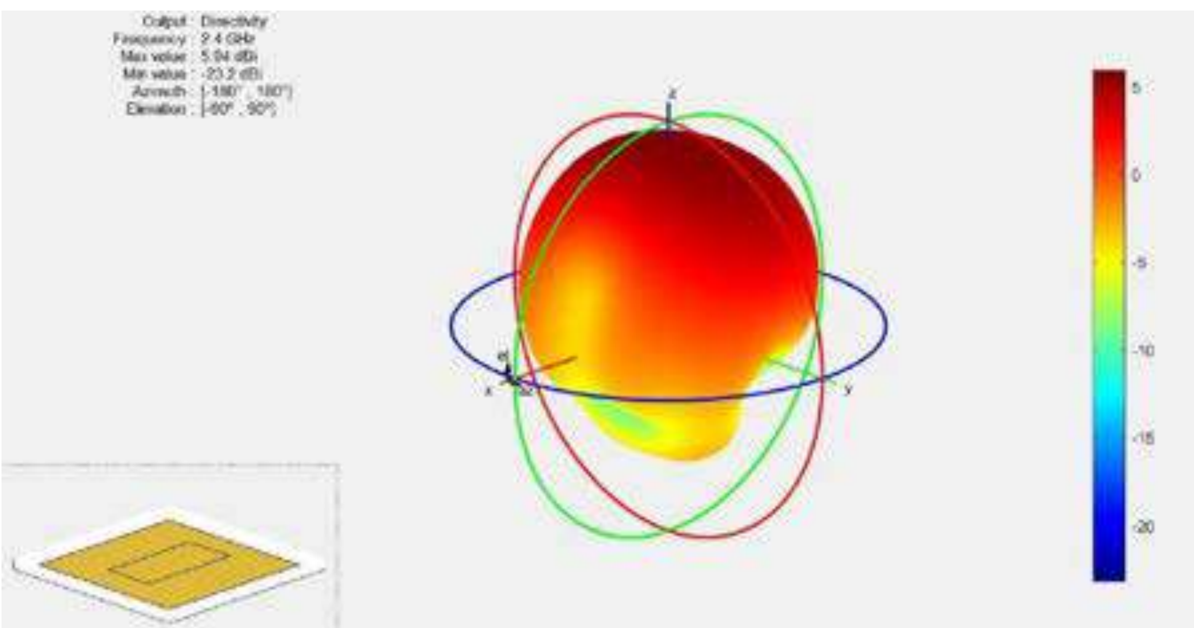
```
r           = 0.3e-3;
width       = cylinder2strip(r);
feedheight  = 3*r;
D           = 56e-3;
radius      = D/2;
turns       = 17.5;
pitch       = 11.2;
spacing     = helixpitch2spacing(pitch,radius);
side        = 600e-3;
radiusGP    = side/2;
fc = 2.4e9;
hx = helix('Radius',radius,'Width',width,'Turns',turns,...
           'Spacing',spacing,'GroundPlaneRadius',radiusGP,...
           'FeedStubHeight',feedheight);
figure;
show(hx);
```

CANSAT Antenna

Antenna Design :



Antenna Radiation Pattern :



Antenna Design Code :

```
d = dielectric('FR4');
pm = patchMicrostrip('Length',75e-3,'Width',37e-3,     ...
        'GroundPlaneLength',120e-3,'GroundPlaneWidth',120e-3, ...
        'Substrate',d);
```

The gain obtained after analysis are :

- GCS Antenna – 11.1 db
- Cansat Antenna – 5.94 db

An after calculating we rectified the changes in the Communication and Link Budget.

ELECTRICAL POWER SUBSYSTEM

There are only some minor changes in Electrical power subsystem as mentioned below :

- The battery configuration is changed from series to parallel which made the step down process more efficient.
- The position of switch is also modified from bottom to panel side of CANSAT.

Electrical Block Diagram

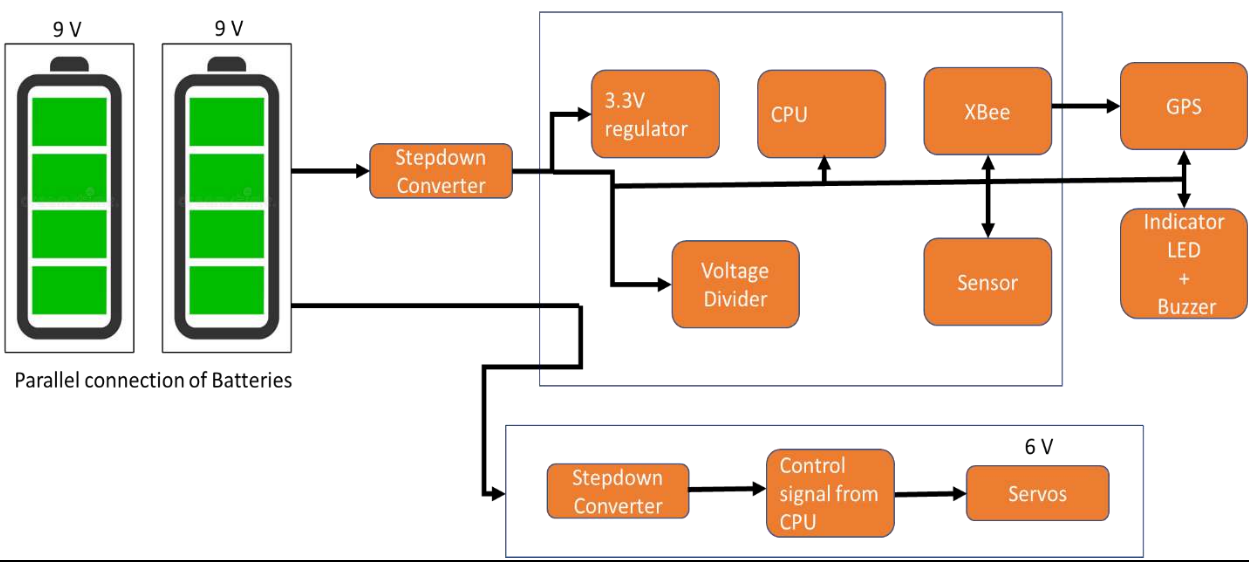


Fig. Electrical Power Subsystem Block Diagram

FLIGHT SOFTWARE DESIGN

Overview of the CanSat FSW Design

- The CanSat will collect sensor data then save to SD card and send to ground station via XBee.
- The CanSat will deploy 2nd Parachute deploy mechanism after reaching 500m altitude.
- The buzzer will keep beeping after landing until turned off with power switch.

