CanSat India 2022-23
Preliminary Design Review (PDR)
Version 1.0

#2022ASI-049

Team Kalpana

Presentation Outline (1/2)

Presentation Outline (2/2)

Team Organization

Team Kalpana

- Ms Shweta Gautam (**Faculty Advisor**)
- 3rd Year — VANSH KUMAR GOEL (**Student Head**)
- 2nd Year — MUSKAN (**Alternative Head**)

ELECTRONICS

- 2nd Year — Yash Sharma
- 2nd Year — Arnav Dev

MECHANICAL

- 2nd Year — Yuvraj Dipak Baishya
- 2nd Year — Divya Rawat
- 2nd Year — Vidushi Bhadana

SOFTWARE

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- 2nd Year — Khush Ahuja

Acronyms

Acronyms	Full Form
GCS	Ground Control System
SD	Secure Digital
COTS	Commercial off the shelf
NA	Not Applicable
Min	Minute
LED	Light Emitting Diode
DS	Datasheet
EPS	ELectrical Power System
E	Estimate
TTFF	Time To First Fix

Acronyms	Full Form
FSW	Flight software Design
ESD	Electrostatic Discharge
Temp	Temperature
RCBL	Rechargeable
LPWAN	Low Power Wide Area Network
MHz	Mega Hertz
DOF	Degree of Freedom
BOB	Break Out Board
GNSS	Global Navigation Satellite System

Acronyms	Full Form
RX	Receiver
TX	Transmitter
Pt	Antenna Transmit Power
Gt	Transmit-Antenna Gain
EIRP	Equivalent Isotropic Radiated Power
TH	Through Hole
SMT	Surface Mount Device
VSWR	Voltage Standing Wave Ratio
Omni	Omnidirectional

Acronyms	Full Form
I2C	Inter Integrated Circuit
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver-Transmitter
VA	Velocity Accuracy
AA	Acceleration Accuracy
PA	Position Accuracy
ABS	Acrylonitrile Butadiene Styrene
SW	Solidworks Software
GUI	Graphical User Interface

System Overview

Mission Summary

Main Objectives

1. Design the cansat having weight of 0.700 kg (+/- 0.050), with dimensions not more than 0.125m diameter and 0.310m height.
2. The cansat will be launched to an altitude of 800 to 900 m from the ground level.
3. The cansat shall contain a total of 2 descent control mechanisms to be used at two different stages while descent.
4. For the first mechanism the cansat shall deploy 1st parachute immediately after ejection from rocket.
5. For it the descent rate shall be 20 m/s (+/- 5 m/s) .
6. For the second mechanism the cansat shall deploy 2nd parachute at an altitude of 500m (+/- 10 m).
7. For it the descent rate of the cansat decreases from 20 to (1-3) m/s.
8. For the entire time cansat shall stabilize using Mechanical Gyro control.

Optional Objectives

1. Novel descent control and Innovative materials.
2. Additional innovative sensor and communication system.
3. Provision of video capture from separation till final touchdown.
4. Innovative recovery techniques viz. HAM radio/ advance beacon.
5. Innovative quality and Reliability analysis methodologies.

External objectives

1. Now more people are aware of the Cansat competition in our country.
2. India is organising cansat for first time so we are trying to get an esteemed position in Cansat India 2023.
3. We wish to get experience, knowledge and make a student satellite and successfully launch it.

System Requirements Compliance (1/6)

Req No.	Requirement	Compliance	Team comments
1.	Total mass of the CANSAT shall be under 0.700 kg (+/- 0.050 kg).	Comply	Mass Budget
2.	CANSAT shall fit in a cylindrical body of 0.125m diameter x 0.310m height. Tolerances are to be included to facilitate container deployment from the rocket fairing.	Comply	Launch Vehicle Compatibility
3.	Any sharp edges on the container body shall be avoided as it can cause interfere during the CANSAT ejection from the rocket.	Comply	Launch Vehicle Compatibility
4.	Color of the CANSAT body shall be fluorescent i.e., pink, red or orange, and shall embody the Indian flag.	Comply	Cansat Recovery
5.	Rocket Airframe will not be allowed to be used as a part of any CANSAT operation.	Comply	Launch Vehicle Compatibility
6.	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.	Comply	Telemetry
7.	Each data field shall be displayed in real-time on the ground station user interface/software.	Comply	GCS
8.	CANSAT shall also record the data and save it into an onboard SD card in case of telecommunication loss	Comply	Telemetry

System Requirements Compliance (2/6)

Req No.	Requirement	Compliance	Team comments
9.	All electronics shall be enclosed and shielded from the environment. No electronics can be exposed except for sensors. There must be a structural enclosure.	Comply	Electronic Structural Integrity
10.	CANSAT structure shall be built to survive 15 Gs of launch acceleration & 30 Gs of shock.	Partially Comply	To be verified in drop test
11.	Electronic circuit boards must be hard mounted using proper mounts such as standoffs and screws. High-performance adhesives can also be used.	Comply	Electronic Structural Integrity
12.	Team number, email address and phone number must be placed on the structure in English, Hindi and the Regional language of the launch state to aid in recovery.	Comply	Cansat location and recovery
13.	An audio beacon shall be installed on CANSAT as a recovery assist. It may be powered after landing or operate continuously. The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Comply	Cansat location and recovery
14.	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 disassembly of CANSATs on the launch pad.	Comply	Physical Layout

System Requirements Compliance (3/6)

Req No.	Requirement	Compliance	Team comments
15.	The CANSAT shall have a battery capacity to support up to 2 hours of wait in on the launch pad with additional time for flight operations.	Comply	Power Budget
16.	The battery source may be alkaline, Ni-Cad, Ni-MH or Lithium ion. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells.	Comply	Cansat Power Trade and Selection
17.	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require total disassembly of the CANSAT.	Comply	Physical Layout
18.	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	Physical Layout
19.	The CANSAT shall contain a total of 2 descent control mechanisms, to be used at different stages while descent.	Comply	Descent Control
20.	CANSAT shall immediately deploy the first parachute after ejection from the rocket.	Comply	Descent Control
21.	The first parachute shall be connected to the outer body of the CANSAT and no ejection mechanism shall be attached to it.	Comply	Descent Control

System Requirements Compliance (4/6)

Req No.	Requirement	Compliance	Team comments
22.	The descent rate of the 1st parachute shall be 20 m/s +/- 5m/s	Comply	Descent Control
23.	The second descent control mechanism shall open at an altitude of 500m (+/-10 m) to further decrease the descent rate of the CANSAT to 1 to 3m/s .	Comply	Descent Control
24.	The descent control system shall not use any hazardous chemical-based explosive or pyrotechnic devices. However, green propulsion is allowed if being used under the same weight constraint.	Comply	Descent Control
25.	CANSAT shall stabilize itself during the decent using the mechanical gyro mechanism	Comply	Mechanical Gyro Control
26.	The CANSAT communications radio shall be the XBEE radio series 1/2/pro	Comply	Payload Radio Configuration
27.	The XBEE radios shall have their NETID/PANID set to the team number.	Comply	Payload Radio Configuration
28.	The XBEE radio shall not use the broadcast mode.	Comply	Payload Radio Configuration

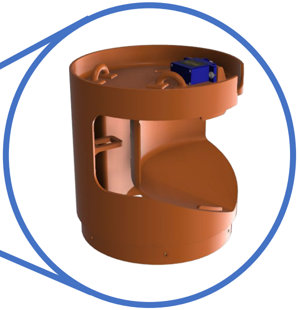
System Requirements Compliance (5/6)

Req No.	Requirement	Compliance	Team comments
29.	The XBEE radio can operate in any mode as long as it does not interfere with other XBEE radios.	Comply	Payload Radio Configuration
30.	Each team shall develop and use their own ground station. All telemetry shall be displayed in real-time during launch and descent. All telemetry shall be displayed in engineering units (meters, meters per second, Celsius, etc.). Teams shall plot data in real-time during flight.	Comply	GCS Software
31.	The ground station shall command the CANSAT to start transmitting telemetry prior to launch.	Comply	Telemetry
32.	The ground control station antenna shall be elevated from ground level to ensure adequate coverage and range.	Comply	GCS Antenna
33.	Stability of the ground station must be ensured.	Comply	GCS Design
34.	The CANSAT shall not transmit telemetry until commanded by the team ground station. Command can be executed while the CANSAT is in the rocket on the launch pad.	Comply	Payload FSW state diagram
35.	The ground station shall be able to command the CANSAT to calibrate gyros, barometric altitude, accelerometer to command the parameters to zero as the CANSAT sits on the launch pad.	Comply	Payload FSW state diagram
36.	The ground station shall generate .csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	Software development

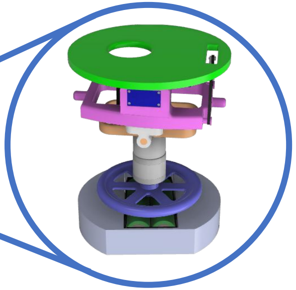
System Requirements Compliance (6/6)

Req No.	Requirement	Compliance	Team comments
37.	Telemetry shall include mission time with one second or better resolution.	Comply	RTC
38.	Mission time/timestamp and system status states shall not be affected in the event of a processor reset during the launch and mission.	Comply	RTC
39.	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	Comply	GCS Overview
40.	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line and if required the team can also move to a different location in case of distant landing location in order to locate the CANSAT.	Comply	GSC Software
41.	The flight software shall maintain and telemeter an indicator of the CANSAT flight software state. An example set of states is 0 (BOOT), 1 (TEST_MODE), 2 (LAUNCH_PAD), 3 (ASCENT), 4 (ROCKET_DEPLOY), 5 (DESCENT), 6 (AEROBREAK_RELEASE), and 7 (IMPACT).	Comply	Command
42.	Upon powering up, the CANSAT shall collect the required telemetry at a 1 Hz sample rate or more. The telemetry data shall be transmitted with ASCII comma-separated fields followed by a carriage return	Comply	Telemetry

System Level Configuration (1/2)

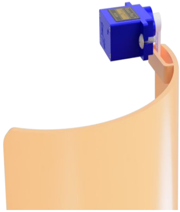


Parachute compartment

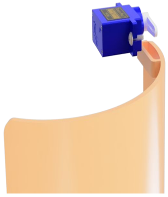


Gyro compartment

1. The shroud lines of the **first parachute** are connected to the smaller hook through an o-ring.
2. The **second parachute** is attached to the bigger hook through an o-ring.
3. The **Parachute compartment** gate is kept in place by a servo shaft which locks the compartment gate.



Locked configuration



Unlocked configuration

O Ring

1. The **servo motor** is connected to the shaft.
2. The pitch servo will help to rotate the wheel of gyro.
3. Its working is based on **bias momentum control method.**
4. As the rotor tilts the changing **angular momentum** causes a **gyroscopic torque** that rotates the spacecraft.

System Level Configuration (2/2)

Stowed Configuration

The first parachute is deployed as soon as CanSat releases from rocket.

First Parachute Deployment

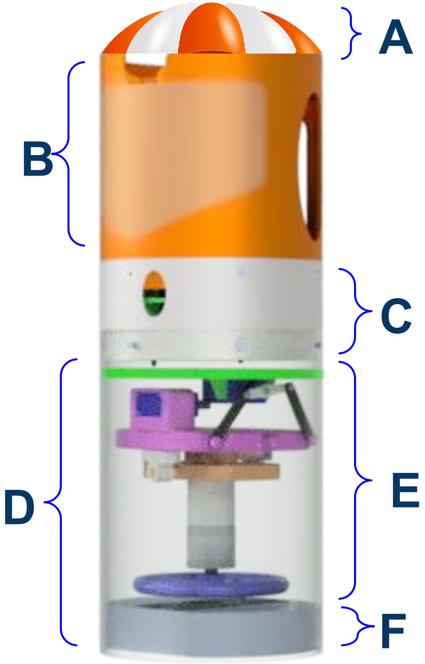
The second parachute is deployed at an altitude of 500m (+/-10m) from CanSat.

Servo motor unlocks the parachute lid.

Second Parachute Deployment

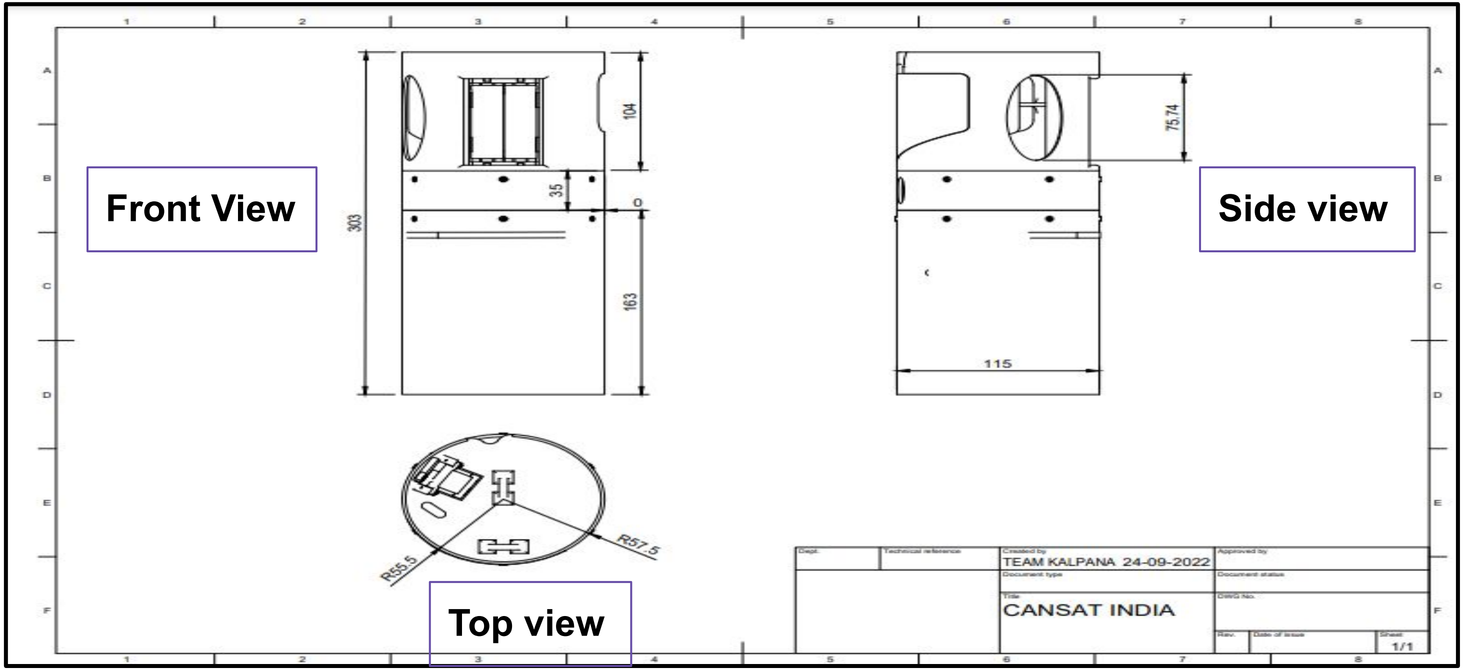
Physical Layout (1/8)

CANSAT Physical Layout

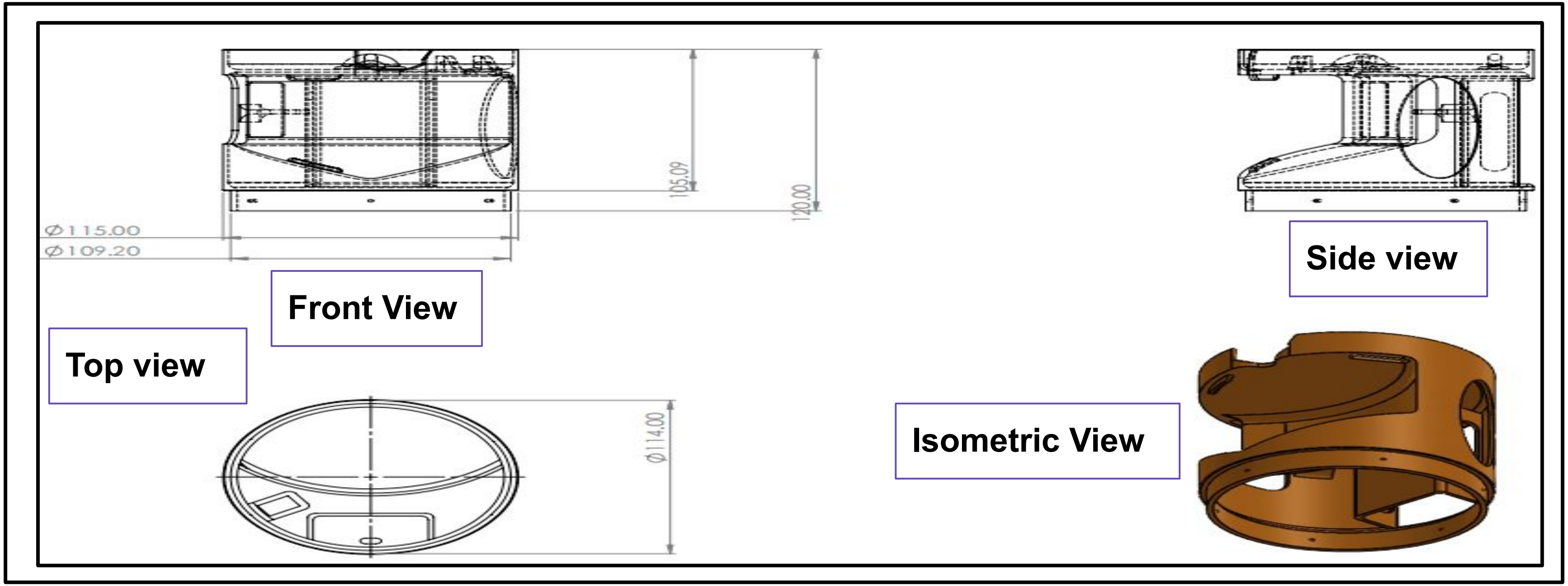


	Components	Dimensions
A	Parachute	Primary Parachute Diameter- 20.94cm Secondary Parachute Diameter- 204.15cm
B	Parachute Compartment	Height: 104mm Inner Diameter: 111mm Outer Diameter : 115mm
C	Electronic Compartment	Height: 35mm
D	Container	Height: 163mm
E	Gyro control system	Height: 119.63mm
F	Battery Compartment	Height: 22mm