Programming Language

- C/C++ for CanSat container
- Python/C++ for ground station

Development Environment

- Arduino IDE
- Visual Studio Code
- Spyder

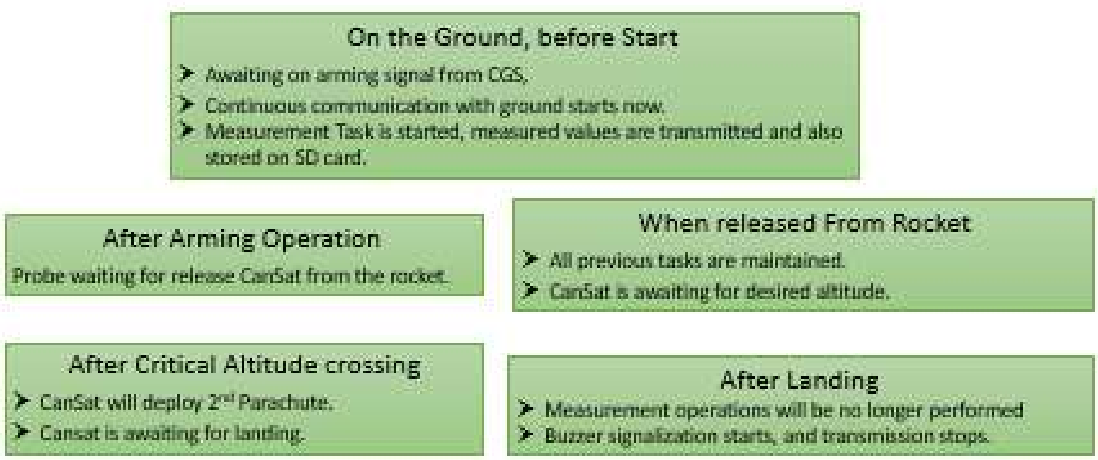


Fig. Flight Software Design Overview

Momentary Power Cut Precaution Strategy :

As far as power management goes, all devices are ON for all time except two (Servo motor for Deployment of 2nd Parachute and Buzzer for recovery) as Servo motor will deployed only for some time after crossing critical altitude (500m) and Buzzer will be turned ON after landing for location and recovery of CanSat.

After reset of processor in flight mode, previous state of mission together with last packet count can be retrieved from flash.

This information with current GNSS time is sufficient to continue mission.

GCS DESIGN AND OVERVIEW

Overview

- Main Computer is a laptop running GS application. The application is configured in GUI so that an appropriate port and baud rate can be selected.
- QHA antenna receives data from the probe (i.e. CanSat CPU) and transmits commands.
- Xbee PRO S2C module forwards and receive data to form communication link between CanSat and GCS.
- GS application, written in C++/Python, saves and displays data. It also saves received data in a local area network.

There is no changes since PDR.

Data Flow and Components

- The antenna receives data over radio from the probe.
- Using Xbee explorer cable , forwards data to the Xbee module.
- Xbee PRO S2C module forwards data to GS's Main Computer using micro USB to USB cable.
- Software developed in C++ parses and then displays data in engineering units and save them into a CSV file.
- Main computer is capable of sending predefined commands to the probe.

Progress Since PDR :

- The login page of GUI is completed and currently working on dashboard page of GUI and the overall data receiving software is tested for sensors individually.
- The development of helical antenna of GCS is started.

Ground Control Station GUI :