Cansat Dimensional Drawing

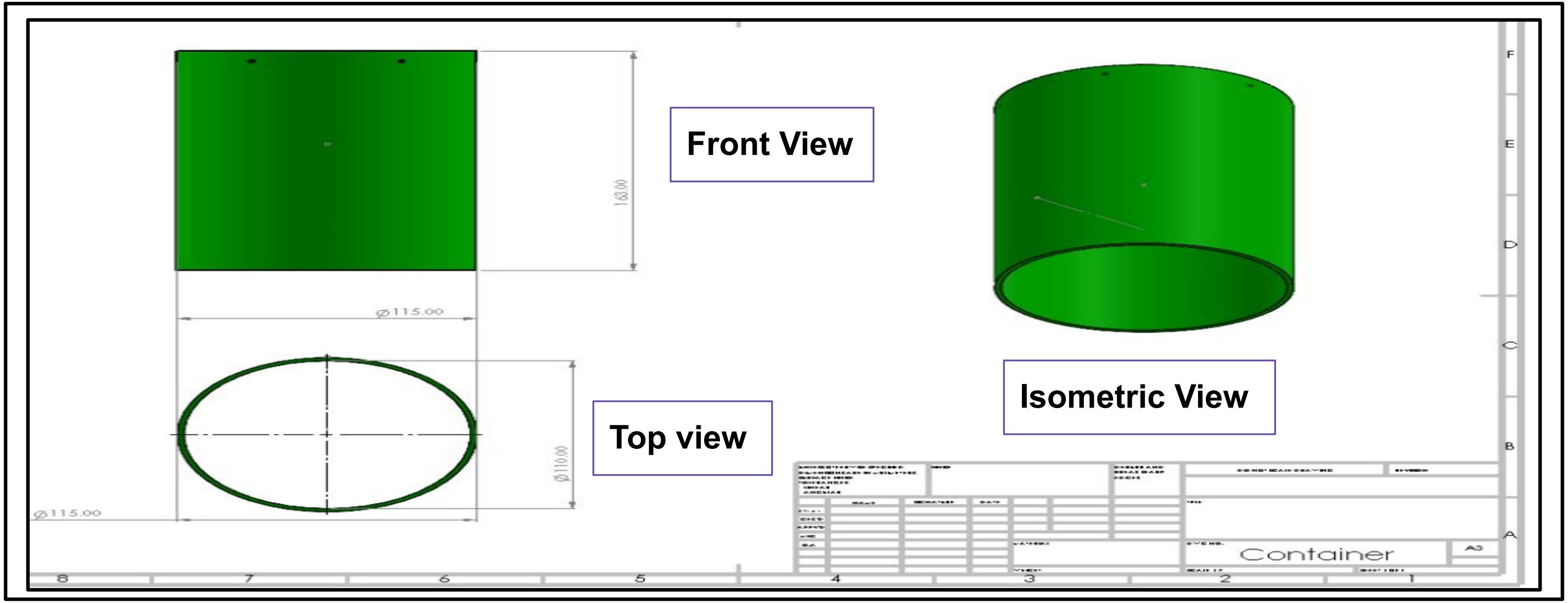


Parachute Dimensional Drawing



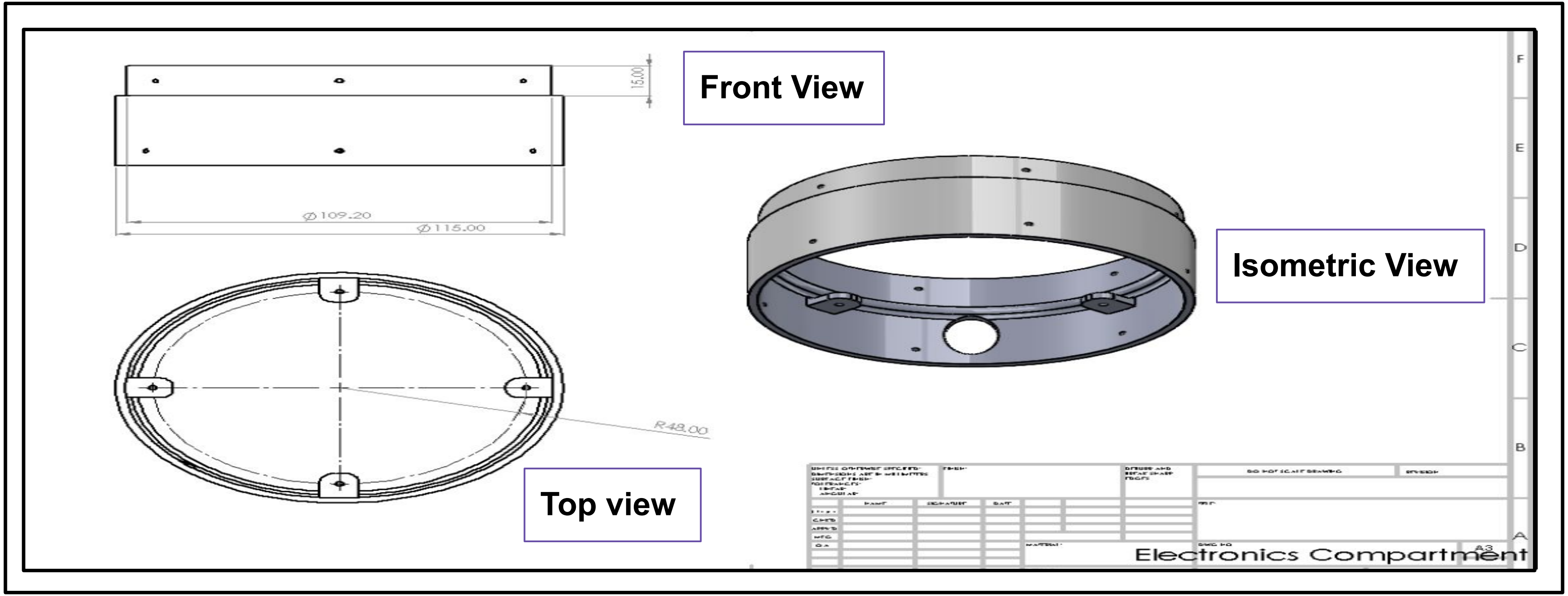
Physical Layout (4/8)

Container Dimensional Drawing

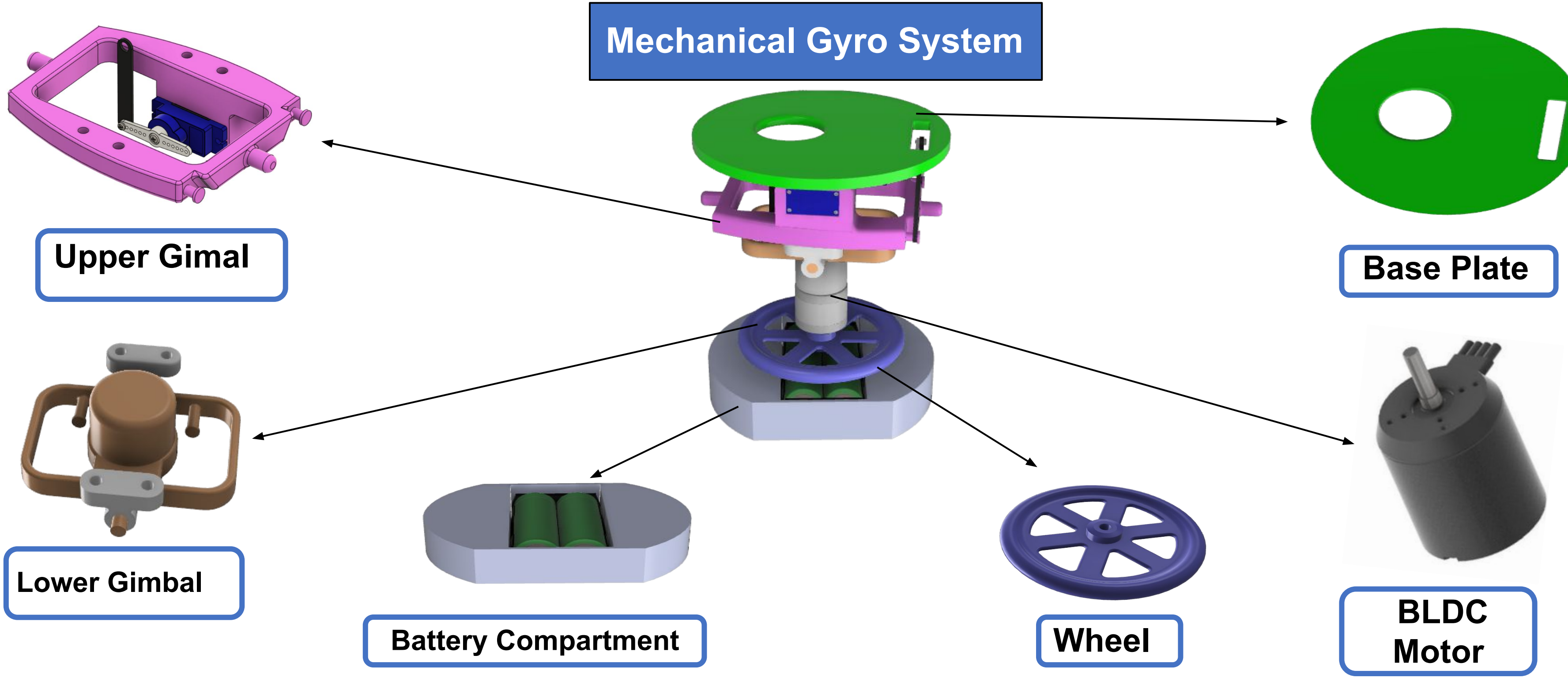


Physical Layout (5/8)

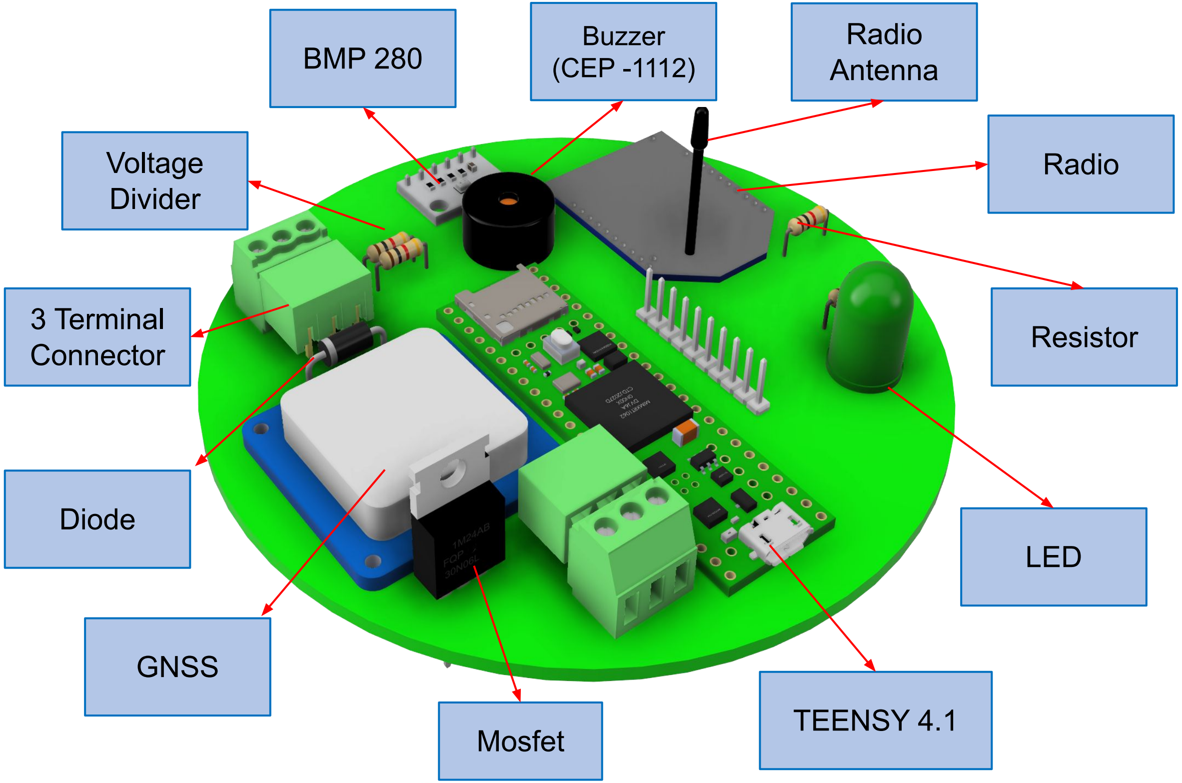
Electronic Compartment Dimensional Drawing



Physical Layout (6/8)



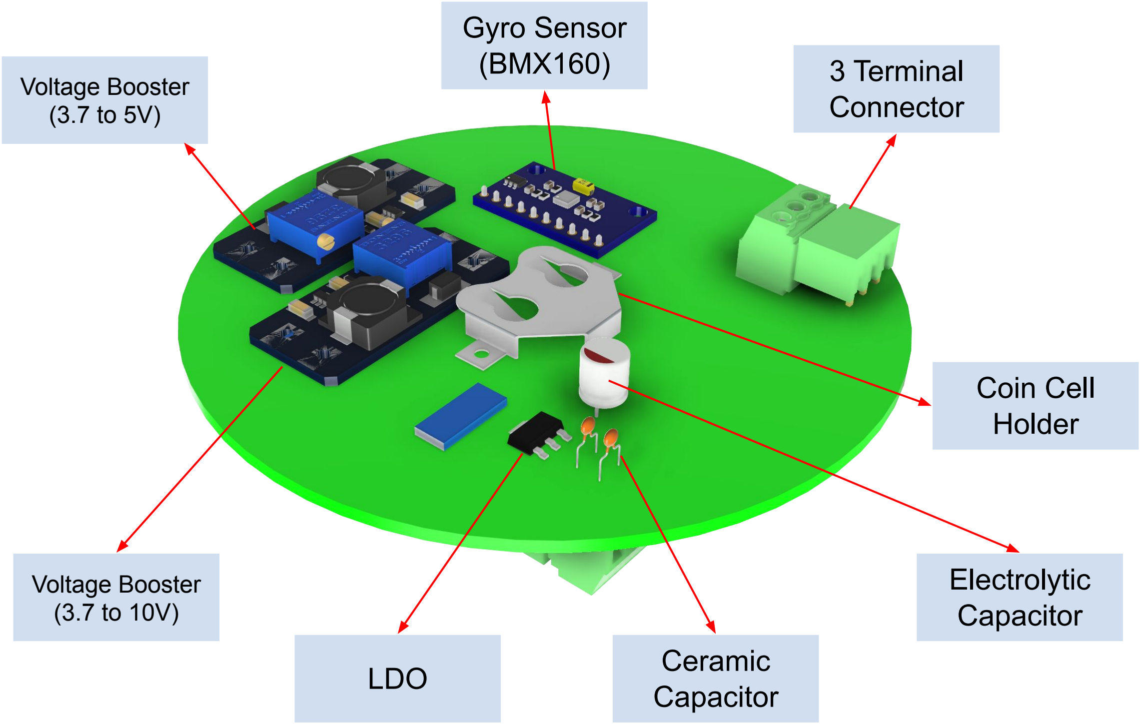
Physical Layout (7/8)



Front View of the PCB

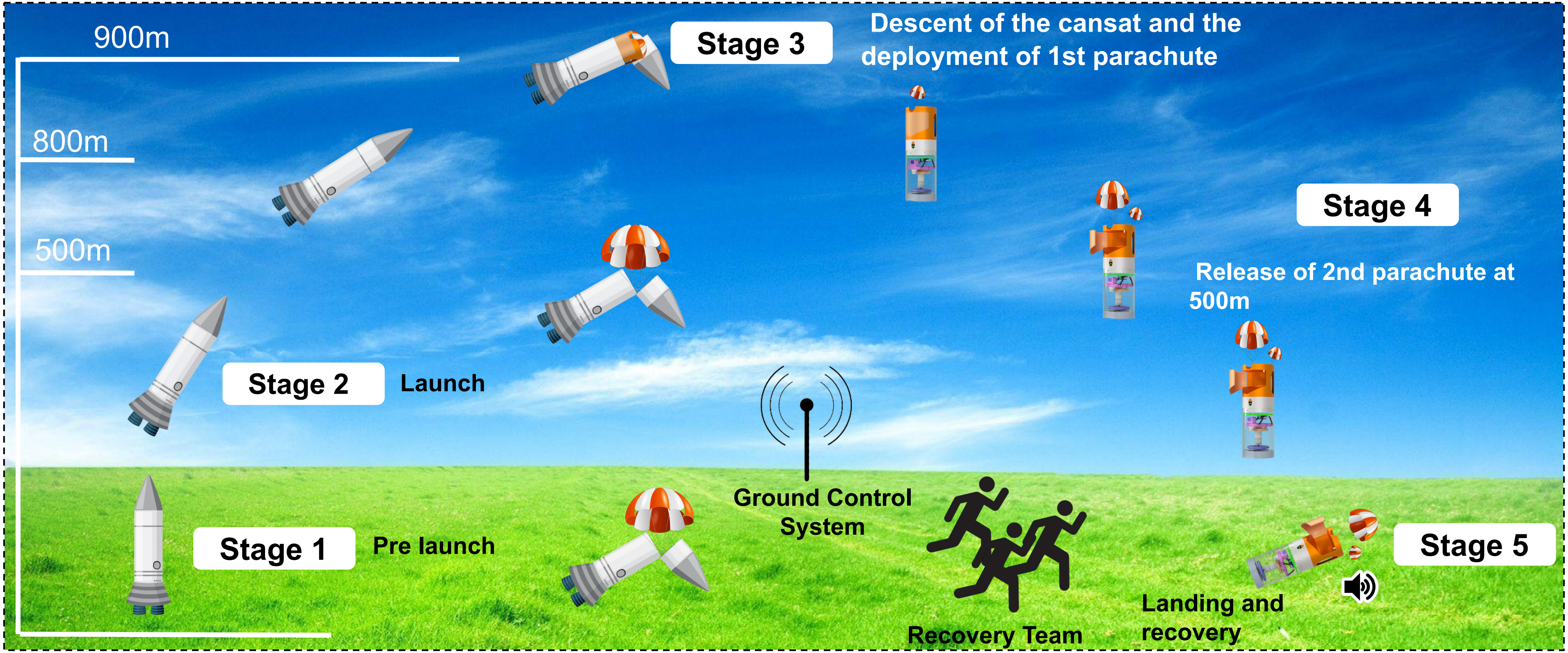
The Diameter of the PCB : **104mm**

Physical Layout (8/8)



Rear View of the PCB

System Concept of Operations (1/4)



System Concept of Operations (2/4)

PRE- LAUNCH STATE

1.CanSat is switched-on.

2.CanSat is placed in the rocket.

3.All mechanical systems, sensors, and telemetry facilities are checked for any dysfunctionality.

4.Ground station is linked with CanSat and CanSat is calibrated.

5.Telemetry transmission starts.

LAUNCH STATE

1.Rocket is Launched.
2.Altitude increases as rocket ascends.
3.Apogee reached at an altitude of 800 to 900m.

System Concept of Operations (3/4)

CANSAT DEPLOYMENT STAGE

1.CanSat is deployed from the rocket at an altitude of 800m to 900m from ground level.
3.CanSat immediately deploys the 1st parachute after ejection from the rocket.

CONTAINER DESCENT WITH FIRST PARACHUTE

1.Container descends with the first parachute at a speed of 20m/s +/- 5 m/s.
2.The container shall receive its own telemetry.

CONTAINER DESCENT WITH SECOND PARACHUTE

1.The Second parachute is deployed.
2.The container descent with the second parachute at an altitude of 500m +/- 10m.
3. The descent rate of cansat decrease from 20 m/s to (1 - 3) m/s.

System Concept of Operations (4/4)

THE MECHANICAL GYRO CONTROL SYSTEM

1.The whole cansat is stabilised by active gyro control mechanism.
2. We are using bias momentum control method.
3. The wheel is rotated and control by BLDC motor and axis of rotation is controlled using servo motors.

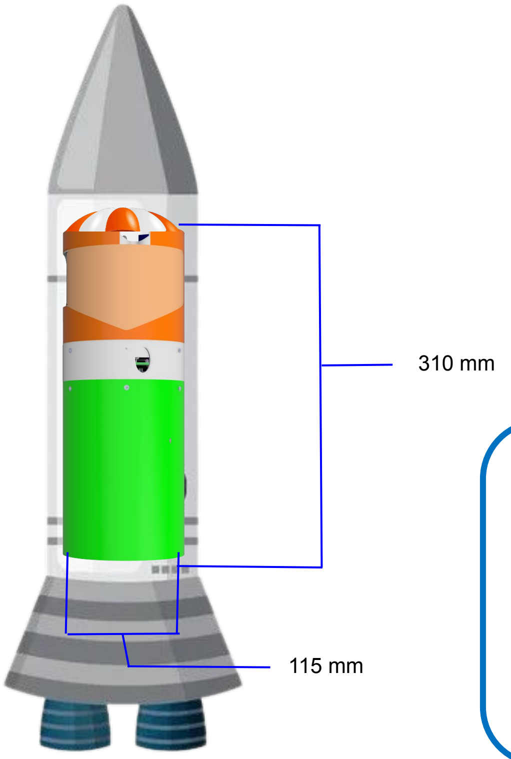
LANDING

1.The Audio Beacon on the container is activated to aid their recovery.
2.The container shall relay all telemetry sent from the payload until it lands.

CANSAT RECOVERY AND DATA REDUCTION

1.The container and payload are located.
2.SD Card is recovered from both the science payloads and the container.
3.The data is saved in the form of csv files at the GCS (different files for payload and container).
4.The PFR is prepared and presented.

Launch Vehicle Compatibility

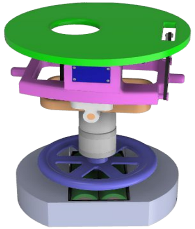


	Height (mm)	Width (mm)
Cylindrical Envelope	310mm	125mm
CanSat	303mm	115mm
Margin	**7mm**	**10mm**

- For easy integration of the CanSat into the rocket, height of cansat is **303mm** and width **115mm**.
- Descent rate is controlled by **dual deployment parachute** mechanism.
- There are **no sharp edges** on the surface of the cansat container as required for the competition.
- **Fit check** is done to make sure it meets launch vehicle compatibility.
- The Container is **not dependent** on the **rocket airframe** for any support to any component.

Optional Objectives

1. Novel descent control :-



- It is achieved by using bias momentum control method.
- It stabilised the whole cansat.

2. Additional innovative sensor and communication system :-

- BMX160, BMP280 and GNSS are used as sensors to measure and provide the telemetry data.
- Communication is through Xbee working at a frequency of 2.4 GHz.

3. Provision of video capture from separation till final touchdown :-

- It is achieved by using a Adafruit mini spy camera mounted on cansat.
- It will capture video throughout the flight and save it in SD card attached to it.

4. Innovative recovery techniques viz. HAM radio/ advance beacon :-

- GNSS telemetry will provide us the last known location which will help to locate it.
- We have used a Buzzer (CEP-1112) which will be powered at the time of final touchdown.
- The buzzer will produce sound (92 dB) which will help to recovery team to locate the Cansat.

5.Innovative quality and Reliability analysis methodologies:-

- Topology Optimization will be done once the designs will be getting finalized during the critical development review report.
- Ansys CAE will be done simultaneously to get the best reliable design and structural integrity.

Sensor Subsystem Design

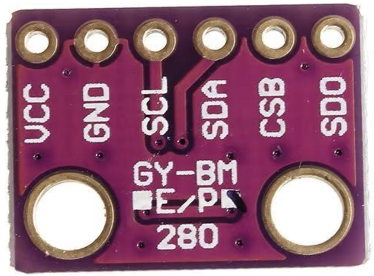
Sensor Subsystem Overview

Sensor Type	Model Selected	Function	Purpose
Gyro/Accelerometer	BMX160 Sensor	Measurement of Acceleration and angular rate (gyroscopic)	It has a Built-in timing unit for highly accurate sensor data fusion.
Camera	Adafruit Mini Spy Camera	Capturing the video during descent	It is light in weight and compact in size compared to other models.
GNSS (Global Navigation Satellite System)	SkyTraQ GNSS S1216F8 GI3	Determining the Location and tracking	It contains SkyTraq Venus 8 positioning engine inside featuring high sensitivity, fast TTFF allowing it to acquire, track, and get position fix autonomously in difficult weak signal environment.
Air Pressure/Temperature and Altitude	BMP 280	Measurement of air pressure/temperature and altitude	It has high accuracy and linearity with high EMC robustness which help it to work in wide range of temperature and emissions.
Battery Voltage Sensor	Onboard ADC + Voltage Divider	Measurement of battery voltage	As we do not require external module hence it is easier to implement and easy to use.