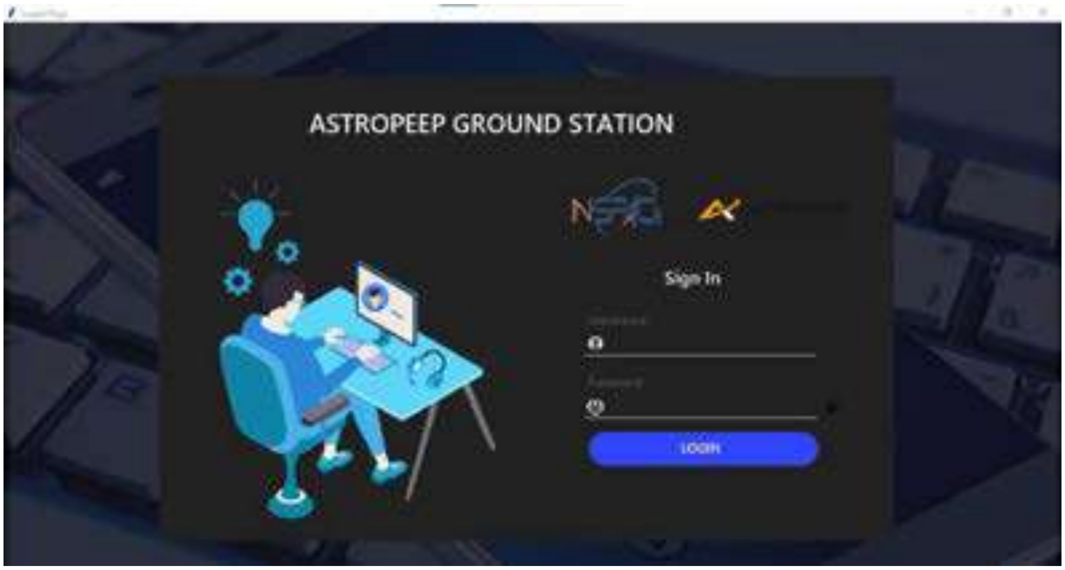
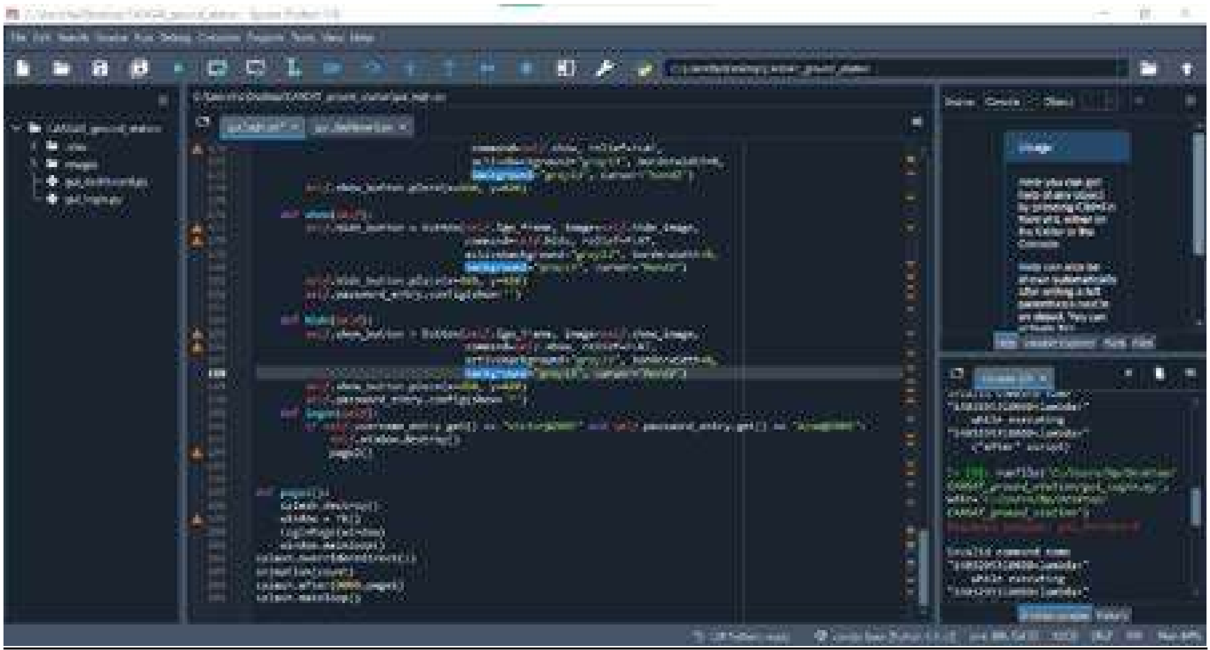
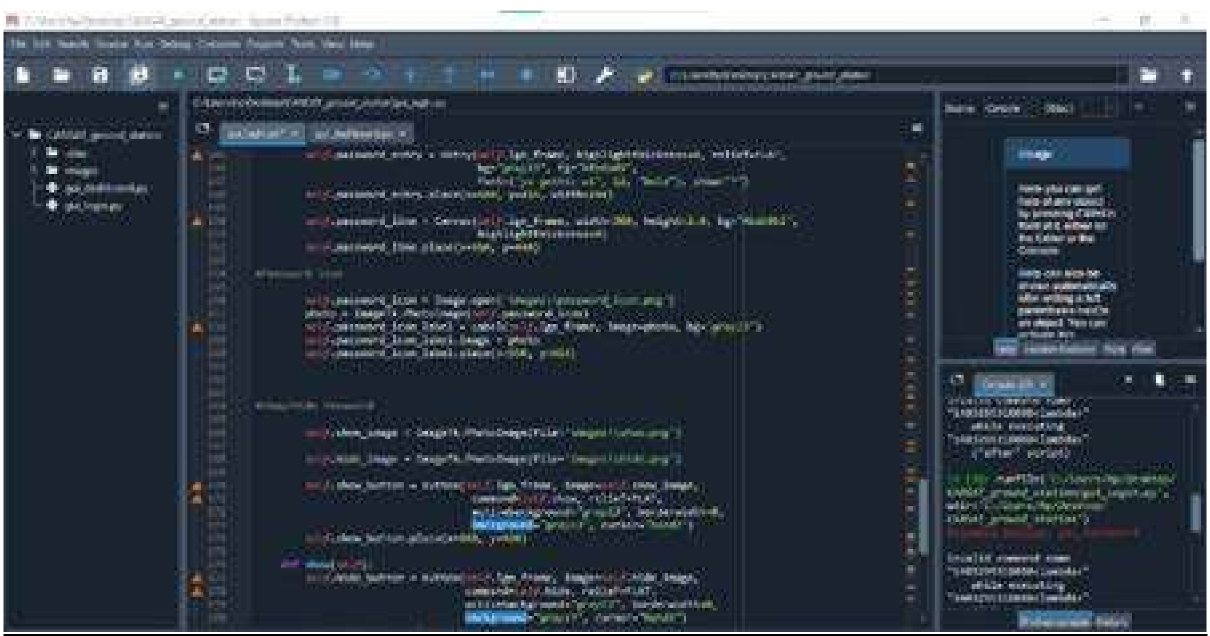