Air Pressure Sensor Trade & Selection

Model	Interface	Voltage (V)	Current (mA)	Accuracy (hPa)	Resolution (Pa)	Cost (₹)	Weight (g)	Dimensions (mm³)
MS5611-01BA03	I2C, SPI	5.0	1.40	±1.5	2.10	900	1.2	19.0 x 13.0 x 3.0
DPS310	I2C, SPI	3.3	3.00	±0.06	0.06	600	2.0	25.5 x 17.7 x 4.0
AMS 6915	I2C, SPI	3.3	4.00	±2.5	1.50	1300	2.0	20.0 x 10.0 x 2.0
BMP280	I2C, SPI	3.3	1.12	±0.12	0.16	80	2.0	15.0 x 12.0 x 2.0

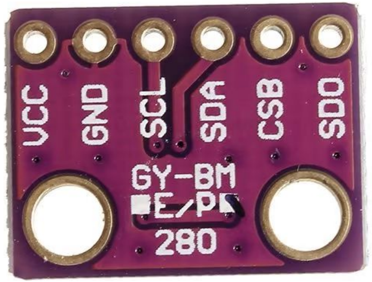
Selected	Reasons
BMP 280	• For less noise readings, capability of taking multiple measurements and performing a low pass filter. • It takes less resolution data for better calculations and data analysis. • It has high accuracy and linearity with high EMC robustness which help it to work in wide range of temperature and emissions. • It has wide range of 300 hPa - 1100 hPa.



Air Temperature Sensor Trade & Selection

Model	Interface	Voltage (V)	Current (mA)	Accuracy (℃)	Resolution (℃)	Cost (₹)	Weight (g)	Dimensions (mm³)
MS5611-01BA03	I2C, SPI	5.0	1.40	±0.8	0.01	900	1.2	19.0 x 13.0 x 3.0
DPS310	I2C, SPI	3.3	3.00	±0.5	0.01	600	2.0	25.5 x 17.7 x 4.0
AMS 6915	I2C, SPI	3.3	4.00	±0.5	0.70	1300	2.0	20.0 x 10.0 x 2.0
BMP280	I2C, SPI	3.3	1.12	±1.0	0.10	80	2.0	15.0 x 12.0 x 2.0

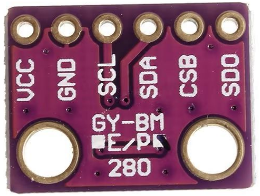
Selected	Reasons
BMP 280	● For less noise readings, capability of taking multiple measurements and performing a low pass filter. ● It takes less resolution data for better calculations and data analysis. ● It has high accuracy and linearity with high EMC robustness which help it to work in wide range of temperature and emissions.



Altitude Sensor Trade & Selection

Model	Interface	Voltage (V)	Current (mA)	Accuracy (m)	Resolution (m)	Cost (₹)	Weight (g)	Dimensions (mm^3)
MS5611-01BA03	I2C, SPI	5.0	1.40	±0.1	0.10	900	1.2	19.0 x 13.0 x 3.0
DPS310	I2C, SPI	3.3	3.00	±0.2	0.02	600	2.0	25.5 x 17.7 x 4.0
AMS 6915	I2C, SPI	3.3	4.00	±0.5	0.01	1300	2.0	20.0 x 10.0 x 2.0
BMP280	I2C, SPI	3.3	1.12	±1.0	0.10	80	2.0	15.0 x 12.0 x 2.0

Selected	Reasons
BMP 280	• For less noise readings, capability of taking multiple measurements and performing a low pass filter. • It takes less resolution data for better calculations and data analysis. • It has high accuracy and linearity with high EMC robustness which help it to work in wide range of temperature and emissions. • It has wide range of -500 - 9000m.



Hypsometric formula

$$h = \frac{\left(\left(\frac{P_0}{P}\right)^{\frac{1}{5.257}} - 1\right) \times (T + 273.15)}{0.0065}$$

Tilt Sensor Trade & Selection

Model	Interface	Voltage (V)	Current (mA)	Resolution			Cost (₹)	DOF	Dimensions (mm³)	Weight (gm)
				g	°/s	µT				
MPU9250	I2C ,SPI	3.3	4	2/16	250/16	4800/14	999	9	25x15x3.5	5
BNO055	I2C , UART	3.3	12.3	2/14	125/16	1300/14	5828	9	27x20x4	3
MPU6050	I2C	3.3	3.9	2/12	250/16	NA	190	6	20x16x4	2.1
BMX160	I2C	3.3	1.5	2/16	125/16	1150/14	1400	9	20x12x4	3

SELECTED	REASONS
BMX160	• It has a Small form factor. • Has integrated interrupts for enhanced autonomous motion detection. • Very low power consumption; typ. **1.6 mA** in high performance mode and comes with built-in power management unit (PMU) for advanced power management.

GNSS Sensor Trade & Selection

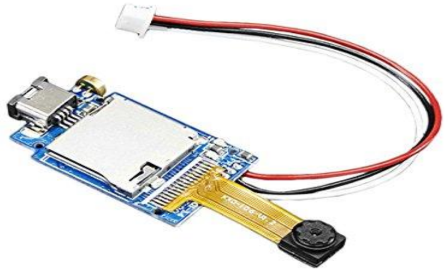
Model	Interface	Voltage (V)	Current (mA)	Accuracy	Cost (₹)	Dimensions (mm^3)	Weight (g)
QUECTEL L89	UART	3.3	99.0	VA < 0.1m/s || AA < 0.1m/s^2 || PA ~ 1.8m CEP	600	26.4 × 18.4 × 6.8	8.2
UTRAQ L100	UART	3.3	97.4	VA< 0.1m/s || AA < 0.1m/s^2 || PA ~ 2.5m CEP	4000	25.0 x 25.0 x 4.0	5.0
SIMCOM A7672X	UART	3.8	2000.0	VA~ 0.1m/s || AA ~0.1m/s^2 || PA : 2.5mCEP	500	24.0 x 24.0 x 0.15	10.0
SKYTRAQ GNSS S1216F8 GI3	UART	3.3	110.0	VA : 0.1 m/s || AA : 0.1m/s^2 || PA ~ 2.5m CEP	5499	16 x 12 x 2.9 (chip) 50 x 55 x 3 (BOB)	5.0

Selected	Reasons
SkyTraQ GNSS S1216F8 G13	• Supports **L5 Band (NavIC),** which we will use for our CanSat. • Support for **Automotive Dead Reckoning** with either built in sensors within the GNSS BOB or with external sensors. • Excellent **Tracking Sensitivity of < -160 dBm.** • Has **56 tracking channels** and **could track all in view satellites**; superior performance in challenging urban environments. • **ESD protection** for all interface pins. • **TTFF** : Cold Start < 30s; Hot Start ~1s.

Camera Trade & Selection

Model	Voltage (V)	Current (mA)	Resolution (px*px)	Cost (₹)	Weight (g)	Size (mm^3)
QUELIMA SQ23	5	36	1920x1080	6135	24	30 x 28 x 25
RASPBERRY PI CAMERA V2.1	5	250	1920x1080	3000	3	25 x 23 x 9
EACHINE 2503	3.8-5	200	1920x1080	2400	6	8 x 8 x 13
ADAFRUIT MINI SPY CAMERA	3.7-5	110	640x480	1000	2.8	28.5 x 17 x 4.2

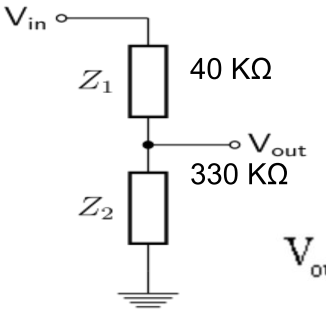
Selected	Reasons
ADAFRUIT MINI SPY CAMERA	• It has an integrated driver and is really easy to use without Arduino or Raspberry Pi. • Resolution(30 fps) meets mission requirements. • Small form factor i.e. it is small in size , and is lightweight. • Has an SD Card module included.



Battery Voltage Sensor Trade & Selection

Sensor	Interface	Voltage (V)	Resolution (Bits)	Cost (₹)	Weight (g)	Dimensions (mm³)
INA260	I2C	0 - 36	16	380	2	22.9 x 22.8 x 2.7
INA219	I2C	0 - 26	12	300	3	51 x 22.8 x 3.6
Voltage Detection Sensor Module 25V	Analog	0 - 25	10	69	4	28 x 14 x 13
Onboard ADC + Voltage Divider	Analog	0 - 3.3	12	NA	NA	NA

SELECTED	REASONS
Onboard ADC + Voltage Divider	• As we do not require external module hence it is easier to implement. • In Teensy 4.1 we have onboard Analogue to Digital Converter (ADC) through which we can read the battery voltage after Voltage Divider.



FORMULA

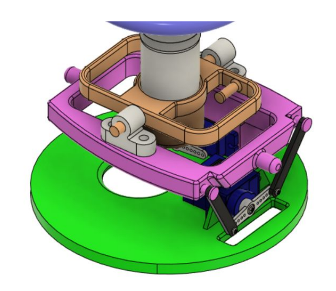
$$V_{out} = V_{in} \times \frac{Z_2}{Z_1 + Z_2}$$

Payload Subsystem Overview

Payload Subsystem Overview (1/2)

Reaction / Momentum Wheel

- Flywheels called **reaction/momentum wheels** are employed by any satellite/CanSat to provide stability and attitude control.
- The satellite responds by spinning when torque is applied to one of its axes by adding or subtracting energy from the flywheel.
- This energy is supplied using a motor attached to flywheel.
- **A single axis of the spaceship is stabilised by maintaining flywheel rotation, also known as momentum.**

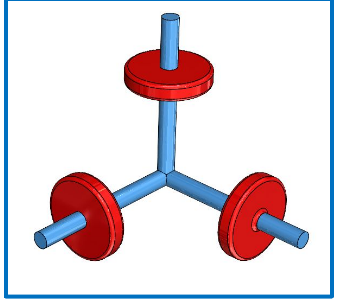


SELECTED

Configuration-2

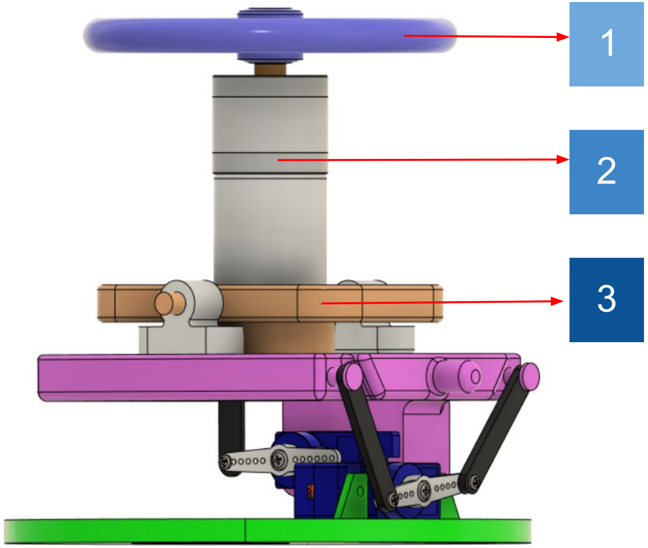
To give complete three-axis attitude control and stability, several reaction/momentum wheels can be utilised or **a single reaction wheel** can be used with a **combination of various gimbals and motors** to provide flexibility in the neutral axis of rotation.

Configuration-1



Payload Subsystem Overview (2/2)

Payload subsystem comprises of an innovative auto mechanical gyro control.



1. **Reaction Wheel** : The reaction wheel is mounted on a BLDC Motor shaft that controls and produces the desired rpm of the wheel.

2. **BLDC Motor** : The motor is selected over other type of motors because of its less weight and more rpm range. The motor is placed in a pocket formed at inner gimbal.

3. **Gimbals** : Two gimals are incorporated having relative rotational linkage whose axis rotation is controlled by two servo motors.

Descent Control Design

Descent Control Overview

Descent Control System

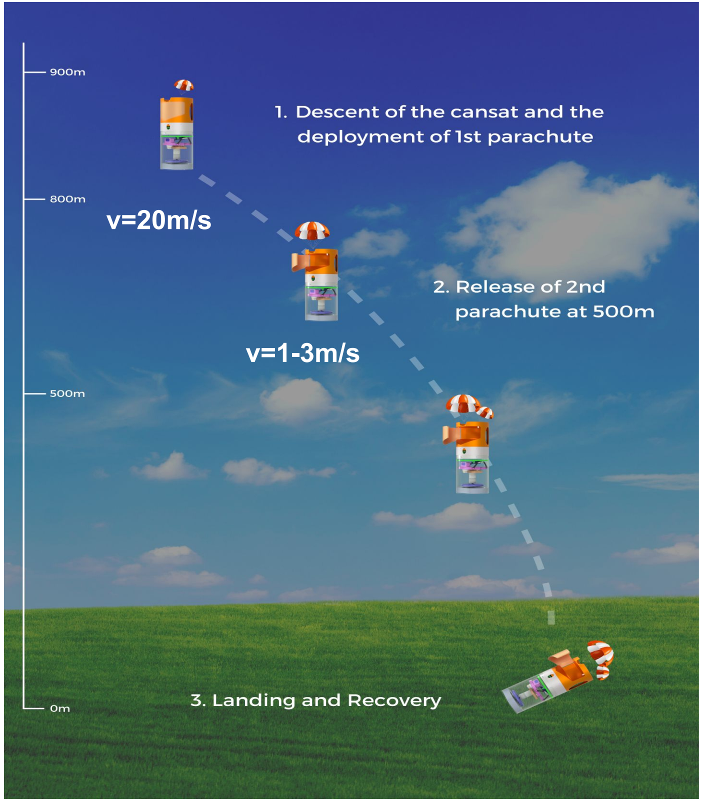
Container Descent: The container descends with the help of a **hexagonal parachute** of **diameter 20.94 cm** at a **descent velocity** of **20(+/-5)m/s**.

At the **altitude** of **500m**, **secondary** hexagonal parachute of **diameter 204.15 cm** is released to decrease the descent rate of the CanSat to **1-3m/s**.

Configuration

Parachute Compartment with an **accessible side lid** used for deployment of the **secondary parachute**.

Container Hexagonal Parachutes are made of **ripstop nylon** with **diameters 20.94 cm** and **204.15 cm**, respectively.



Parachute Descent Control Strategy Selection and Trade

Parachute Descent Control Strategy

Shape	Cruciform	Streamers	Flat Round Canopy	Hexagonal
Diameter (cm)	30.86	20.00	24	**20.94**
Drag Coefficient	0.75	0.50	0.45	**1.09**
Weight (g)	28	10	16	**14.65**
Descent Rate (m/s)	19.14	20	15.21	**20.01**
Cost (₹)	2042.40	1633.92	1388.83	**816.96**

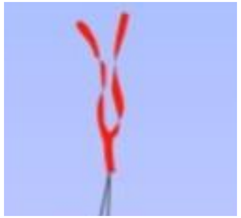
SELECTED : HEXAGONAL PARACHUTE

- **High** drag coefficient and made of **ripstop nylon.**
- **Lightweight** and easily **foldable** to fit in parachute compartment.
- **Stable** descent is achieved due to **spill hole** in the parachute design.

Cruciform

Flat Round Canopy

Hexagonal



Streamers

Descent Rate Estimates

$$v = \sqrt{\frac{2mg}{\rho C_d A}}$$

Formula Used: (For Descent using parachutes)

- **v = Descent velocity**
- **C_d = Coefficient of Drag**
- **m = mass of cansat Mas**
- **A_1= Area of Primary Parachute**
- **A_2= Area of Secondary Parachute**

Assumptions-

- The effect of crosswind is neglected.
- The value of (g) is taken 9.81 m/s^2
- The force due to gravity will be balanced by the drag force.

Calculation of first parachute:

- **m** = 700g
- **C_d** = 1.09 (including spill hole)
- **A_1** = 0.0252 m^2
- ρ = 1.2 kg/m^3

V_1 = **21.12m/s**

Calculation of second parachute:

- **m** = 700g
- **C_d** = 1.09(including spill hole)
- **A_1** = 0.0252 m^2
- **A_2** = 2.7077 m^2
- **A** = A_1+ A_2= 2.7329 m^2
- ρ = 1.2 kg/m^3

V_2= **1.96 m/s**

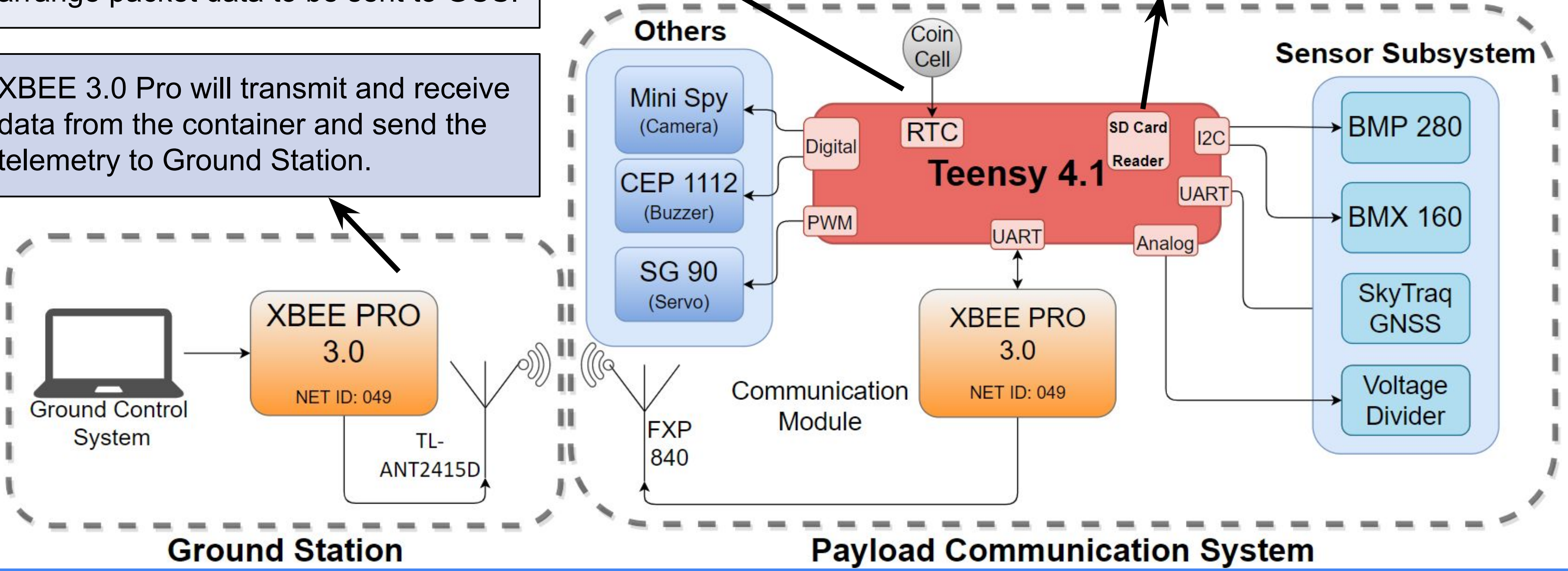
Communication and Data Handling (CDH) Subsystem Design

Command Data Handler (CDH) Overview

Teensy 4.1 is used to perform sensors acquisition, control actuators and arrange packet data to be sent to GCS.

XBEE 3.0 Pro will transmit and receive data from the container and send the telemetry to Ground Station.

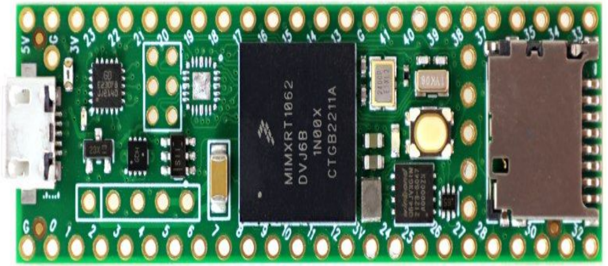
Telemetry Data will be stored in .csv file which will be stored in SD card using in-built in Teensy 4.1.



Processor & Memory Trade & Selection (1/5)

Model	Boot Time (ms)	Processing Speed(MHz)	Voltage (V)	Current (mA)	Memory (Flash) (RAM)	Pins	Communication Protocols	Cost (₹)	Weight (gm)	Dimensions (mm³)
ESP 32 WROOM	300	240	3.3	80	4 MB 520 KB	12 Digital 18 Analog 16 PWM	3x UART, 2x I2C 3x SPI	950	10	25.5 x 18 x 3.2
RASPBERRY PICO	700	133	3.3	90	2 MB 264 KB	23 Digital 3 Analog 16 PWM	2X UART, 2x I2C 2x SPI	450	15	51 x 21 x 4
PARTICLE PHOTON	20	120	5.0	120	1 MB 128 KB	18 Digital 10 Analog 9 PWM	1x UART, 1x I2C 2x SPI	570	5	36 x 20 x 6
TEENSY 4.1	5	600	5.0	100	8 MB 1 MB	42 Digital 18 Analog 35 PWM	8x UART, 3x I2C 3x SPI	3241	10	61 x 18 x 4

Selected	Reasons
TEENSY 4.1	• It has faster processing speed which helps us to use in various operations such as controlling Gyroscope Motors. • It has big **8 MB of Flash Memory** which helps us to store bigger programs like flight software. • It has **in built SD card slot and RTC**, so that external modules are not required. • Tightly Coupled Memory which allows us fast single cycle access to memory using a pair of 64 bit Bus. • The processor-ARM Cortex M7 is a dual-issue superscalar processor, meaning it can execute two instructions per clock cycle.



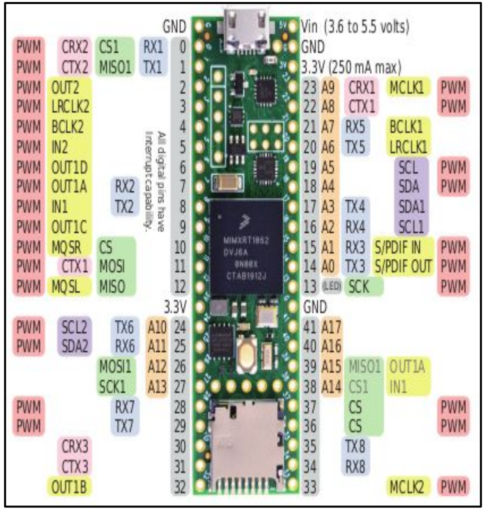
Processor & Memory Trade & Selection (2/5)

Teensy 4.1 runs off of the NXP iMXRT1062 IC, which is a 32-bit ARM Cortex-M7

- **Dual Issue Superscalar Architecture**
  Cortex-M7 is a dual-issue superscalar processor, meaning M7 can execute 2 instructions per clock cycle, at 600 MHz.
- **Branch Prediction**
  Cortex-M7 is the first ARM microcontroller to use branch prediction. On Cortex-M4 & earlier, loops and other code which much branch take 3 clock cycles. With M7, after a loop has executed a few times, the branch prediction removes that overhead, allowing the branch instruction to run in only a single clock cycle.
- **Tightly Coupled Memory**
  Allows Cortex-M7 fast single cycle access to memory.
  The DTCM bus is actually a pair of 32 bit paths, allowing M7 to perform up to 2 separate memory accesses in the same cycle.

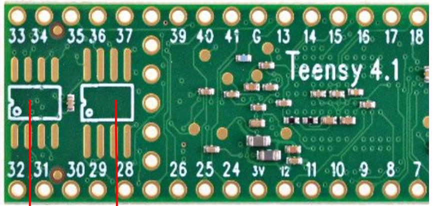
All digital pins have interrupt capability.

Teensy 4.1 is designed to bring all general purpose I/O pins to breadboard friendly pads on the outside edges.



Feature	Number of Pins
SDIO (4 bit data)	Micro SD Socket
PWM Pins	35
Analog Inputs	18
Serial Ports	8
Total I/O Pins	55

I2C	3 ports
SPI	3 ports
UART	8 ports



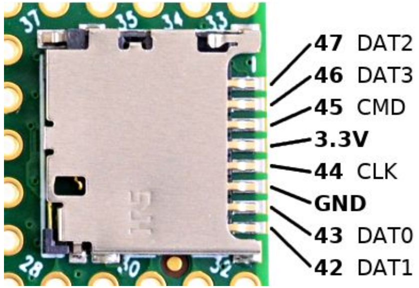
Meant for Flash Memory

Meant for SRAM

Flash Memory	8 MB
RAM	1 MB
EEPROM	4 KB

Model	Voltage (V)	Mass (g)	Size of sd card supported (GB)	Interface	Size (mm^3)	Cost (₹)
MINI microSD Card Reader	2.6-3.6	4	16	SPI	20 x 18 x 3	60
CATALEX microSD Card Reader	4.5-5.5	6	32	SPI	40 x 24x 4	70
SD Card Reader Writer Module for Arduino	3.3	8	32	SPI	47 x 31 x 3	90
TEENSY 4.1 Inbuilt SD card Reader	3.3	NA	32	SPI	NA	NA

SELECTED	REASONS
TEENSY 4.1 Inbuilt SD Card Reader	• No extra space and weight required as Inbuilt SD card Reader is present in Teensy 4.1. • Better Writing speed. • It works on lower voltage (3.3V).



Processor & Memory Trade & Selection (4/5)

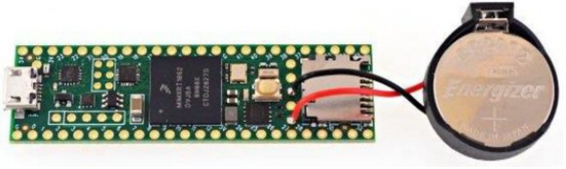
Model	Memory (GB)	Interface	Data Transfer Rate (Mb/s)	Writing Speed (MB/s)	Reading speed (Mb/s)	Cost (₹)
STRONTIUM NITRO	16	Mounted on SD Card Shield	85	80	95	359
SAMSUNG EVO	16	Mounted on SD Card Shield	80	20	80	479
TRANSCEND SD Card	16	Mounted on SD Card Shield	95	45	95	600
SanDisk Ultra	16	Mounted on SD Card Shield	98	51.5	99.5	395

Selected	Reasons
SanDisk Ultra	• It is more reliable and easy to use than using **EEPROM**. • A very stable data transfer rate **(98 Mb/s)** as compared to others. • It has good reading speed **(51.5 Mb/s)** and writing speed **(99.5 Mb/s).**

Real-Time Clock (5/5)

Model	Interface	Current (mA)	Voltage (V)	Accuracy (s/day)	Cost (₹)	Weight (g)	Dimensions (mm^3)
ADAFRUIT PCF8523	I2C	0.5	3/5	±2.0	550	2.2	21 x 20 x 12
DS3231	I2C	0.3	3/5	±0.3	320	8.0	38 x 22 x 14
DS1307	I2C	1	5	±1.0	60	5.0	27 x 28 x 8
Teensy 4.1 On board RTC	Analog	NA	3	±1.0	NA	NA	On Board

SELECTED	REASONS
Teensy 4.1 On board RTC	• As we do not require an external RTC module hence it is easier to implement RTC. • Teensy 4.1 have internal RTC we have to connect a coin cell to provide uninterrupted Date & Time.



Container Antenna Trade & Selection (1/2)

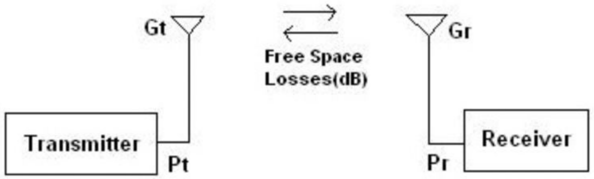
Model	Frequency Range(GHz)	In Power (W)	Impedance (ohm)	Range (km)	Gain (dBi)	Directivity	Cost (₹)	Weight (g)	Dimension (mm)
FXP 400	1.72-3.13	2	50	5.97	5.6 (for 2.2GHz)	Omni	1974.0	1.3	33 x 115 x 0.2
FXP 830.07.0100C	2.4- 5.8	2	50	4.24	2.55	Omni	745.5	7.0	42 x 77 x 0.2
FXP 72.07.0053A	2.4 - 2.5	5	50	4.29	4.4	Omni	316.2	1.2	31 x 30.4 x 0.2
FXP 840.07.0055B	2.4 - 2.5	2	50	4.39	3.6	Omni	621.4	1.0	14 x 5 x 0.1

SELECTED	REASONS
TAOGLAS FXP 840.07.0055B	• Made from flexible material thus, tolerant to mechanical deformations. • Tiny form factor (physical size and shape of component). • Particular model more easily available in Indian market.

Container Antenna Trade & Selection (2/2)

ANTENNA RANGE CALCULATION METHODOLOGY

- We've assumed the Receiver and Transmitter to be the same antenna
- Cable Loss = 3 dB
- Sensitivity = -80 dBm



Step-1: EIRP = Pt - Cable_loss + Gt

Step-2: FSL (Free Space Loss) = EIRP - Pr

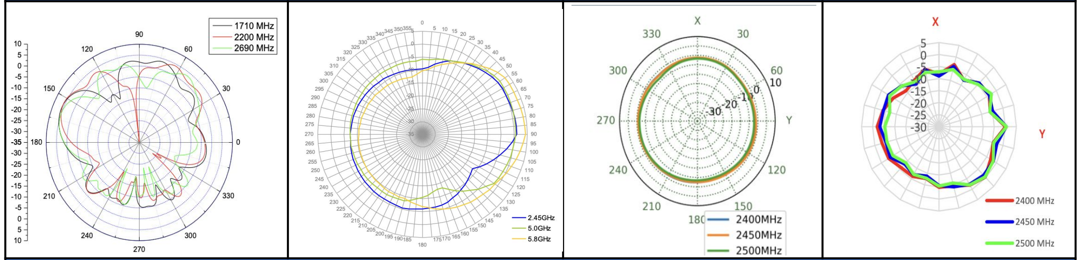
Step-3: dist = FSL + 20*Log10(Lambda) - 21.98

=>Antenna coverage distance = 10^(dist/20)

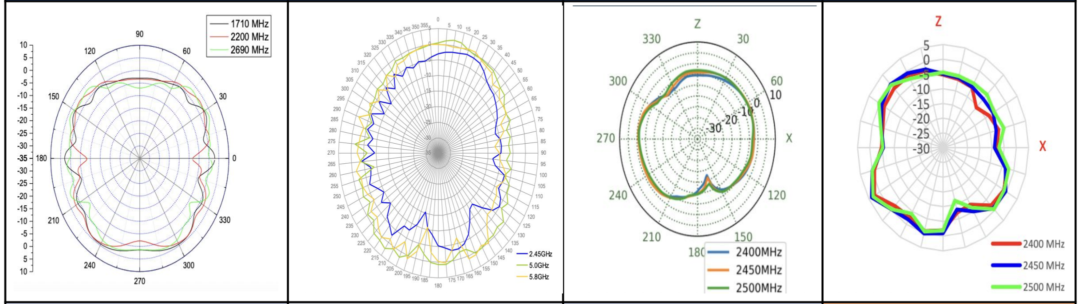
Transmit power = (Efficiency/100)*(input Power)

Power (W to dBm): $P\,(dBm) = 10 \times Log10(P(w)) + 30$

XY PLANE



XZ PLANE



FXP400.07.0100A	FXP830.07.0100C	FXP72.07.0053A	FXP840.07.0055B

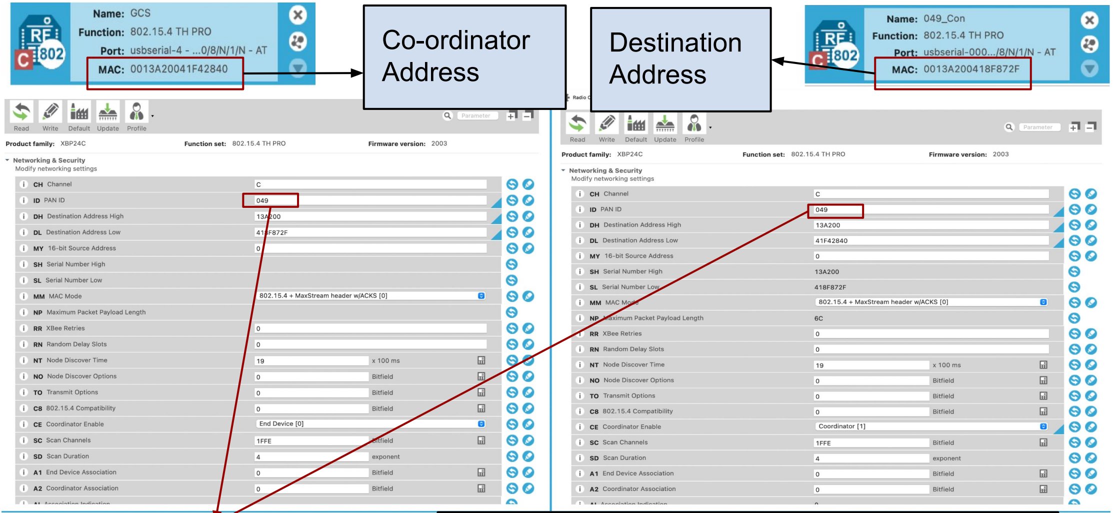
Payload Radio Configuration (1/3)

Model	Interface	Data Rate (Kbps)	Line of Sight (m)	Transmit Power (dBm)	Supply Voltage (V)	Supply Current (mA)	Cost (₹)	Dimensions (mm)	Sensitivity (dBm)	Weight (g)
Digi XB 3	UART,I2C, SPI	250	1200	+8	3.3	Tx : 40 Rx : 17	2085	TH: 24.38 x 27.61 SMT: 21.99x34x 3.05	-103	10
DIGI XBEE S2C 802.15.4	UART, SPI	25	1200	+8	3.3	Tx : 45 Rx : 31	1869	TH: 24.38 x 27.61 SMT: 19.9 x 34x 3.05	-102	8
Digi XBEE-PRO S2C	UART,SPI	250	3200	+18	3.3	Tx: 120 Rx: 31	2,399	TH: 24.38 x 32.94 SMT: 21.99x 34x3.05	-101	6
Digi XBEE 3 PRO 2.4GHz ZB3.0	UART, SPI, I2C	250	3200	+19	3.3	Tx : 135 Rx: 17	3,499	TH: 24.38 x 27.61 SMT: 21.99 x34x3.05	-103	10.8

SELECTED	REASONS
Digi XBEE 3 PRO 2.4GHz ZB3.0	• **Micro-Python-programmable** – RF connectivity for short range or Low Power Wide Area Network (LPWAN). • Offers **Design flexibility** – RF and cellular options. • Includes Zigbee 3.0 for mesh networking and Digi XBee 3 Cellular with the **latest LTE technologies like LTE-M and NB-IoT.**

NETID : 049

Payload Radio Configuration (2/3)



Co-ordinator Address

Destination Address

NETID : **049**

Container to GCS Transmission

Transmission Control

- **Transmission begins** when the Cansat is turned ON. The communication is established between the **GNSS** and the Cansat.
- **Transmission stops** on completing the landing stage of the cansat and all the data telemetry is saved in .csv file.

This stage is detected using sensors-

- When the air pressure sensor **(BMP 280)** measures maximum pressure.
- GNSS sensor returns the altitude of the launch site (i.e. the ground altitude)
- Accelerometer in rotation sensor **(BMX 160)** returns a sudden decreasing pulse value.

On landing buzzer activates.

Configuration

Coordinator : GCS Radio
Endpoint : Container Radio

Destination address: 0013A200418F872F
Coordinator address:0013A20041F42840

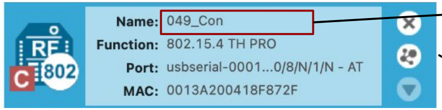
Xbee will communicate in Unicast mode.

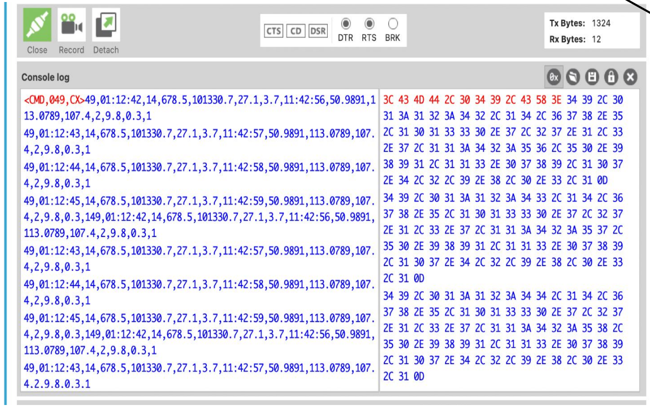
Xbee is set to send data packet to the GCS at a frequency of **1Hz.**

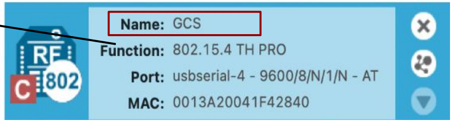
Payload Radio Configuration (3/3)

Container Xbee

GCS Xbee







Communication takes place between the Xbees on the container and the Ground Control Station

Blue indicates data that has been **sent** by Xbee.

Red indicates data that has been **Received** by Xbee.

Payload Telemetry Format (1/2)

S.No.	Parameter	Description
1.	<TEAM ID>	The id of the team.
2.	<TIME STAMPING>	Time count from the state of initial power.
3.	<PACKET COUNT>	Number of packets that have been transmitted.
4.	<ALTITUDE>	Altitude in meters relative to the ground. The resolution must be 0.1 meters.
5.	<PRESSURE>	Atmospheric pressure. The resolution must be 1 Pascal.
6.	<TEMP>	Temperature in degrees Celsius with a resolution of 0.1°C.
7.	<VOLTAGE>	Voltage of the CANSAT power bus. The resolution is 0.01V.
8.	<GNSS TIME>	Time in seconds generated by the GNSS receiver.

S.No.	Parameter	Description
9.	<GNSS LATITUDE>	Latitude coordinates generated by GNSS receiver with a resolution of 0.0001 degrees.
10.	<GNSS LONGITUDE>	Longitude coordinates generated by GNSS receiver with a resolution of 0.0001 degrees.
11.	<GNSS ALTITUDE>	Altitude in meters generated by GNSS receiver. The resolution is 0.1 meters.
12.	<GNSS SATS>	Number of satellites being tracked by GNSS This is an integer number.
13.	<ACCELEROMETER DATA>	Data received from the gyroscopic sensor including acceleration and roll & pitch parameter in m/s^2.
14.	<GYRO SPIN RATE>	Spin rate of Mechanical Gyro wrt CANSAT in degrees per second.
15.	<FLIGHT SOFTWARE STATE>	Operating state of the software (eg. launch wait, ascent, decent).

Payload Telemetry Format (2/2)

Telemetry Data Format

<TEAM ID>,<TIME STAMPING>,<PACKET COUNT>,<ALTITUDE>, <PRESSURE>, <TEMP>,<VOLTAGE>,<GNSS TIME>,<GNSS LATITUDE>,<GNSS LONGITUDE>, <GNSS ALTITUDE>,<GNSS SATS>,<ACCELEROMETER DATA>, <GYRO SPIN RATE>, <FLIGHT SOFTWARE STATE>,<ANY OPTIONAL DATA>

Telemetry Sample Data

49,01:12:42,14,678.5,101330.7,27.1,3.7,11:42:56,50.9891,113.0789,107.4,2,9.8,0.3,1

The Data Rate of Packets

The frequency of data transfer rate is **1Hz**.