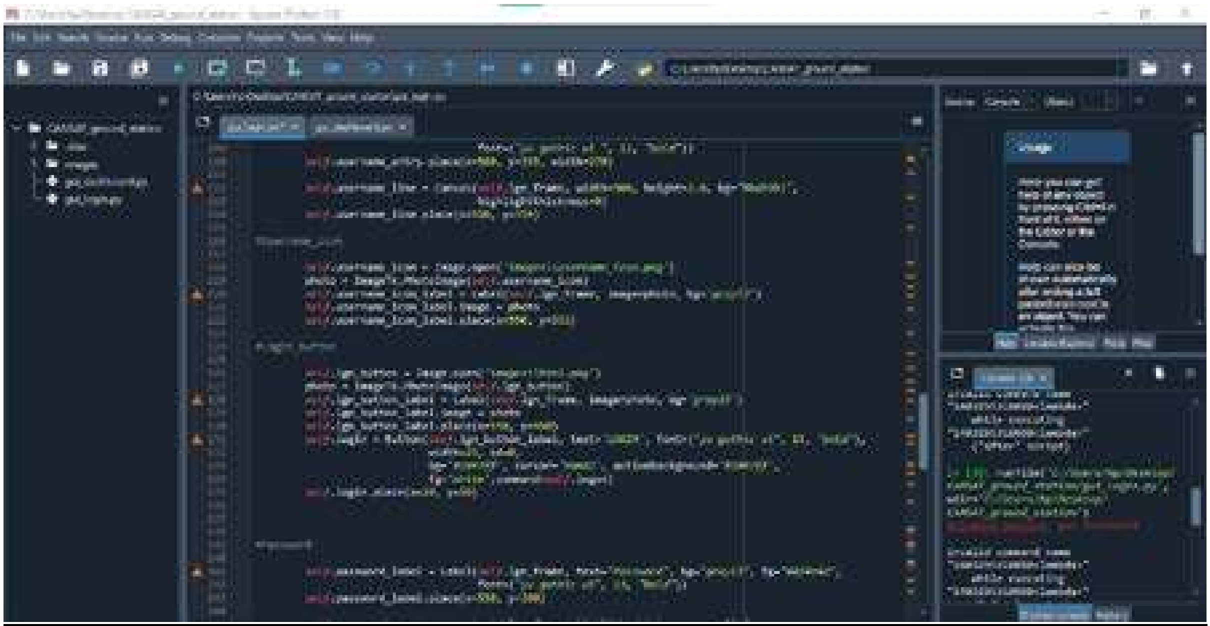
Fig. GCS GUI login page

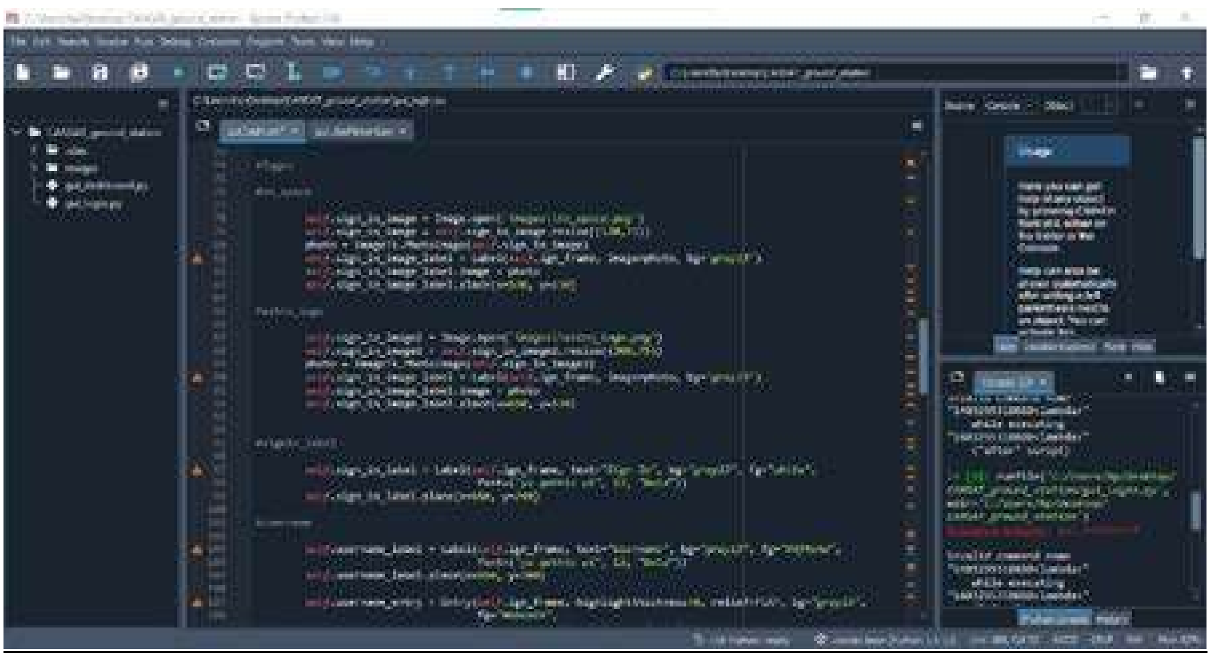
The GUI is build using SPYDER IDE using Python language and the work is still in progress the login page is build as shown above and the dashboard work is in progress and for testing we individually tested the sensor by sending data using our microprocessor and plotted graph in the SPYDER IDE using Python function matplotlib.

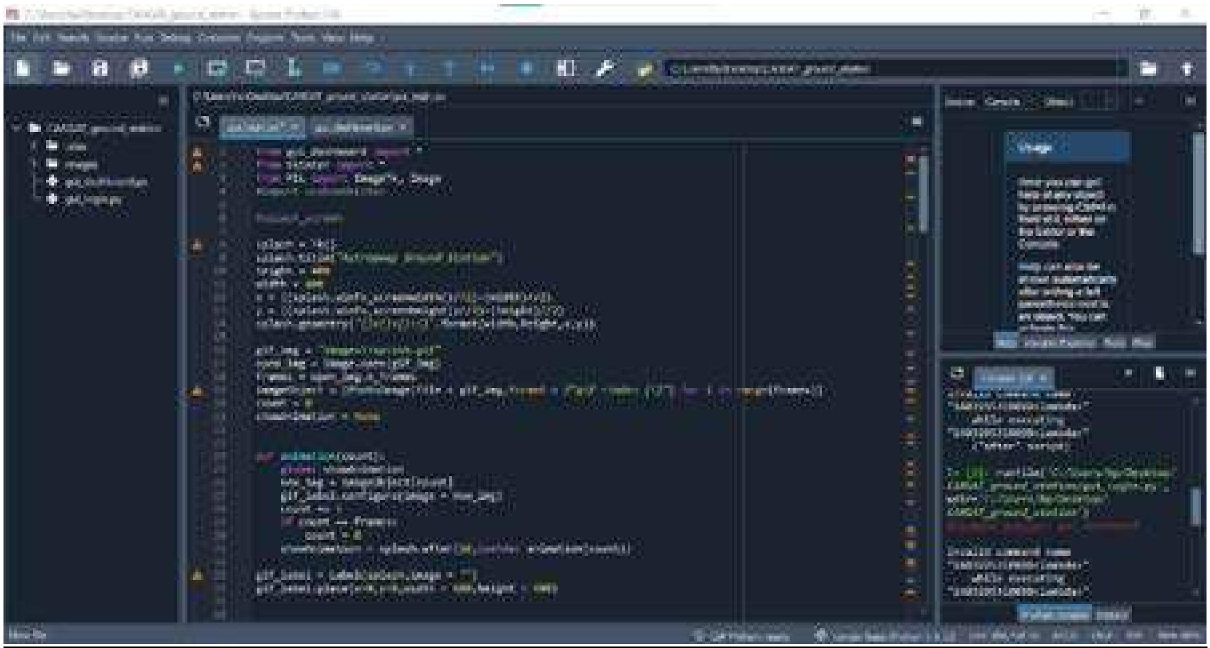
The screenshots of code written in SPYDER IDE are attached below :











The development of dashboard were all the data will be plotted is in progress and after development the dashboard will be like as shown below :

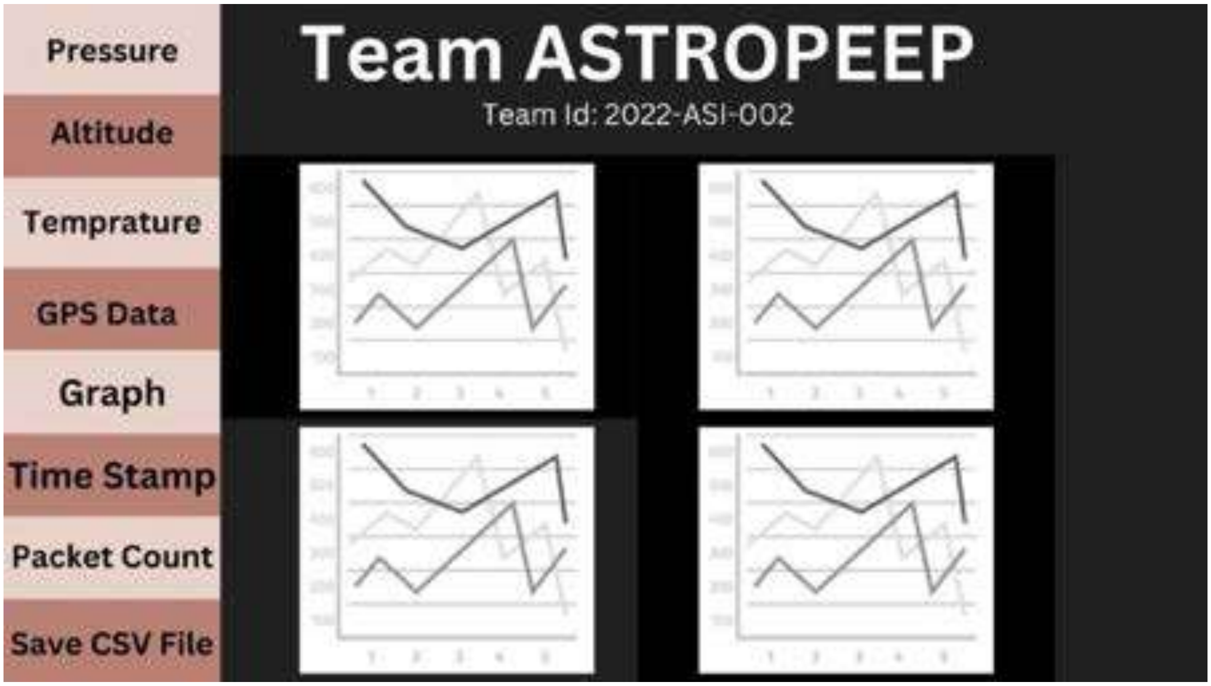


Fig. GCS GUI Dashboard

CANSAT ALGORITHM

The CANSAT algorithm is developed in C/C++ language using Visual Studio Code and Arduino IDE and the flow chart of the algorithm is shown below :