The CSV file containing our telemetry is named as **FLIGHT_2022ASI049.csv**

Above data format matches competition guide requirements

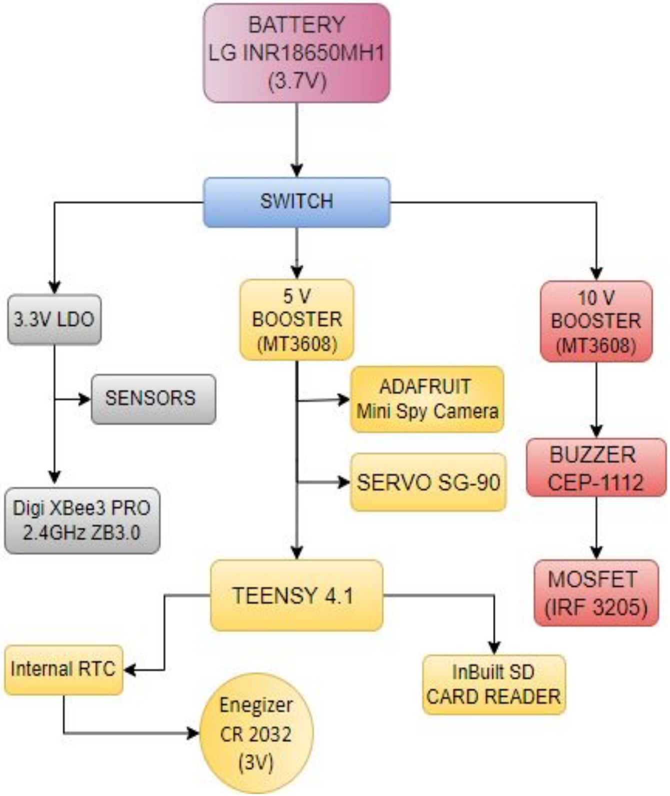
Payload Command Formats

S.No.	Command Name	Description	Command Format	Example
1.	CX (Telemetry ON/OFF Command)	This command is used to turn on/off the telemetry.	CMD,<Team_ID>,CX,ON/OFF	CMD,049,CX,ON CMD,049,CX,OFF
2.	SET TIME	This command is used to set the mission time.	CMD,<Team_ID>,SET_TIME,<IST_Time>	CMD,049,SET_TIME,10:08:49
3.	CALIBRATE	This command calibrates gyros, barometric altitude, accelerometer.	CMD,<Team_ID>,CALIBRATE,<mode>	CMD,049,CALIBRATE
4.	SIM ENABLE	This command is used to send control status of the simulation mode.	CMD,<Team_ ID>,SIM_ENABLE	CMD,049,SIM_ENABLE
5.	SIM DISABLE	This command is used to send control status of the simulation mode.	CMD,<Team_ID>,SIM_DISABLE	CMD,049,SIM_DISABLE
6.	SIM ACTIVATE	This command is used to send control status of the simulation mode.	CMD,<Team_ID>,SIM_ACTIVATE	CMD,049,SIM_ACTIVATE
7.	ON	To Start FSW Logic.	CMD,<Team_ID>,<ON>	CMD,049,ON
8.	OFF	To Stop FSW Logic.	CMD,<Team_ID>,<OFF>	CMD,049,OFF

Electrical Power Subsystem (EPS) Design

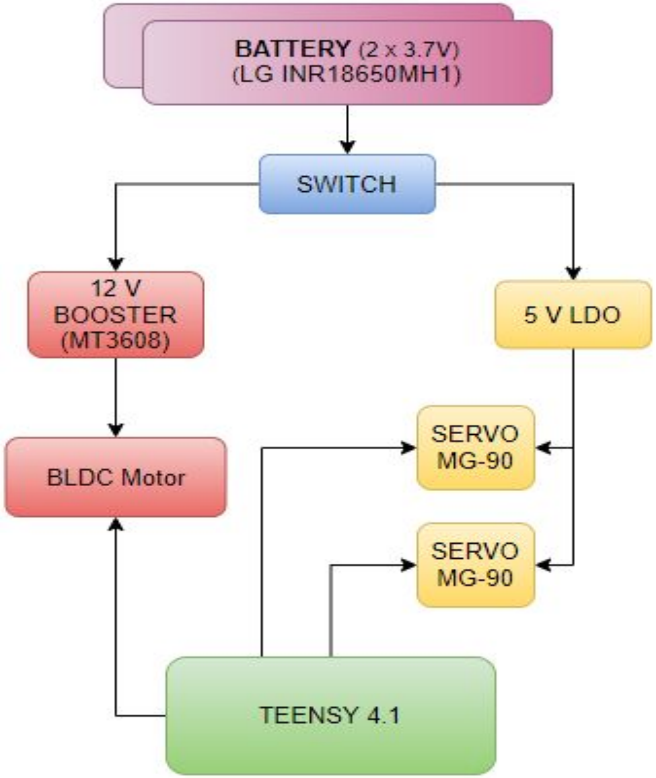
EPS Overview (1/2)

Components	Description
Power **(Battery and coin cell)**	Battery is used to supply power to all components. The coin cell is used to power **RTC** in **Teensy 4.1.** An external power switch is used to connect or disconnect the power.
Sensors **(BMP280, BMX160, GNSS, Adafruit Mini Spy Camera)**	The sensors will collect temperature, pressure, orientation and acceleration data. The GNSS will collect the position parameters. They will be supplied **3.3V** **Camera** will record video and save it in SD card. It will be supplied **5 V.**
MCU **(TEENSY 4.1)**	It will collect all data from sensors and drive the Descent Control Mechanisms.
Communications **(Digi XBee 3 PRO ZigB3.0)**	It will transmit the telemetry data and receive the commands.
Others **(Buzzer, LED, servo, boost converter, voltage regulator)**	**Buzzer(CEP112)** will be used as a audio beacon when the payload lands. **LED** is used as an indicator for the power being turned ON/OFF. A voltage regulator is used to supply 3.3 V to all sensors and **XBEE.** Servo will be used to execute Descent Control Mechanism. Boost converters are used to step up **3.7 V to 5 V** and one for **3.7 V to 10 V**.



EPS Overview (2/2)

Components	Description
Power	**Two batteries (LG INR18650MH1)** are connected in series to provide a voltage of **7.4V** (3.7V x 2). These batteries will be used to power up the whole **Mechanical Gyro** System.
Motor	Gimbal Brushless DC Motor (**BLDC Motor**) is used which will be supplied 10V. **Two servo motors (MG-90)** are used which will be supplied 5 V.
Switch	A switch is used to turn on/off the power.
Others (Boost converter, Voltage regulator)	A voltage Booster (**MT3608**) is used to step up from **7.4V to 12V**. And a voltage regulator is used to supply a voltage of **5V** to the servo motors.

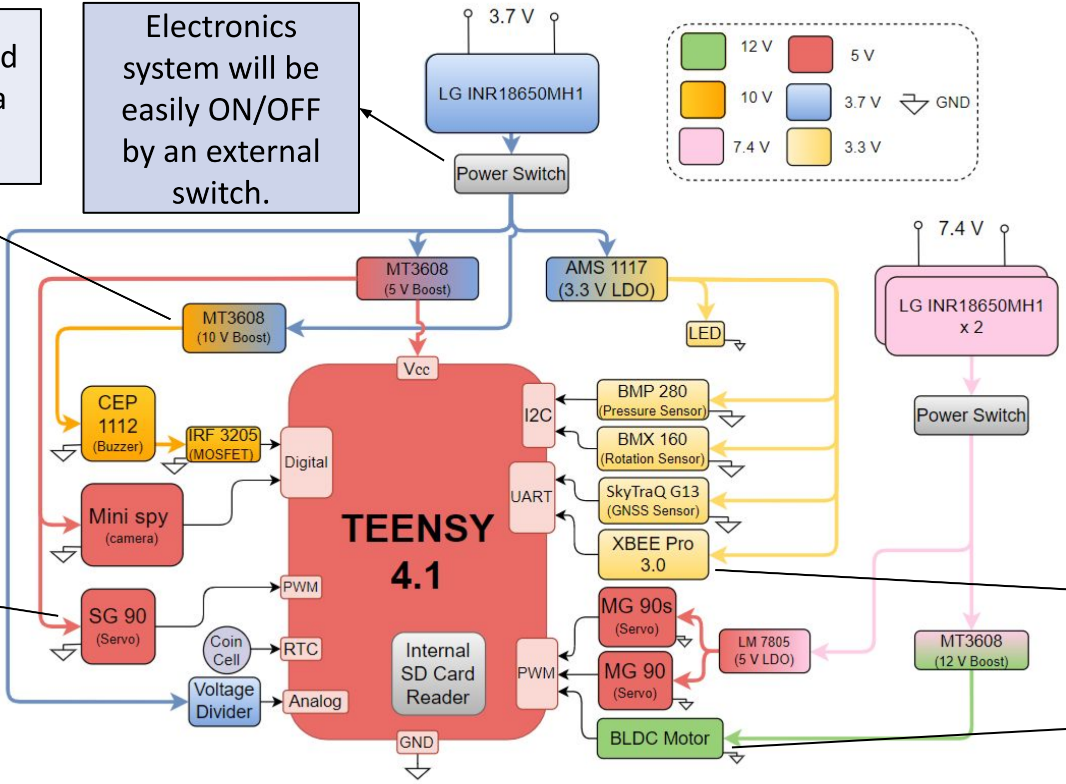


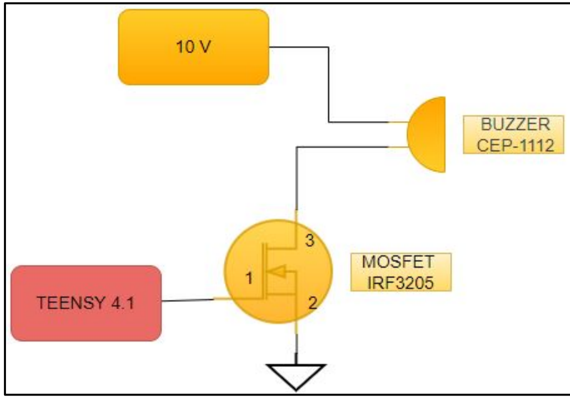
Electrical Block Diagram

Buzzer is powered with 10 V from a voltage booster.

Electronics system will be easily ON/OFF by an external switch.

A servo is used to deploy the parachute by opening the lid of parachute compartment





Buzzer is powered with 10 V from a voltage booster.

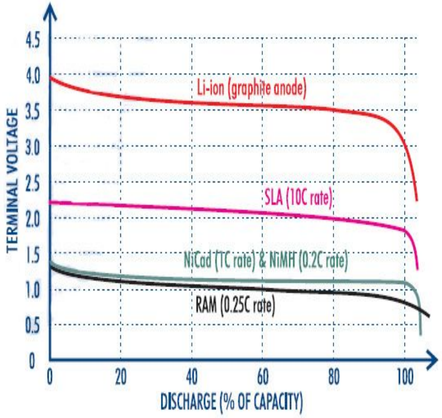
XBEE Pro 3 will transmit telemetry to Ground Control Station having NETID 049

Brushless DC motor will be used in GYRO Control Mechanism

Power Trade & Selection (1/2)

Model	Type	Voltage (V)	Capacity (mAh)	Cost (₹)	Weight (g)	Dimensions (diameter x height in mm)
Panasonic NCR18650B	Li-ion, RCBL	3.6	3200	899	48.5	18 x 65
Orange ISR 18650	Li-ion, RCBL	3.7	2500	349	44	18 x 65
Intrinsic TA041539	Li-ion, RCBL	7.4	2200	1040	90	36 x 65
LG INR18650MH1	Li-ion, RCBL	3.7	3200	699	49	18 x 65

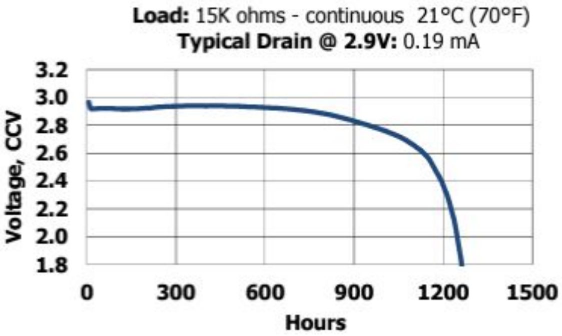
SELECTED	REASONS
LG INR18650MH1	• Higher energy density; Higher energy stored per unit volume of battery (3.7 V and 3200 mAh capacity). • Rechargeable with no ‘memory effect’; providing a complete charge with each cycle. • Lasts 800 cycles of recharging. • Max. continuous discharge current as high as : 10A, and an internal Impedance as low as 7 mΩ.



Power Trade & Selection (2/2)

Model	Voltage (V)	Type	Capacity (mAh)	Operating Temperature (°C)	Cost (₹)	Weight (g)	Dimensions (Diameter x Height in mm)
CR 1220	3	Lithium	35	-30 to +60	40	0.9	12.0 x 5.0
CR 2025	3	Lithium	170	-30 to +60	70	2.6	20.0 x 2.5
CR 2450	3	Lithium	620	-30 to +60	75	6.3	24.5 x 5
CR 2032	3	Lithium	225	-30 to +60	65	3.0	20.0 x 3.2

SELECTED	REASONS
Energizer CR 2032	• High Current Capacity so as to complete our requirements of flight timings. • CR2032 Battery holder are easy to access. • Very Low self Discharge and Very High power to weight ratio.



Flight Software (FSW) Design

FSW Overview

Overview

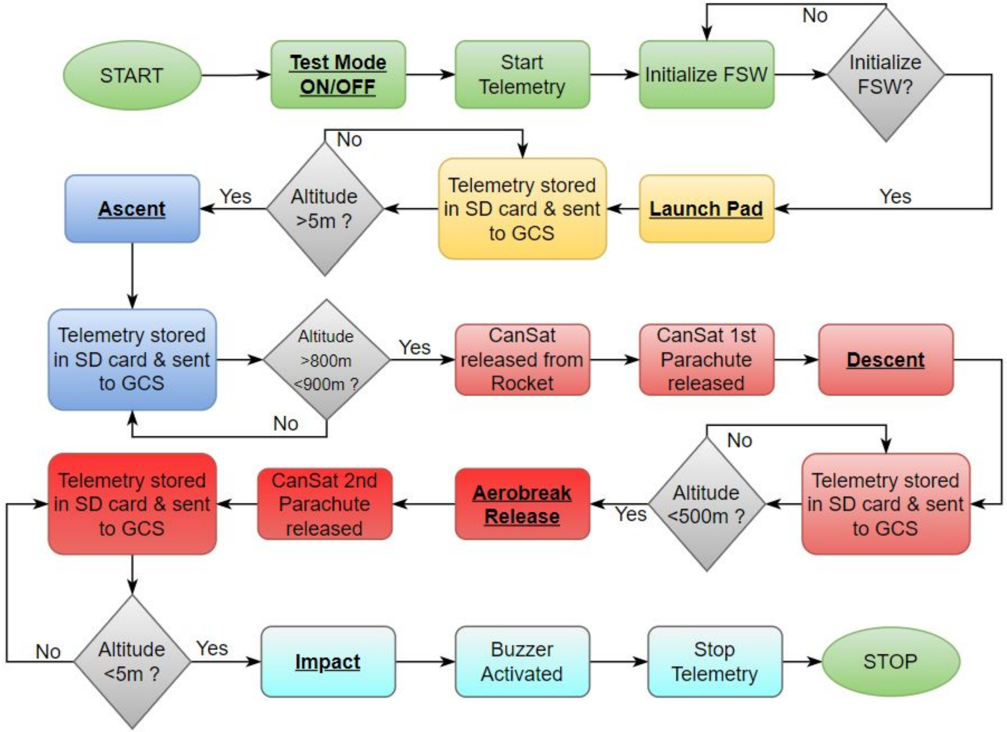
- The CanSat will collect sensor data, store in SD card and send to the Ground Control Station via XBEE.
- Ground Control Station will send the various commands like CX,SET TIME,Calibrate etc.

Programming Languages

- C++ is used for CanSat data processing and Transmission of Telemetry.
- GUI of Ground Control Station is made using Python.

Development Environment

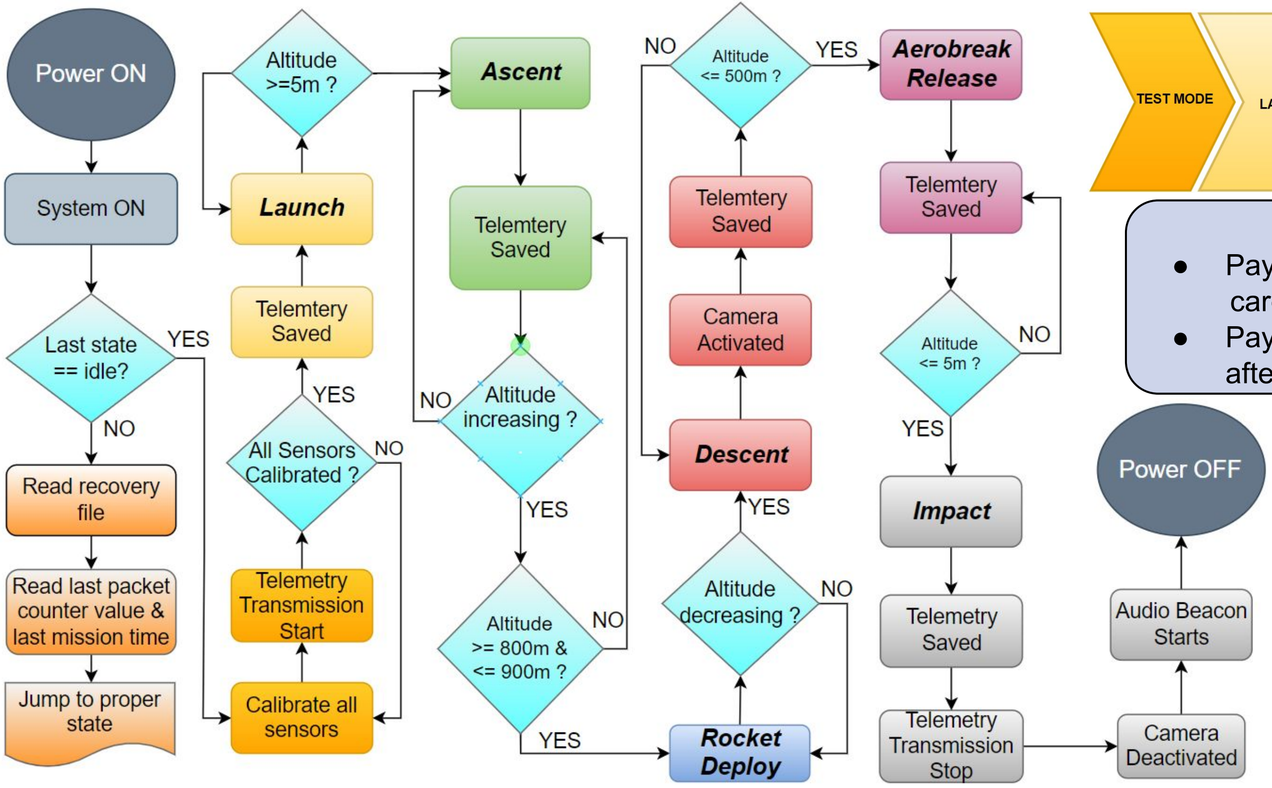
- Arduino IDE is used for CanSat MCU.
- PyCharm is used for GUI development.
- XCTU for XBEE 3 Pro Configuration.

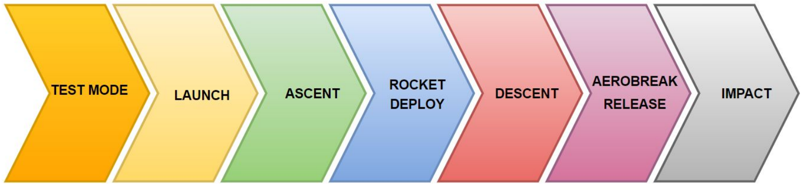


FSW State Diagram (1/4)

TEST_MODE	LAUNCH_PAD	ASCENT	ROCKET_DEPLOY	DESCENT	AEROBREAK_RELEASE	IMPACT
This mode is used to calibrate and set all the sensors for the flight.	Telemetry is storing in .csv file and sending to GCS has been started.	Payload ascents till 900m in the rocket.	At the apogee the payload is released from the rocket and descent starts.	1st Parachute is released to descent at 20m/s.	2nd Parachute is released to decrease descent rate to 3m/s	Payload will be on the ground and Audio Beacon
• Sensors are calibrated and checked. • Set Time for flight. • Simulation Mode is enabled by commands form GCS.	• Payload Activation commands will be received. • Sensors data saved to SD card and sent to GCS via XBEE.	• If Altitude is between 800m to 900m, move to next state. • Sensors data saved to SD card and sent to GCS via XBEE.	• Payload is deployed from the rocket. • Sensors data saved to SD card and sent to GCS via XBEE.	• If Altitude is less than 500m, move to next state. • Sensors data saved to SD card and sent to GCS via XBEE.	• If Altitude is less than 5m, move to next state. • Sensors data saved to SD card and sent to GCS via XBEE.	• Audio Beacon is Activated. • Sensors data saved to SD card and sent to GCS via XBEE have been stopped. • Power OFF.

FSW State Diagram (2/4)



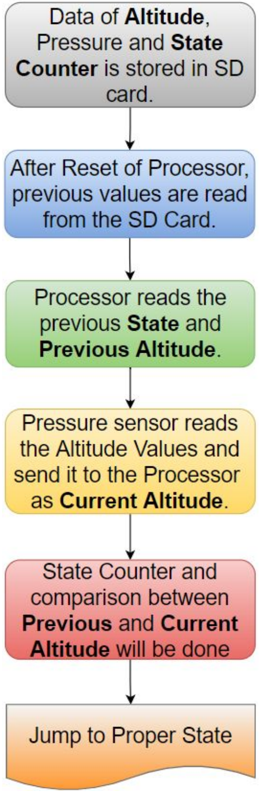


Telemetry Data

- Payload Telemetry Data is stored in the SD card @ 1Hz.
- Payload will start transmitting telemetry @ 1Hz after the activation is received from the GCS.

- Two variables **Present Altitude** & **Previous Altitude** have been made to check if the altitude is increasing or decreasing.
- The communication between Payload and GCS takes place via XBEE 3 Pro.

FSW State Diagram (3/4)



Reset Reasons

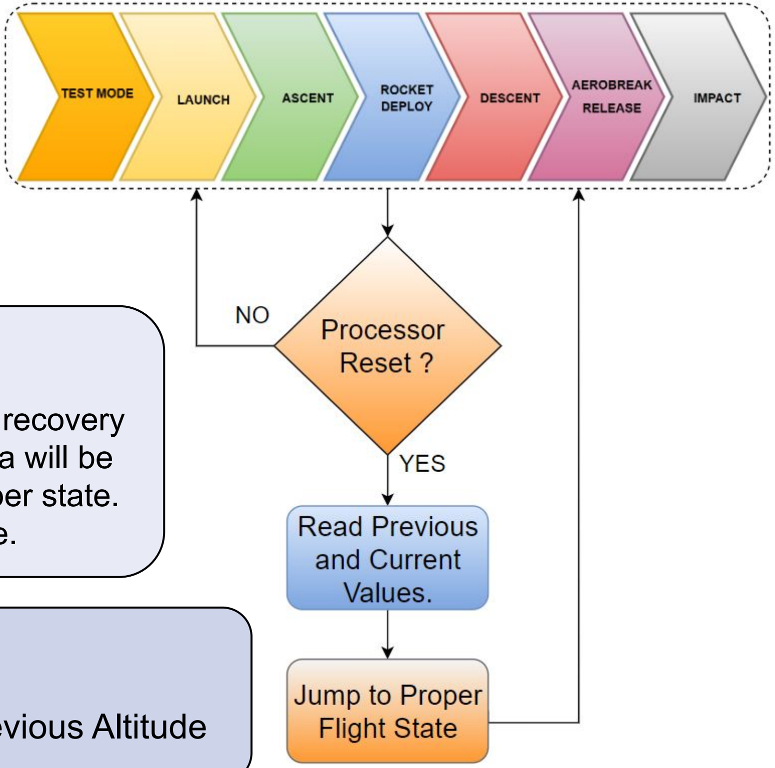
❑ Shock Impact in the rocket while Ascent.
❑Voltage Drop due to any glitch in Power Transmission.
❑High Temperature affecting the Processor.