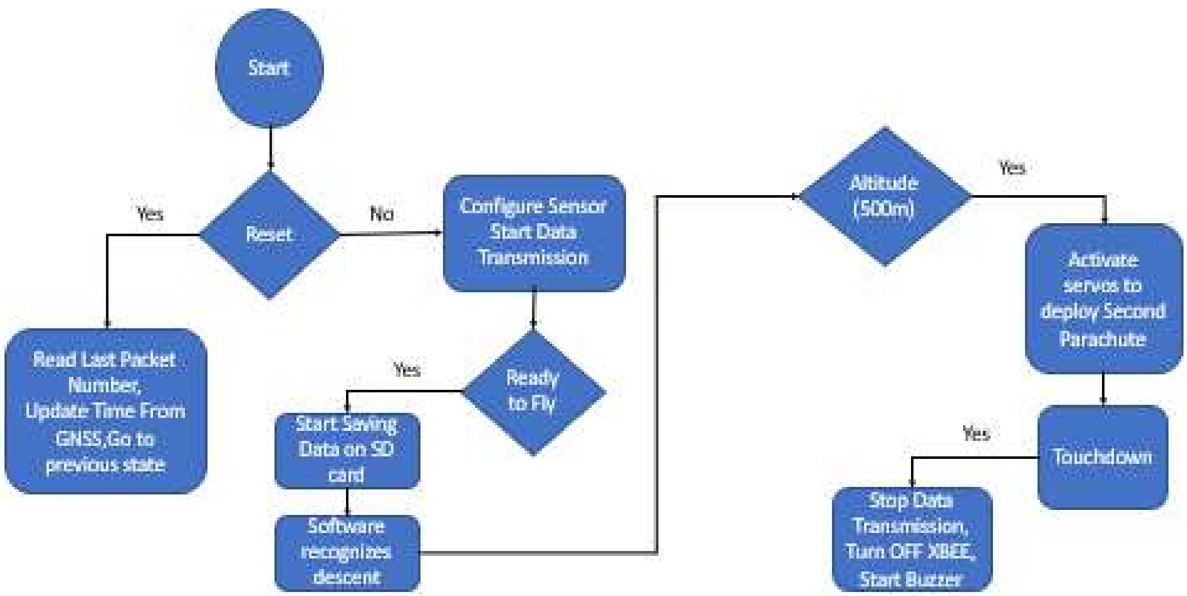


Fig. CANSAT Algorithm Flow Chart

Ground Station Final Test Results

The Cansat Ground Station final test results is still in progress as the test of data collection is done individually for all the sensors and in next step we will be combining the overall data into our GUI.

Our GUI work is also still in progress and final glimpse of our GUI is shown below:

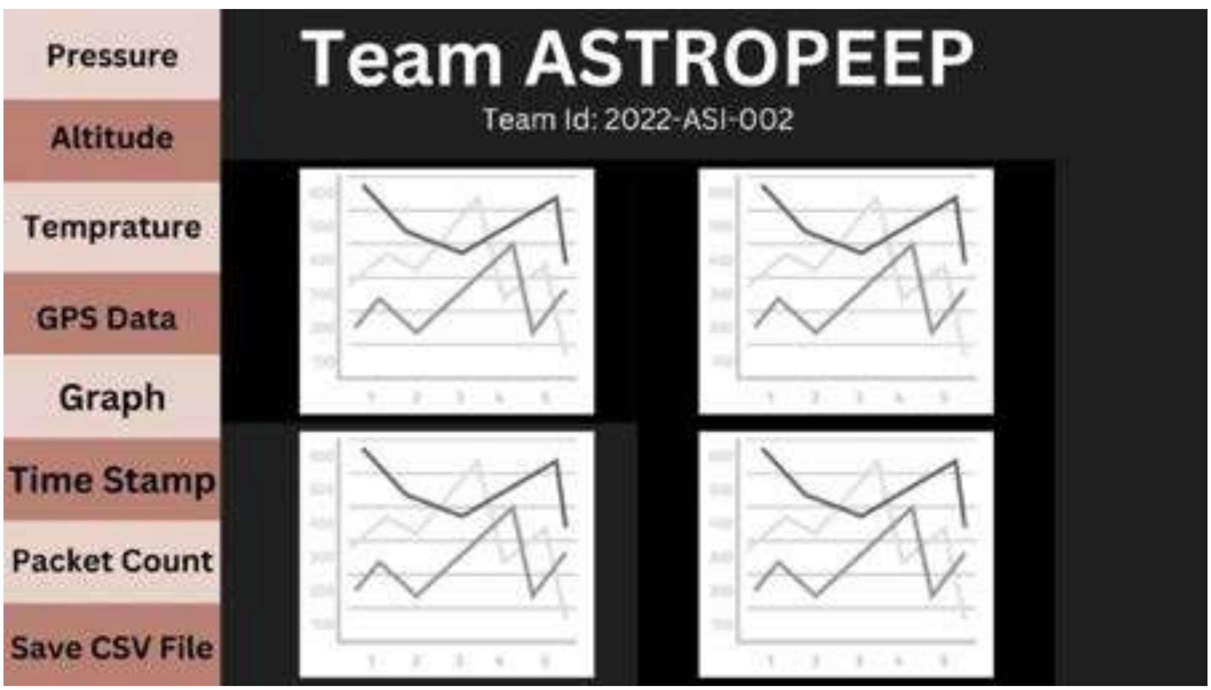
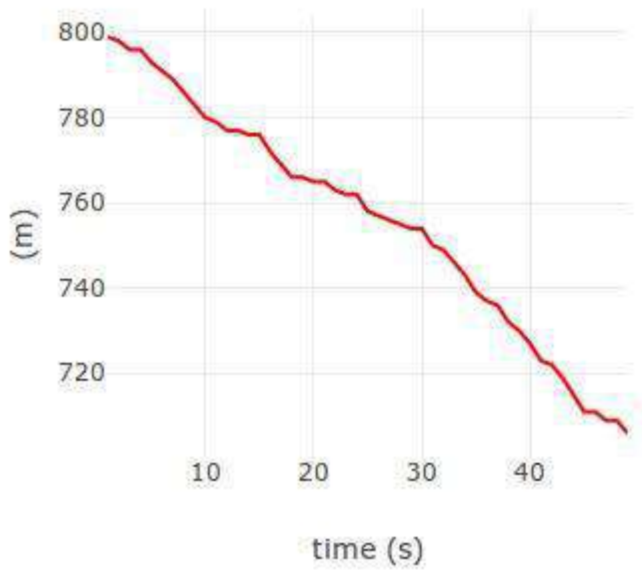


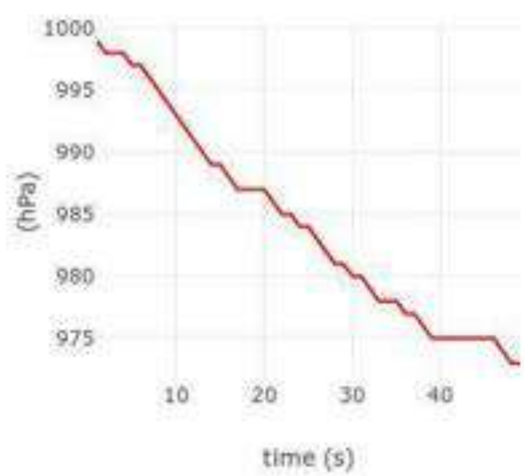
Fig. CANSAT GUI Dashboard

The test result plots of the individual sensor data are shown below:

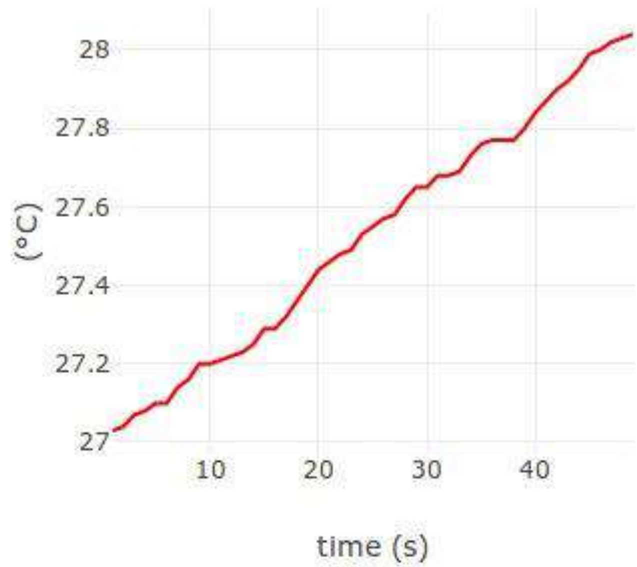
Altitude Test Plot:



Pressure Test Plot:



Temperature Test Plot :



The testing of some of the components are still in progress like GPS , Gyroscope and Accelerometer.We are still working on the testing of the above mentioned components.

CANSAT INTEGRATION AND TESTING

Testing before Integration :

CanSat subsystems level tests (before integration)	
Sensors	Sensors will be checked and properly calibrated separately, before mounting them to a CanSat. It will assure us, that all used components are fully functional and will not cause mission failure. Calibration will be done with usage of oscilloscope sending the data via UART to PC and checking if the values are correct.
CDH	Preliminary tests for data acquisition – checking if sample data send via radio modules can be properly handled by ground station software. Checking the time of sending data along working under various conditions. Checking if data frame format is as desired.
EPS	Supplying a voltage divider with various voltages of a battery working range from laboratory power supply to determine the correct behaviour of the circuitry. Checking for damage such as short circuits. Battery tests will be performed - maximum current consumed by hot wires need to be compromised with battery parameters - checking if they make hotwire hot enough. Checking battery lifetime. Voltage checking on the checkpoints.
Radio Communication	Sending and receiving known amount of packets and checking the loss percentage in various areas, such as between buildings/trees or on an open field. Verification of radio modules parameters and communication quality on ground.
FSW	Checking designed software functionalities such as: proper visualization of sample data, sending remote commands to the onboard computer. Sequences chronology and order will be tested in all possible scenarios and events.

CanSat subsystems level tests (before integration)	
Mechanical	All mechanical elements separately must be checked if they are made properly and have good dimensions. Then, components must be preassembled in order to see if a whole structure is stiff enough and have no looseness. Checking if fast moving and rotating structure does not cause any problems. If not, then we test all mechanisms used separately if they work properly – e.g. if wings can be opened and closed easily. Container has to be checked on the ground for its stiffness and durability and visually if a composite does not have any cracks and flaws. Container must be fluorescent color to be easy to find - test of luminescent addings to glass fiber composite
Descent Control	Checking if parachute descent is stable with a sample mass attached. For probe - checking if descent rate of the designed wings is as desired and what is their rotation rate. Test performed in aerodynamic tunnel. Rotation rate checked by suitable sensor.

CanSat subsystems level tests (after integration)	
Descent Testing	Checking if the flight is stable and detumbled with parachute deployed. Testing if the flight is stable with rotors. We check it by deploying CanSat from high building with known height - recording the test with the camera lets us calculate descent rates of parachute and rotors. Testing the parachute from a smaller height if it is stable and if the descent rate is appropriate. Testing if detumbling system works as desired and stabilizes Probe during auto-gyro descent and if recording from camera is stable. Preliminary tests were performed with our rocket and will be repeated with the drone and rocket again.
Communication	Checking on the ground if communication between CanSat and Ground Station works. Checking wireless modules, every sensor, the power modules, CanSat – ground station application. On that stage we can perform final data flow from sensors to its acquisition on the ground station application.
Mechanism	Testing if rotors open well and work in desired way and if elastic bands give enough force for unfolding rotors. Everything is well-fitted and the capsule is able to slide easily in the structure.