Method

To recover state after restart, microcontroller will read recovery file and check if it was unwanted restart. If it was, data will be saved to variables and state selector will jump to proper state. In other case, state selector jumps to state Idle.

Data Used To Recover

- State Counter
- Current Altitude
- Previous Altitude



FSW State Diagram (4/4)

Processes	Description
Sampling Of Sensors	The Sampling Of Sensors starts when the Payloads gets the command of SIM Enable to start simulation in the Launch_Pad mode.
Communications	The communications between Payload and Ground Control Station is done via XBEE 3 Pro having NETID 049.
Data Storage	The Data from all the sensors is saved in the SD card with the help of In-built SD card reader in Teensy 4.1.
Mechanisms Activations	At 500m, Second Parachute is released to decrease the descent rate to 1 - 3 m/s. After landing (altitude < 5m), Audio Beacon is started and Telemetry Transmission stops.
Major Decision Points	During the flight, unwanted resets occur due to various reasons hence a backup of data is made so that processor can read and jump to proper state.
Power Management	When some of the components are not in use then those components are switched into standby mode which help us to conserve power.

Simulation Mode Software

To enter simulation mode Ground Station should send two commands (**SIM ENABLE** and **SIM ACTIVATE**) to Payload. Two commands are required to prevent accidental initiation. Then GS will start sending air pressure values at **@ 1Hz** to payload via XBEE 3 Pro. FSW will use received values in place of real data from pressure sensor. It will let FSW calculate simulated altitude used by software logic.

Ground Control Station

SIM ENABLE & **SIM ACTIVATE** are sent to start the simulation mode.

<Pressure> readings are sent from GCS.

<Pressure>

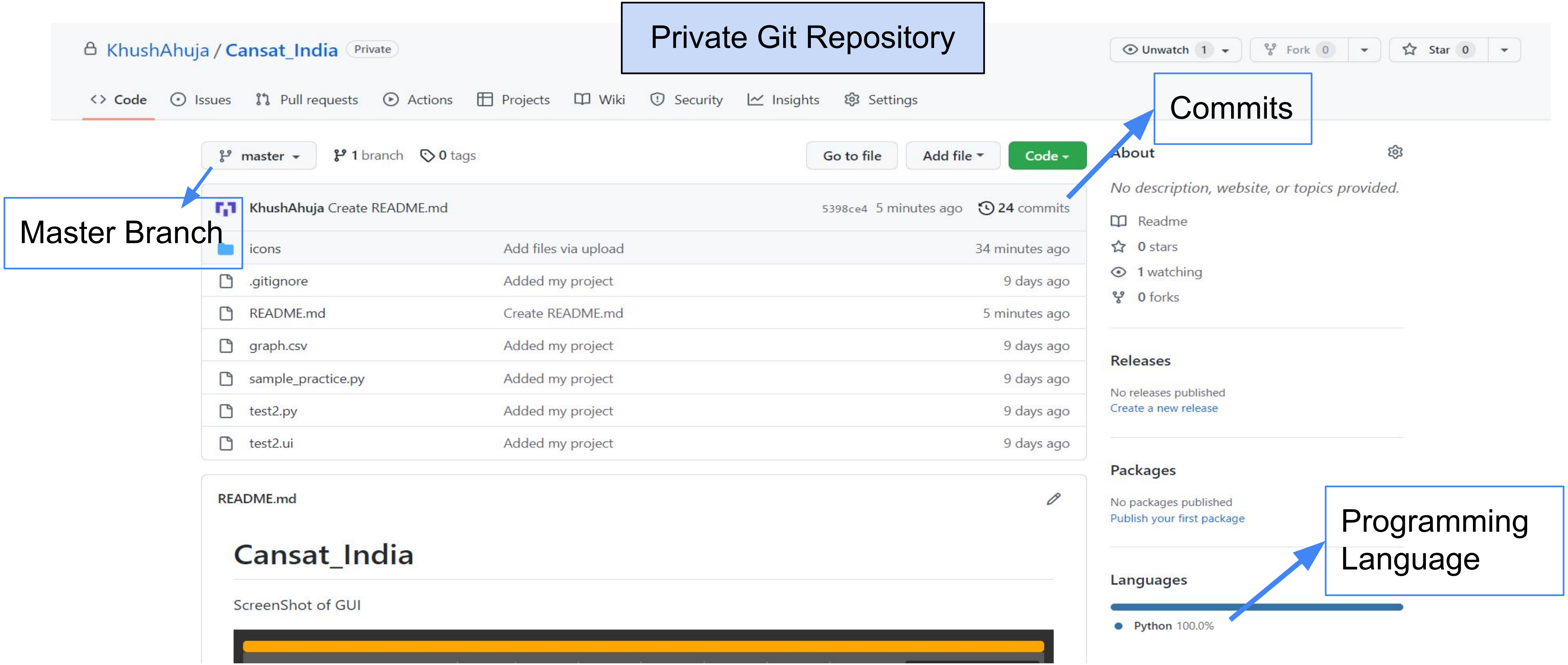
Data with substituted altitude calculated from given Pressure. Looping will be continued until the **SIM DISABLE** command is received from GCS.

<Altitude>

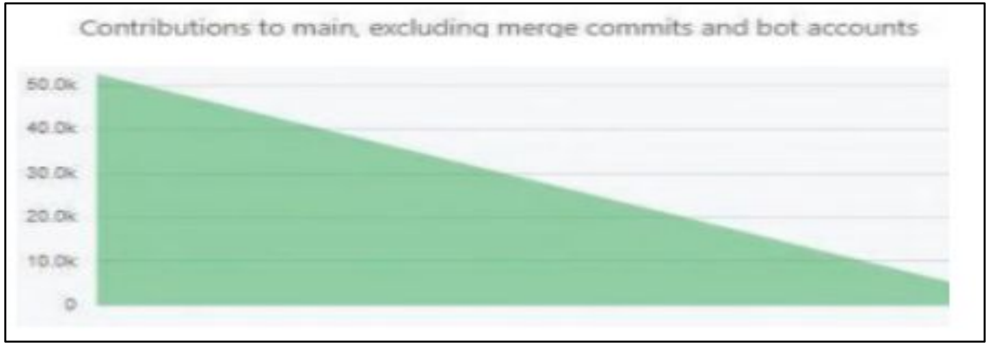
SIM DISABLE command is sent to stop the simulation mode.

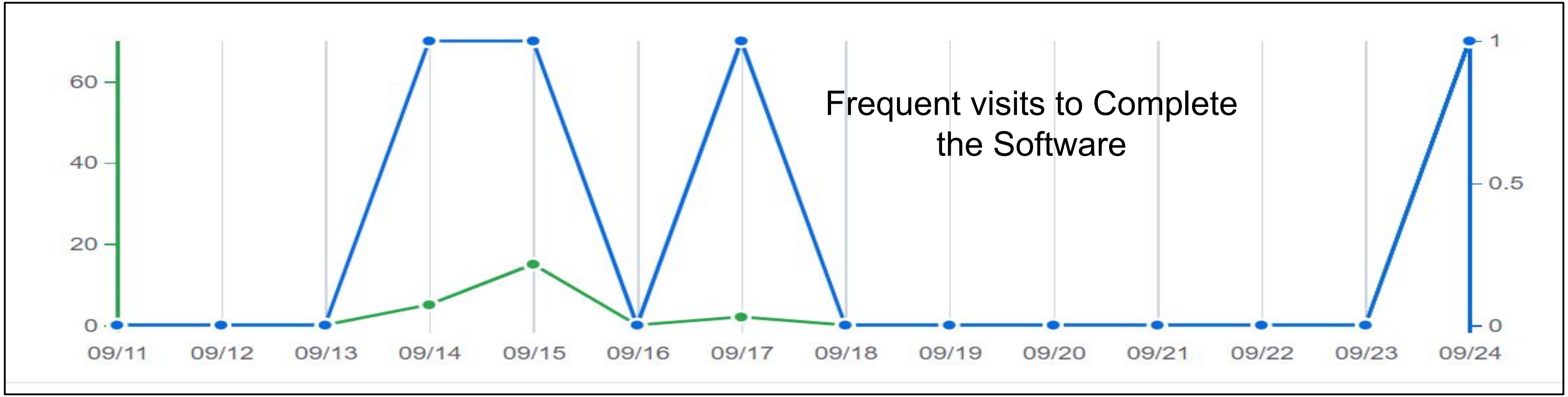
Payload

Software Development Plan(1/4)



Software Development Plan(2/4)





Software Development Plan(3/4)

Prototyping and Prototyping Environment

- Each step includes **parallel verification and validation**, noting requirements and conducting a problem analysis, with each module being developed, **constructed**, and **tested with the integration and its integration tests**.
- **2 week** appropriate deadline placement and report **generation schemes**.
- **Correction measures** for off-schedule work. **2 week** scheduled **buffer** before **event start**.
- Figma was used for prototyping the GUI, which was utilised to create wireframes for the GUI, which were then included into the **PyCharm** using **Python (PyQt5)**.
- On-board equipment testing environment rules must be followed to the letter.

Plan Against Risk of Late Software Development

- **Early procurement** and **use of required tools**.
- **Modularity in development** makes the **integration process** easier.
- **Troubleshooting beforehand** would help **avoid** late software development risks.

Test Methodology

- Sensors that will be used in the system will be put to the test.
- Algorithms for the release, parachute mechanisms and data recovery will be tested.
- Checking whether the FSW meets the CanSat competition requirements.

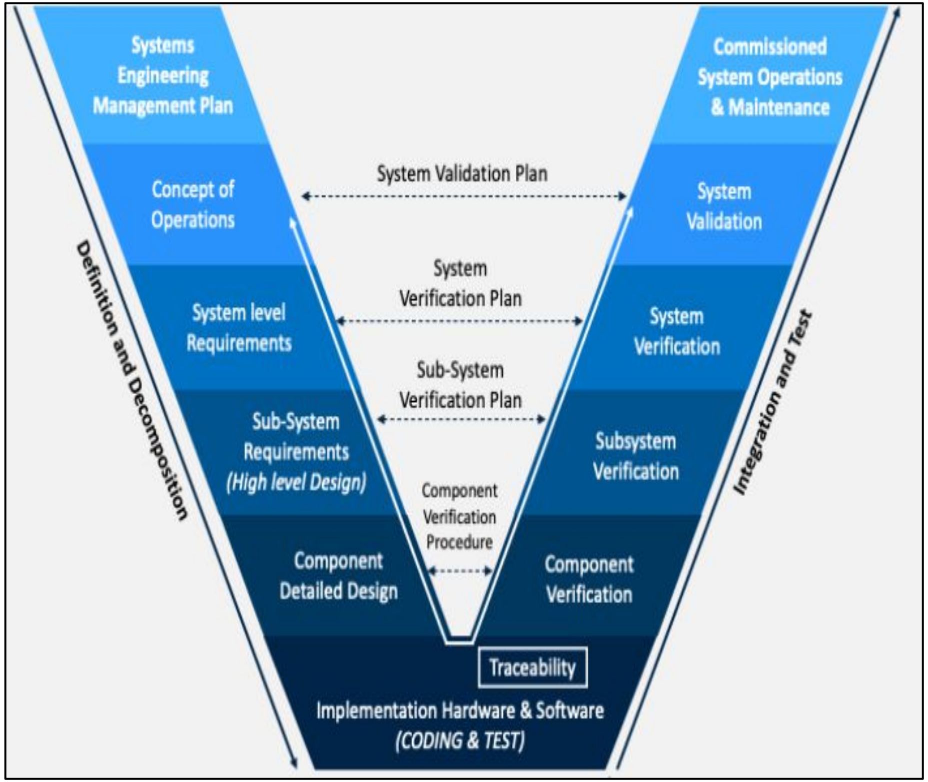
Software Development Plan(4/4)

SOFTWARE DEVELOPMENT TEAM

1) KHUSH AHUJA
2) ARNAV DEV

SOFTWARE SUBSYSTEM DEVELOPMENT SEQUENCE

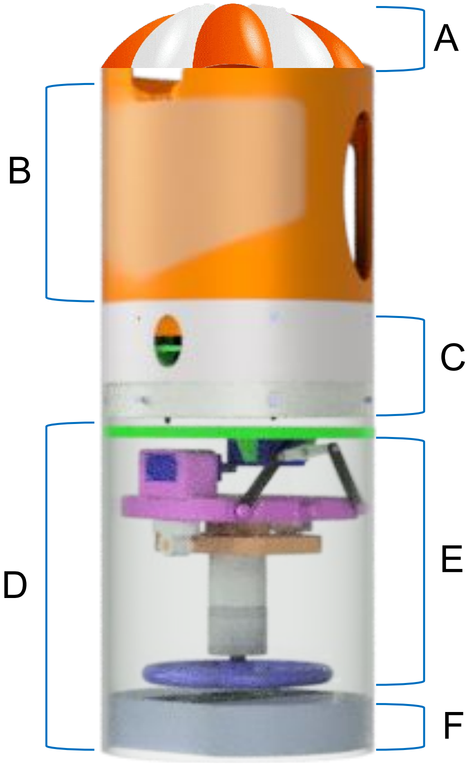
1) **V-Model (verification and validation)**:
2) Extension of waterfall model where **development** and **testing** go hand in hand.
3) Defining **FSW Functions , states, and requirements**.
4) Breakdown of tasks with **analysis of the problem**.
5) **Integrated testing** of **GCS** and **Cansat to be done**.
6) **Application** and **implementation** of **different algorithms** for checking various FSW states.
7) **Final system Testing**



Mechanical Subsystem Design

Mechanical Subsystem Overview

Container	Material
Parachute (A)	Ripstop nylon
Parachute compartment (B)	ABS
Electronic compartment (C)	ABS
Container(D)	ABS
Gyro control system (E)	Gimbal (ABS), Links (ABS), Reaction Wheel (Aluminium)
Battery compartment (F)	ABS



Interface Definition
Parachute compartment : Both parachutes are shown here , smaller is kept on the surface and larger is stuffed inside a separate compartment.
Gyro control system :We are using bias momentum control method by attaching a momentum wheel that incorporates an angular momentum inside a satellite. The wheel is rotated and control by BLDC motor.

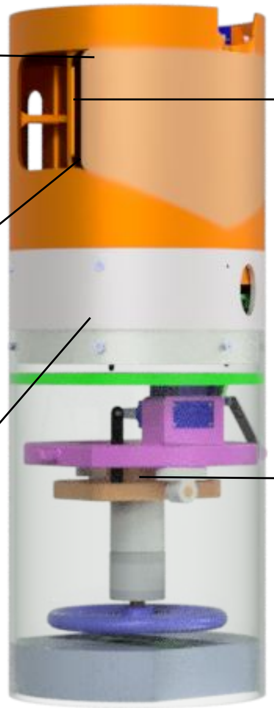
Container Mechanical Layout of Components

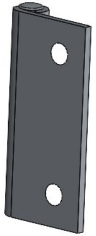
Parachute Compartment : The shroud lines of both parachutes are connected to an o ring which is connected to these **hooks.**

- First Parachute Stowed on the top of the container.
- Second parachute is stowed inside the parachute compartment and the compartment door is kept in place through a servo shaft.

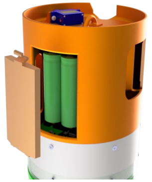
Closed State

Open State





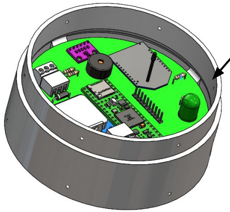
Hinge for door attachment



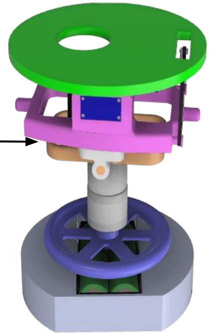
Battery can be easily accessed by the battery enclosure lid present on the side of parachute compartment.

Battery Compartment

Electronics Compartment: Container PCB is stowed here on the mounts and secured with the help of screws.



Electronics Compartment



Gyro control mechanism: For it we are using **bias momentum control method** by attaching a momentum wheel that incorporates an angular momentum inside a satellite. The wheel is rotated and control by **BLDC motor.**

Gyro Control System

Container Parachute Attachment Mechanism

Hooks

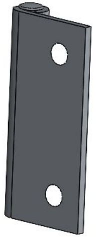
Container Top View

O ring

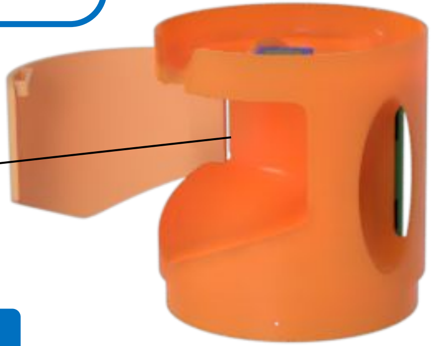
The shroud lines of both parachutes will be connected to a hook via **O rings.**

Container Closed Configuration

First parachute is stored here during launch.
Deployment: Once the parachute is released from the rocket, air will push back and flow into the canopy of the parachute, increasing drag until a terminal velocity of **20m/s** is attained.



Hinge

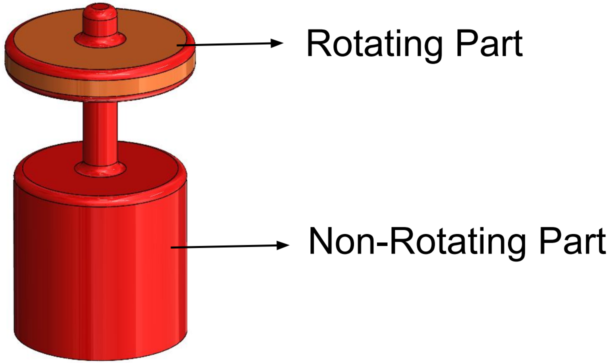


Container Open Configuration

Mechanical Gyro Control (1/3)

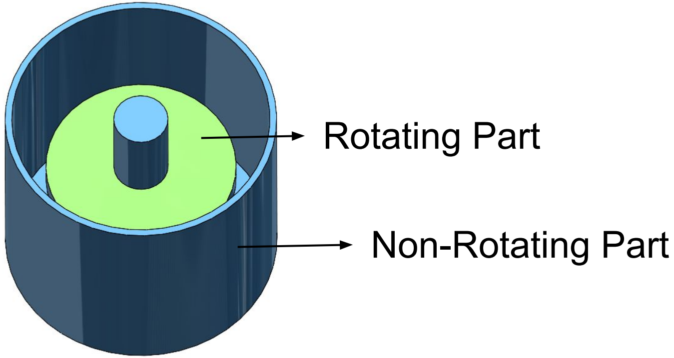
Gyrostat Approach: Gyrostat is a modified form of gyroscope that consists of a **rotation wheel (reaction wheel)** pivoted on a rigid case or structure.
It consists of a rotating and a non-rotating part.The various orientations that can be achieved from this combination is as shown below.

Orientation 1



SELECTED

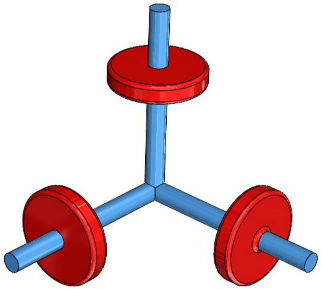
Orientation 2 (Bias Momentum Orientation)



Mechanical Gyro Control (2/3)

Two Approaches of Bias Momentum Method

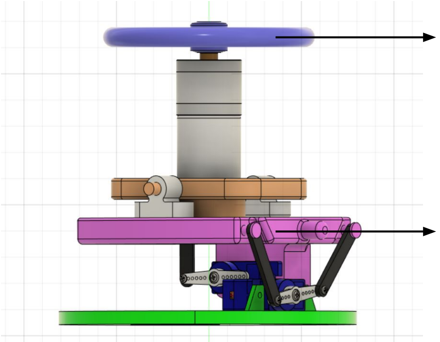
Using 3 Reaction wheels(3 axis stabilization)



Here, 3 different reaction wheels are implemented , each controlled by individual electronically controlled motor to provide the desired 3-axis stabilization.