CanSat subsystems level tests (before integration)	
Sensors	Sensors will be checked and properly calibrated separately, before mounting them to a CanSat. It will assure us, that all used components are fully functional and will not cause mission failure. Calibration will be done with usage of oscilloscope sending the data via UART to PC and checking if the values are correct.
CDH	Preliminary tests for data acquisition – checking if sample data send via radio modules can be properly handled by ground station software. Checking the time of sending data along working under various conditions. Checking if data frame format is as desired.
EPS	Supplying a voltage divider with various voltages of a battery working range from laboratory power supply to determine the correct behaviour of the circuitry. Checking for damage such as short circuits. Battery tests will be performed - maximum current consumed by hot wires need to be compromised with battery parameters - checking if they make hotwire hot enough. Checking battery lifetime. Voltage checking on the checkpoints.
Radio Communication	Sending and receiving known amount of packets and checking the loss percentage in various areas, such as between buildings/trees or on an open field. Verification of radio modules parameters and communication quality on ground.
FSW	Checking designed software functionalities such as: proper visualization of sample data, sending remote commands to the onboard computer. Sequences chronology and order will be tested in all possible scenarios and events.

The above mentioned steps are for testing the cansat before integration and after this testing we will go ahead for integration.

Integration of CANSAT :

- As our primary structure fabrication process which will let be a homogenous structure with no mechanical joints.
- Other than this the outer body panels will be connected using the shock absorbing screws.
- Batteries , PCB and Servo motors are connected to the particular damper used which are then connected to the structure of CANSAT using screws and other mechanical joints as shown below.

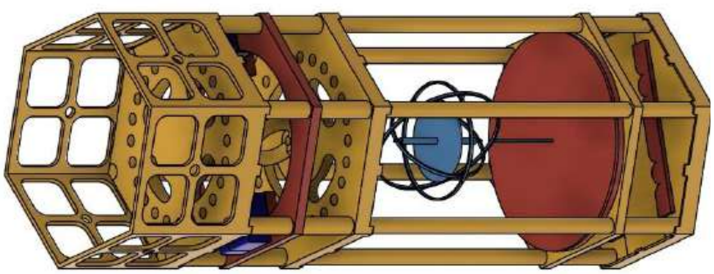


Fig. CANSAT Integration Stage 1

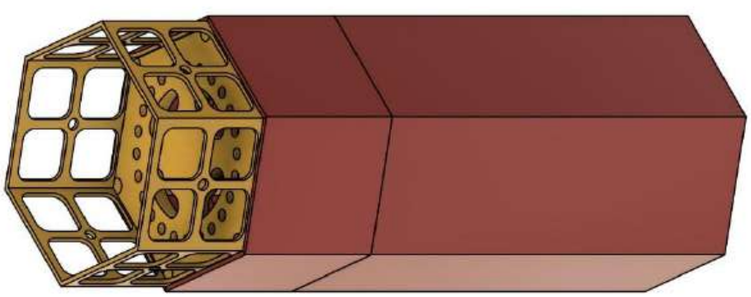


Fig. CANSAT Integration Stage 2

MISSION OPERATION AND ANALYSIS

Preparation for Flight
- Power Cansat On
- Integrate CanSat into rocket payload
- Confirmation of telemetry data reception by line of judges.

Mission
- Telemetry is constantly transmitted to the ground station and monitored.
- First Parachute opens right after deployment of the cansat.
- The second descent control mechanism shall open at an altitude of 500m.
- Buzzer is turned on upon Landing.

Recovery
- Retrieval of the CanSat.
- Delivery of the telemetry data file to a line of judge for inspection.

Arrival
- Check in Weight and Fit check of the CanSat
- Check for any damages caused by the travel

Setting Up Ground Station
- Localization of the place allocated for the ground station.
- Antenna assembly and setting up ground station.
- Checking communication devices and algorithms.

CanSat Preparation and Assembly
- Communication test
- CanSat structure has no mechanical damages
- CanSat Assembly

Analysis

- Analysis of the obtained data
- Mission assessment and analysis

PRE-FLIGHT REQUIREMENT-CHECK-ANALYSIS

Setting up GS
- Computer and Antenna

Communication Test

Pre-Flight check and Tests
- Structure
- Electronics
- DCS components

Cansat Integration
- Container assembly

CanSat recovery

LOGISTICS AND TRANSPORTATION:

For the Logistics and Transportation:

- We will be packing the fragile and non-secured elements independently using cartons and bubble wraps.
- Whereas other all the elements will be packed in a wooden sheet box by using Thermocol sheets, Bubble Wraps, Cardboard and Straps as per the requirements of the fabricated model of CANSAT.

CANSAT READY TO LAUNCH AND FINAL COMMENTS.

- The testing was made on similar kind of prototypes and we found the rectifications in the model as observed.
- Accordingly, we have made changes and as of that our software part is almost done however in Hardware our work is still in progress.
- Due to the delay in the delivery of the materials and the electronic components required for the final fabrication of the CANSAT.
- The work will be completed in accordance to the availability of material however all the analysis, simulations and test results are completed through the alternative scale models of the similar materials.

CONCLUSION

Accomplishments

- Telemetry is tested.
- GCS GUI is developed up to some extent.
- Antenna testing is completed.
- Mechanical analysis (Stress-strain , Vibration and Fit check) is completed.

Unfinished work

- The fully integrated electronic & mechanical subsystem are not entirely functional yet and needs to be tested.
- Prototypes are being tested and more refinements are required.
- Flight software is in progress.

Next stage of development

- Final Fabrication work completion
- Code Review
- Testing of integrated system
- Assembly of complete CANSAT
- Integrated testing of CANSAT.