SELECTED

Using 1 Reaction wheel (Gimbal Mechanism)

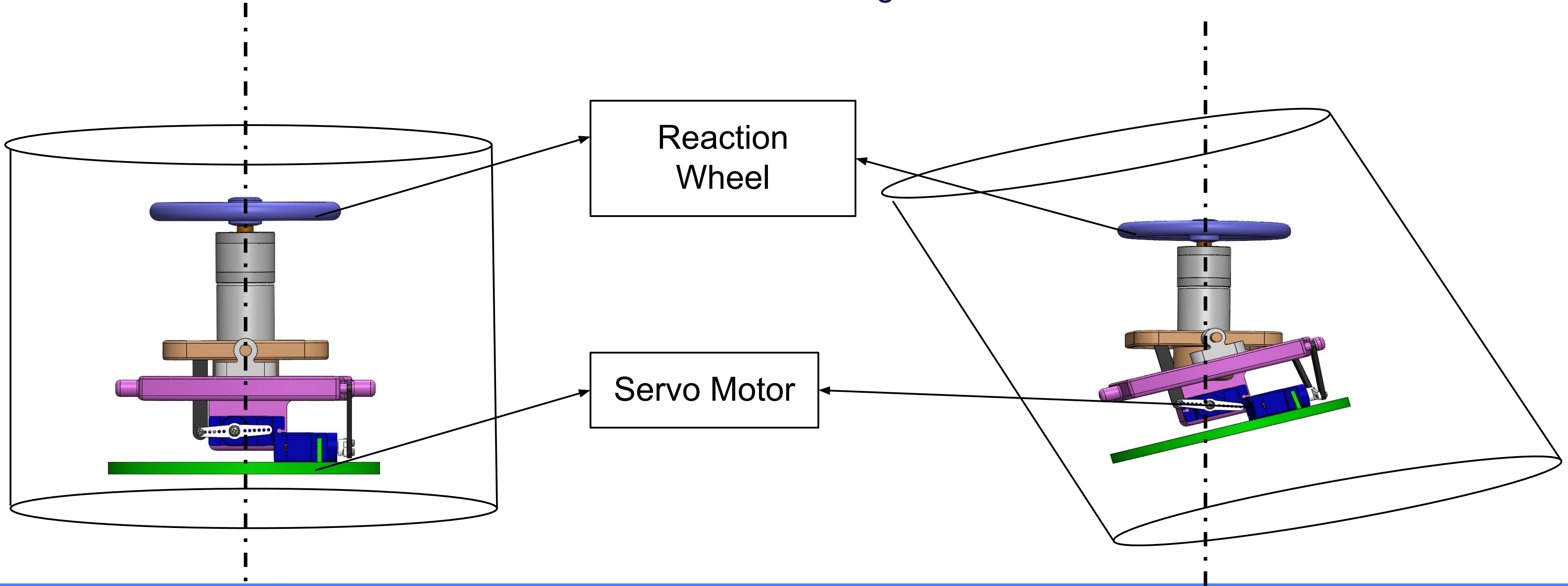


Here, instead of 3 wheels, **only one wheel**, with a flexible axis of rotation is enough to provide the required stability of 2 axis of the cansat. The axis of rotation can be controlled and tilted by using various servo motors and mechanical links.

Mechanical Gyro Control (3/3)

REACTION WHEEL CONFIGURATIONS

based on the axis of cansat during descent



Electronics Structural Integrity

Securing Connections

The PCB and motors are enclosure are attached using fasteners.

Enclosures

1. A separate compartment and sitting is provided for the PCB to provide efficient structural integrity
2. A battery enclosure is made to secure continuous electrical supply

Mounting Methods

1. Electrical Connections have been done through **Soldering** and **Headers** on PCB, which is screwed firmly to the body.
2. The connections are secured via epoxy, resin, hot glue and electrical insulation tape.

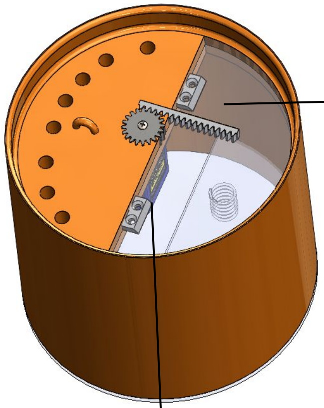
Descent Control Attachments

A Servo Motor is mounted on top of cansat to control deployment of 2nd parachute.

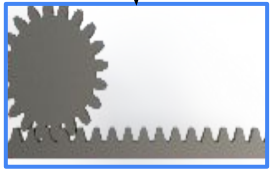
Deployment Mechanism Design and Selection

Deployment Mechanism Design and Selection

Design 1

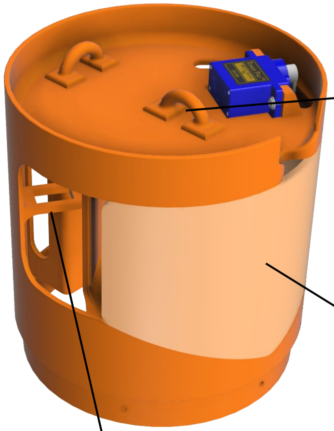


A compartment for larger parachute, guarded by a lid which opens by **rotation of the servo shaft.**



A combination of **Rack-Pinion and Hinge Mechanism** is used to open the upper gate.

Design 2(Selected)



The second parachute is attached to the bigger hook through an o-ring.

The Parachute compartment gate is kept in place by a servo shaft which locks the compartment gate.

Placement for External Switch.

Power Budget

Power Budget (1/5)

In - Flight

Calculation Methodology

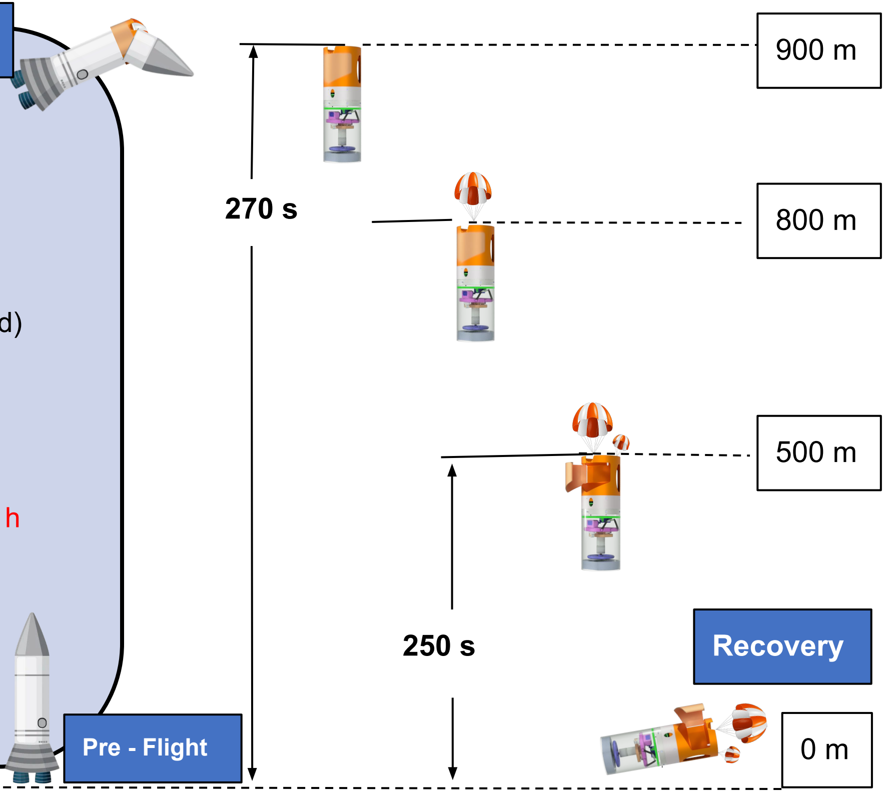
- ➔ Pre Launch Time (T_{PRE}) [Until CanSat is launched] = 120 min.
- ➔ In Flight Time (T_{IN}) [While the CanSat is in air] =

  Airtime after deployment of 1st parachute at 900m (till 500m)

  \+ airtime after deployment of 2nd parachute at 500 m (to ground)

  \+ Time taken by parachute whilst deploying

  = 20 + 250 +(⅔) ≈ 270 seconds ≡ 4.5 min.
- ➔ Recovery Stage Time (T_R) = 60 min.
- ➔ Total Time (T_S) = T_{PRE} + T_{IN} + T_R = 120 + 4.5 + 60 = 184.5 min. ≡ 3.075 h
- ➔ Duty Cycle % = (Time for which the component is active / Total time of operation)*100
- ➔ Base Power = Voltage * Current
- ➔ Average Power Consumption = (Base Power) * (Duty Cycle) * (T_S)



Power Budget (2/5)

Component (SYSTEM 1)	Current (mA)	Voltage (V)	Source	Duty Cycle (in %)			Average Consumed Energy (Wh) [V*I*t (in hours)]		
				PreFlight	In Flight	Recovery	Pre Flight	In Flight	Recovery
BMP280 (Altitude, Pressure,and Temperature Sensor)	0.0027	3.30	DS	100.00	100.00	0.00	0.000018	0.000001	0.000000
BMX160 (Rotation Sensor)	1.5900	3.30	DS	100.00	100.00	0.00	0.010461	0.000392	0.000000
SkyTraq S1216F8-GI3 (GNSS sensor)	110.0000	3.30	DS	100.00	100.00	0.00	0.726000	0.027225	0.000000
ADAFRUIT Mini Spy (Camera)	110.0000	5.00	DS	0.00	100.00	0.00	0.000000	0.041250	0.000000
MOSFET	110.0000	10.00	DS	0.00	0.00	100.00	0.000000	0.000000	1.100000
Buzzer	11.0000	10.00	DS	0.00	0.00	100.00	0.000000	0.000000	0.110000
SG90 Servo	200.0000	5.00	DS	0.00	2.00	0.00	0.000000	0.001500	0.000000
Teensy 4.1 (Microcontroller Unit)	100.0000	5.00	DS	100.00	100.00	100.00	1.0000	0.0375	0.5000

Power Budget (3/5)

Component (SYSTEM 1)	Current (mA)	Voltage (V)	Source	Duty Cycle (in %)			Average Consumed Energy (Wh) [V*I*t (in hours)]		
				PreFlight	In Flight	Recovery	Pre Flight	In Flight	Recovery
MT3608 Voltage Booster (5 V Line)	20.0000	3.70	E	100.00	100.00	100.00	0.1480	0.0056	0.0740
MT3608 Voltage Booster (10 V Line)	20.0000	3.70	E	0.00	0.00	100.00	0.0000	0.0000	0.0740
XBEE 3 Pro (RF Module) Tx	135.0000	3.30	DS	100.00	100.00	0.00	0.8910	0.0334	0.0000
XBEE 3 Pro (RF Module) Rx	17.0000	3.30	DS	100.00	100.00	0.00	0.1122	0.0042	0.0000
RTC	0.1000	3.00	E	100.00	100.00	100.00	Inbuilt into Teensy 4.1		
SD Card	0.1000	3.00	E	100.00	100.00	0.00	Inbuilt into Teensy 4.1		
MISCELLANEOUS AND PASSIVE COMPONENTS							**0.9896717 Wh**		
TOTAL ENERGY REQUIREMENT							**5.8863884 Wh**		

Power Budget (4/5)

Sources of Uncertainty

- Although switched ON, the components consume some power owing to their **standby currents** whose values have been added in the final power budget with an uncertainty of **10%.**
- **0.5 Wh** is added to the final total accounting for **miscellaneous power** consumed by LDR,LDO,internal resistances, and passive components.
- **Some data** in the power budget have been **estimated.**

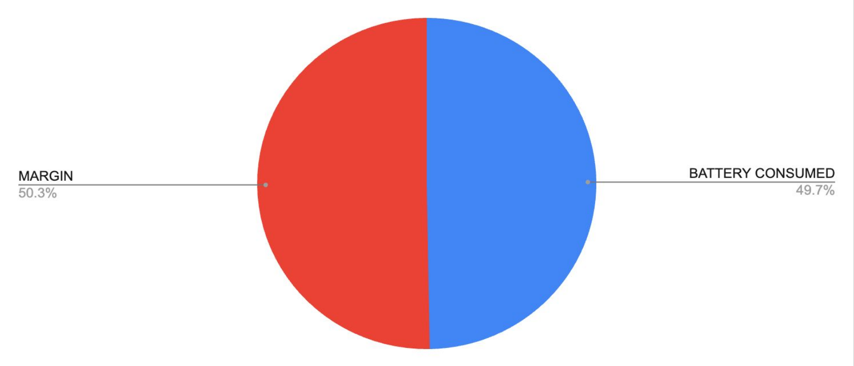
Battery operating time = Capacity (mAh) / Current consumed (mA)

Thus, Battery Operating Time = 3200 / 814.5877 = **3.928 Hr**

Energy of each component = (Power consumed)*(SUM(duty cycle*cycle duration))

- Average Energy consumed in 3.075 Hr = **5.8863884 Wh**
- Average Energy supplied by battery = **11.84 Wh**
- Power Margin = 11.84 - 5.886388453 = **5.9536115 Wh**

Nearly 50% of Total Battery Power is consumed in 3.075 Hrs of operation



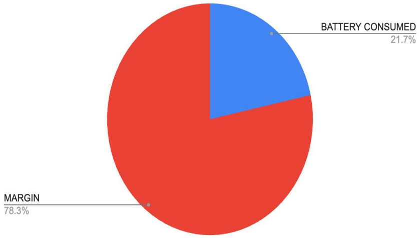
Power Budget (5/5)

Component (SYSTEM 2)	Current (mA)	Voltage (V)	Source	Duty Cycle (in %)			Average Consumed Energy (Wh) [V*I*t (in hours)]		
				PreFlight	In Flight	Recovery	Pre Flight	In Flight	Recovery
MG90S Servo x 2	400	5.0	DS	0.00	100.00	0.00	0.0000	0.1500	0.0000
2805 140KV Gimbal Brushless Motor	5000	12.0	DS	0.00	100.00	0.00	0.0000	4.5000	0.0000
Voltage Booster (10 V Line)	20	7.4	E	0.00	100.00	0.00	0.0000	0.0111	0.0000
MISCELLANEOUS AND PASSIVE COMPONENTS							**0.46611 Wh**		
TOTAL ENERGY REQUIREMENT							**5.12721 Wh**		

Battery operating time = Capacity (mAh) / Current consumed (mA)

Thus, Battery Operating Time = 3200 / 5420 = **0.5904 Hr = 35.424 min**

Thus, nearly 20% of our Total Battery Power is consumed in 3.075 Hrs of operation



Energy of each component = (Power consumed)*(SUM(duty cycle*cycle duration))

- Average Energy consumed in 3.075 Hr = **5.12721 Wh**
- Average Energy supplied by battery = **23.68 Wh**
- Power Margin = 23.68 - 5.12721 = **18.55279 Wh**

Mass Budget

Mass Budget (1/3)

Component	Model Name	Quantity	Determination	Unit Mass(g)	Mass(g)	Uncertainty (g)
Microcontroller	Teensy 4.1	1	E	10.0	10.0	±0.1
Temperature /pressure sensor	BMP 280	1	DS	2.0	2.0	0
Radio	Digi Xbee 3 Pro2.4GHz ZB3.0	1	E	10.80	10.80	±0.2
Battery	LG INR18650MH1	3	DS	49.0	3x49.0=147	0
GNSS	Skytraq GNSS S1216F8GI3	1	E	7.0	7.0	0
Coin cell	Energizer CR2032	1	DS	3.0	3.0	0
Container Gyro Sensor	BMX 160	1	DS	3.0	3.0	±0.2
Mosfet	IRF3205	1	DS	2.0	2.0	0
Buzzer	CEP 1112	1	DS	2.0	2.0	0
Camera	Adafruit Mini Spy Camera	1	DS	2.8	2.8	0
Voltage Booster	MT3608	3	E	1.0	3x1.0=3.0	±0.2
PCB	-	1	E	7.0	7.0	±0.3
SD Card	SanDisk Ultra	2	DS	0.5	2x0.5=1.0	0
Antenna	FXP 840.07.0055B	1	E	1.0	1.0	±0.1
Miscellaneous (LEDs ,Switch,etc)	-	-	E	3.0	6.0	±0.6
Total Electronic Mass					**207.6g**	**±1.7 g**

Mass Budget (2/3)

Cansat system	Component	Material/Specs	Quantity	Determination	Mass (g)	Uncertainty(g)
Container	Container	ABS	1	SW Determination	64.281	±1.2
	Parachute+Electronics Compartment	ABS	1+1	SW Determination	47.104	±0.4
	Battery Compartment	ABS	2	SW Determination	42.77	±0.2
	Nut & Bolts	M2 Pan Head	2	Measured	4.124	±0.1
	Parachute(Both)	Hexagonal	2	Calculated	86.09	±0.01
	Screws	ST4 cross head	12	Measured	5.55	±0.1
	Sorbothane pads	2 mm thickness	1	DS	0.680	±0.01
Gyro Control system	Mechanical Body and links	ABS	1	SW Determination	77.52	±0.2
	Motor(BLDC + Servos)	-	1 + 2	DS	56	-
	Reaction Wheel	Aluminium	1	Calculated	100	±0.5
	Nut & Bolts	M2 Pan Head	3	Measured	6.186	0.01
Total Mechanical Mass (g)					**490.305**	**±2.73**

Mass Budget (3/3)

Sub Division	Total Mass(g)	Uncertainty(g)
Container	250.599g	2.12
Gyro Control System	239.706g	0.71

TOTAL MASS (MECHANICAL+ELECTRONICS) = 490.305g + 207.6g

Total Mass: 697.905grams

Source of Uncertainty

1. Least count of the weighing scale used is 0.1 g, so an error of ± 0.1 g is introduced in all the components whose weight is measured.
2. SolidWorks provides an estimated mass of the design based on ideal manufacturing and ideal material properties, which is not achievable so an error of 10% of the estimated weight can be considered.

Method of Correction

Two containers which have different wall thickness will be manufactured before the actual launch.

1. MoC 1 - If mass of CanSat < 650g, container with thicker wall will be used. We would also carry dummy mass to add weight to the system if it falls short of the specified lower mass limit.
2. MoC 2 - If mass of CanSat > 750g, container with thinner wall will be used. Moreover, a container of a slightly lower density material will be carried.

CANSAT Budget

CanSat Budget – Hardware (1/2)

Category	Model Selected	Quantity	Cost per piece (₹)	Total Cost (₹)
Sensors	BMP 280	1	80	80
	BMX160	1	1400	1400
	SkyTraQ GNSS S1216F8 GI3	1	5499	5499
Radio	Digi XBee 3 PRO	1	3499	3499
Microcontroller	Teensy 4.1	1	3241	3241
Payload Antenna	FXP 840.07.0055B	1	620	620
Camera	Adafruit Mini Spy	1	1000	1000
Power	LG INR18650MH1	3	700	2100
	Coin cell CR2032	1	65	65
SD Card	SanDisk Ultra	2	395	790
PCB	-	1	700	700

CanSat Budget – Hardware (2/2)

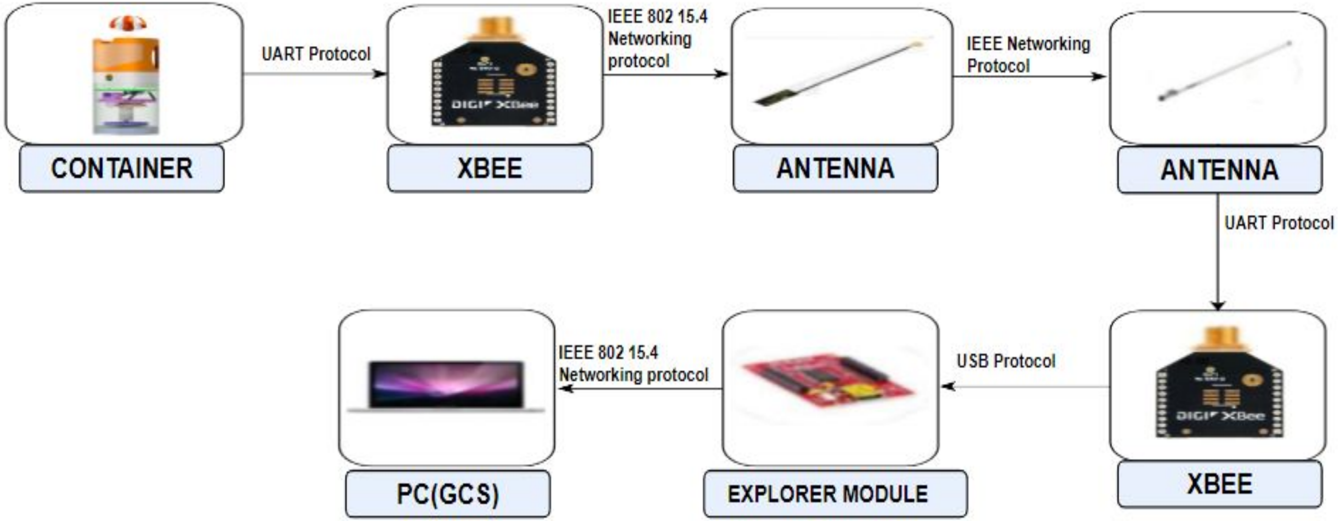
Category	Model Selected	Quantity	Cost per piece (₹)	Total Cost (₹)
Voltage Booster	MT3608	3	55	165
Servo motor	SG90	1	120	120
	MG90	2	270	540
LDO	LM1117DT	2	25	50
Electronic Module	ABS Printed	1	2000	2000
Parachute Module	ABS Printed	1	1300	1300
Parachute	FIrst Parachute	1	2100	2100
	Second Parachute	1	4800	4800
Body	Container parts	1	6000	6000
	Payload Subsystem Parts	1	7000	7000
Total Hardware Cost				**43,069**

CanSat Budget – Other Costs

<table>
<tr><th rowspan="2">Category</th><th colspan="2">Component</th><th rowspan="2">Total Cost
(₹)</th></tr>
<tr><th>Type</th><th>Model</th></tr>
<tr><td rowspan="3">Ground Control Station</td><td>Antenna</td><td>TL-ANT2415D</td><td>3,500</td></tr>
<tr><td>Laptop</td><td>-</td><td>85,000</td></tr>
<tr><td>Radio</td><td>Digi XBee 3 PRO
2.4GHz ZB3.0</td><td>3,499</td></tr>
<tr><td>Travel</td><td colspan="3">80,000</td></tr>
<tr><td>Registration</td><td colspan="3">5,000+20,000</td></tr>
<tr><td>Total</td><td colspan="3">1,97,000</td></tr>
</table>

Ground Control System (GCS) Design And Overview

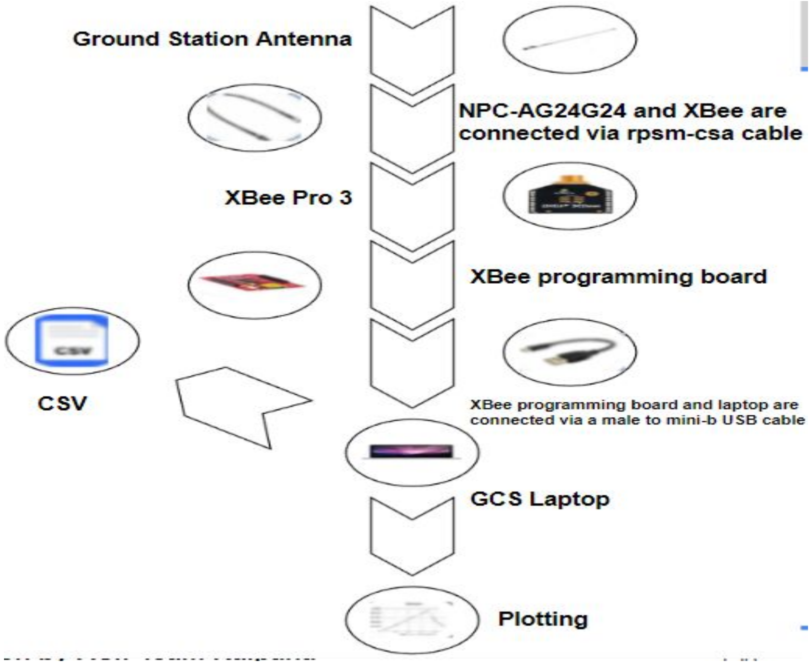
GCS Overview



- The calibration, CX, Set Time, SIM commands are transmitted from the ground station to the Container via XBEE Pro 3 Module, explorer module and antenna.
- The calibration command will be transmitted from the ground station to the container.

GCS Design

GCS DESIGN DIAGRAM



SPECIFICATIONS

BATTERY

Battery backup will be greater than 3 hours.

OVERHEATING

An external cooler with its own battery will be there and to prevent the direct exposure to sunlight an umbrella will be installed.

AUTO-UPDATE

The auto update feature will be disabled on Windows OS before the launch.

BACKUP

The ground system software will also be downloaded as a backup.

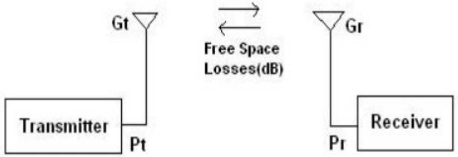
GCS Antenna Trade & Selection (1/2)

Model	Frequency (GHz)	Gain (dBi)	Mounting	Connector	Directivity	VSWR	Range (Km)	Cost (₹)	Weight (g)
TL-ANT2412D	2.4 ~ 2.5	12	Pole Mount	N Jack	Omni-Directional	< 2.0	12.528	7100	500
TL-ANT2414A	2.4~2.5	9	Wall Mount	RP-SMA Female	Directional	<1.92	7.905	4100	907
TL-ANT2410MO	2.35 ~ 2.55	14	Pole Mount	2*RP-SMA Female	Directional	<1.85	14.057	6700	210
TL-ANT2415D	2.4 ~ 2.5	15	Pole Mount / Wall Mount	N jack	Omni-Directional	< 2.0	17.697	3500	600

Selected	Reasons
TL-ANT2415D	• High gain of 15dBi. • Omnidirectional so no need to reorient continuously. • Range of more than 17 Km which is much longer compared to others. • Weatherproof design ideal for ground station.

GCS Antenna Trade & Selection (2/2)

FORMULA USED



Step-1: EIRP = Pt - Cable_loss + Gt

Step-2: FSL (Free Space Loss) = EIRP - Pr

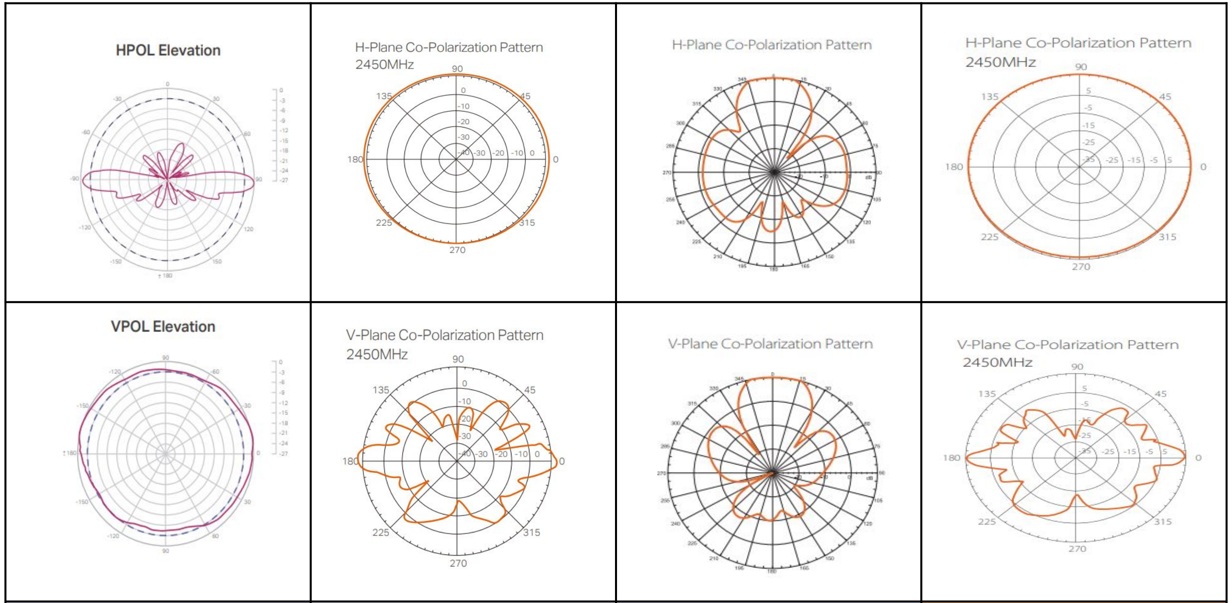
Step-3: dist = FSL + 20*Log10(Lambda) - 21.98

=>Antenna coverage distance = 10^(dist/20)

ASSUMPTIONS

The given ranges are calculated taking the receiver sensitivity as -100, respective gains of the given antennas, frequency as 2.4Ghz and considering a cable loss of 3dB.

RADIATION PATTERNS



TL-ANT2410MO	TL-ANT2412D	TL-ANT2414A	TL-ANT2415D

GCS Software(1/5)

DATA VISUALISATION

We are using **graphs** and **labels** for Data visualisation.

REAL TIME PLOTTING SOFTWARE DESIGN

The **Ground Control Software** reads the data from Serial Port and plots Real Time graphs for Payload in the GUI.

COMMERCIAL OFF THE SHELL(COTS)

Python, **Arduino** and **XBEE Program Module** is used for GCS Development.

DESCRIBE .csv FILE CREATION FOR JUDGES

The telemetry data is taken from Serial Ports and is diverted into **flight_2022asi-049.csv**. These files are first created and then the values are stored.

COMMAND SOFTWARE AND INTERFACE

Various commands have been incorporated in the interface as per the guidelines provided in the this year’s Mission Guide. Apart from this, we have also included commands that will be used for this mission.

GCS Software(2/5)

TELEMETRY DISPLAY PROTOTYPES

TELEMETRY

<TEAMID>	<TIME STAMPING>	<PACKET C	ALTITUDE	PRESSURE	TEMP	VOLTAGE	GNSS TIMI	GNSS LAT	GNSS LON	GNSS ALT	GNSS SATS	GYRO_R	GYRO_P	GYRO_Y	ACCEL_R	ACCEL_P	ACCEL_Y
49	10:12:42	1	0	86.70127	50.9891	7.4	10:12:42	29.312	77.0642	0	9	0.01	-0.03	0.01	1.58	0.36	1.25
49	10:12:43	2	9.9	64.7535	49.8398	7.4	10:12:43	29.312	77.0642	9.9	9	-0.03	0.01	0.02	1.58	0.36	1.25
49	10:12:44	3	19.3	84.0923	82.6615	7.4	10:12:44	29.312	77.0642	19.3	9	0.02	-0.03	0.01	1.58	0.36	1.25
49	10:12:45	4	29.9	45.2376	46.5844	7.4	10:12:45	29.312	77.0642	29.9	9	0.03	0.02	-0.03	1.58	0.36	1.25
49	10:12:46	5	40	41.187	29.0767	7.4	10:12:46	29.312	77.0642	40	9	-0.01	0.01	0.02	1.58	0.36	1.25
49	10:12:47	6	51	22.6727	34.6789	7.4	10:12:47	29.312	77.0642	51	9	0.02	0.03	0.01	1.58	0.36	1.25
49	10:12:48	7	62.3	38.8354	43.2868	7.4	10:12:48	29.312	77.0642	62.3	9	0.03	0.01	0.02	1.58	0.36	1.25
49	10:12:49	8	71.9	68.58084	39.7871	7.4	10:12:49	29.312	77.0642	71.9	9	-0.01	0.03	0.03	1.58	0.36	1.25
49	10:12:50	9	80	44.05676	43.9384	7.4	10:12:50	29.312	77.0642	80	9	-0.02	0.02	-0.02	1.58	0.36	1.25
49	10:12:51	10	90.9	83.89752	74.9527	7.4	10:12:51	29.312	77.0642	90.9	9	0.01	-0.03	0.01	1.58	0.36	1.25
49	10:12:52	11	100.8	53.0932	55.1895	7.4	10:12:52	29.312	77.0642	100.8	9	0.03	0.01	-0.03	1.58	0.36	1.25

RAW DATA

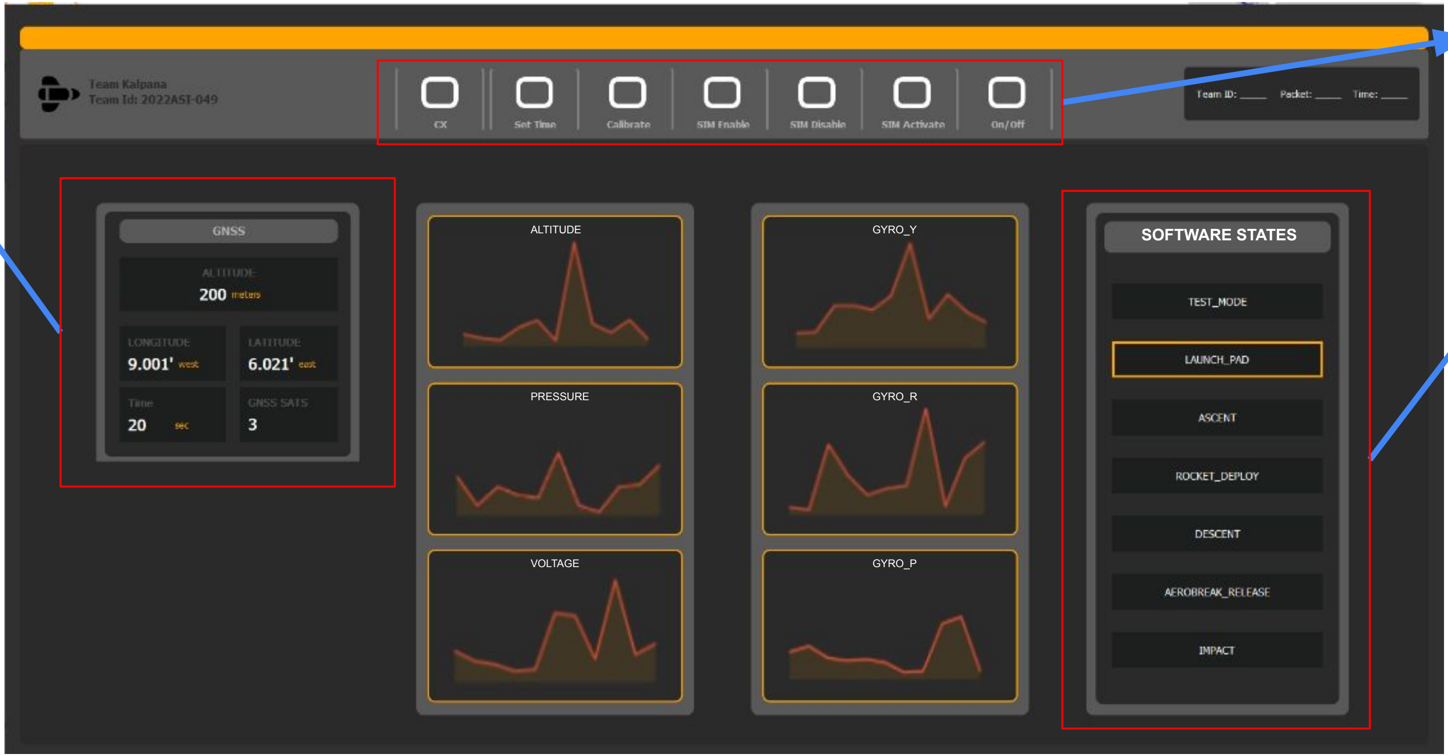
49,01:12:42,14,678.5,101330.7,27.1,3.7,11:42:56,50.9891,113.0789,107.4,2,9.8,0.3,1

GCS Software(3/5)

GNSS

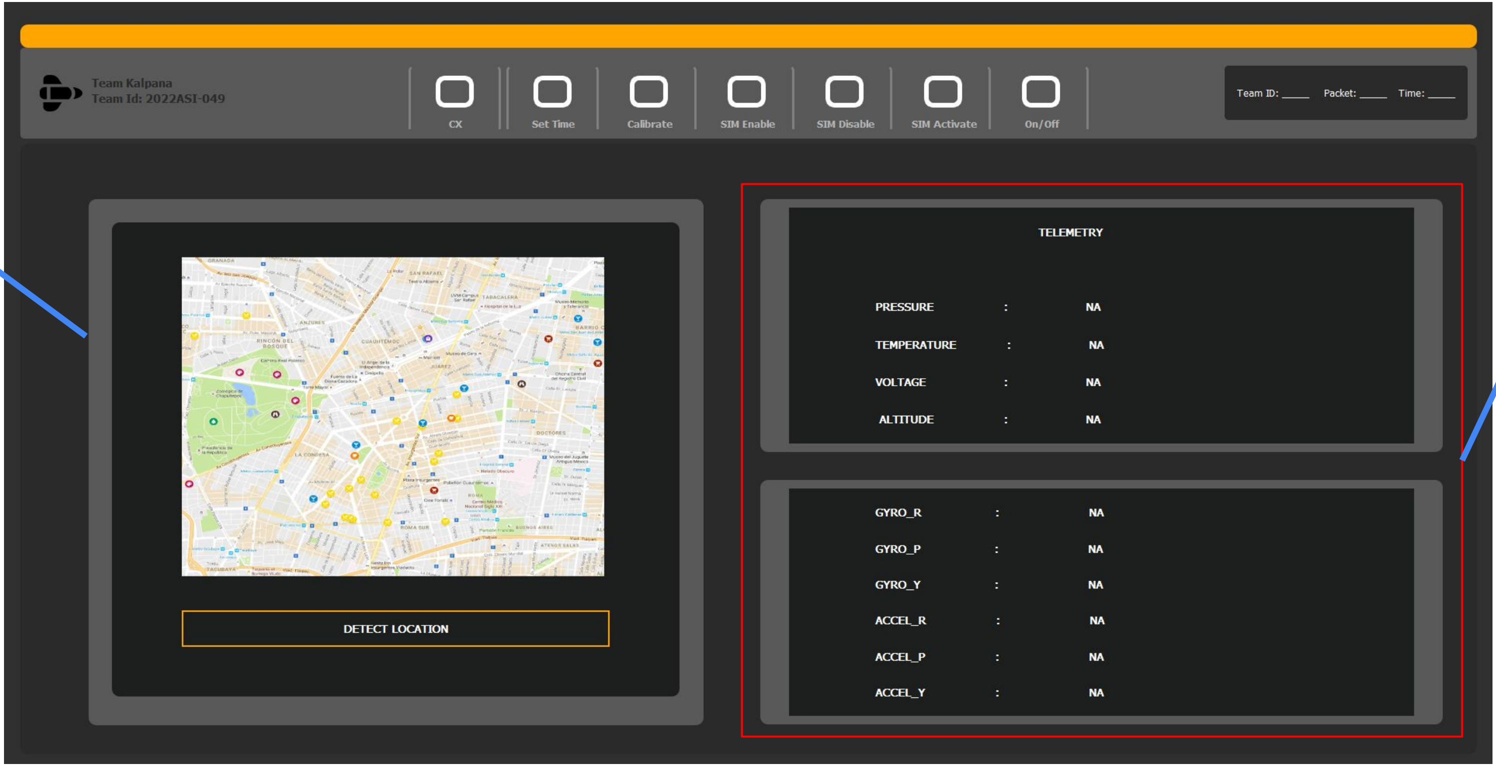
COMMANDS

SOFTWARE STATES



GCS Software(4/5)

MAP SHOWING LIVE LOCATION



TELEMETRY

GCS Software(5/5)

COMMANDS IN GCS

- Commands are coded as functions in PyCharm and integrated with buttons as shown in the above image.
- Commands will run when the buttons are clicked. Hence enabling our GUI to send the commands from our GUI.
- The commands are transmitted by the XBee Module at GCS to Payload via Antennas.

CanSat Integration and Test

CanSat Integration and Test Overview

CDH And FSW Testing
- Receiving and transmission of data through antenna was tested.
- speed of processing of data is verified.

Communication Testing
- Radio Communication through XBee is verified for different ranges.
- Tested communication various times to ensure correct data.

Mechanical Testing
- Total mass of Cansat is calculated and verified which is 700±50 g
- Parachute, servo and mechanical gyro will be checked.

Integrated Level Testing
- Complete Sensor Subsystem with battery will be tested.
- Container drop test will be verified using drone along with sensor mechanism.
- Radio and Antenna shall be tested.
- The polarisation of antenna will be checked and verified.

Environmental Testing
- Thermal test will be done to check if cansat changes characteristics or fails to withstand high temperature
- Fit test will be done to check whether it's good to launch.
- Drop test, vacuum test and vibration test will be performed.

Decent Control Testing
- Parachute release of Cansat will be verified using drone test.
- Descent rate of the Cansat is checked and verified.

Simulation Testing
- FSW switching is verified.
- GCS switching is tested to verify whether the software is inconsistent..

Sensor Testing
- Sensors will be calibrated until high accuracy is achieved.
- Software Integration compliance shall be verified.

Subsystem Level Testing Plan(1/3)

SUBSYSTEM LEVEL TESTING PLAN	
SENSORS	• **Performance** testing shall be done on **EPS prototype** (**breadboard**). • Sensors shall be **calibrated** until high **accuracy** is achieved. • Testing shall be **repeated** . • **Software Integration Compliance** shall be verified.
EPS	• Test for **Voltage regulation and stability.** • Test a **trial run** for **operation time** under **mission conditions** with **actual connections** to other subsystems. • Check **durability** of the system. • Test system under **heavy load** of components to ensure **fuse** functionality and system **safety.** • Test the system after **transferring** it from the prototype onto the **PCB** designed.

Subsystem Level Testing Plan(2/3)

SUBSYSTEM LEVEL TESTING PLAN	
FSW	● Test by simulating each sensors shutdown or complete shutdowns and ensuring that it recovers from last state and is not stuck in loops. ● Ensure recovery data in case of microcontroller resets. ● Test to verify the speed of processing of the telemetry. ● Test to put random and false sensor data/telemetry and checking its ability to handle it and thus the result. ● Test to check the software-hardware integration with every component like sensors, motors, radio, MPU etc.
Mechanical and Descent Control Testing Plan	● Drop CanSat from 900m - 800m height using a drone and deployer, and check if Descent Control Subsystem will function. ● The overall descent of CanSat will be tested with drone to make sure that system functions at corresponding altitude levels. ● To test whether the parachute can be ejected from Container (immediately after deployed from simulated rocket). ● 3D printed model of gyro system is tested by tilting the CanSat container in a controlled manner.

Subsystem Level Testing Plan(3/3)

SUBSYSTEM LEVEL TESTING PLAN	
Radio Communication	• Tested data communication between XBee radios at different distances. • Checked radio communications at ranges greater than required. • Testing communications various times to ensure correct data. • Open air and ground level range testing is done to make sure the range is maintaining required standards.
CDH	• Test receiving, transmitting and processing of data of processors and executing calculations. • Verifying that the video recorded by camera is stored in micro SD Card. • All antenna gain and range are tested. • Verify that the measured numerical data is stored in SD card connected to Teensy 4.1. • Ensured accuracy of the data transmitted at huge distances. • Testing of command systems were done multiple times to ensure speed and accuracy.

Integrated Level Functional Test Plan

TEST	Operational requirements	Procedure	Pass/Fail Criteria
Communications	Communication between the container and Ground station remains stable.	• Simulate flight conditions by placing the container at an appropriate distance from the ground station. • Check and verify the polarization of the antenna. • Try sending commands from the ground station to the container.	Pass: All the commands are sent and received between the container and ground station properly. There is no connection loss in any orientation of the container or on varying the distance.
Mechanical Subsystems	Various control and deployed mechanisms are tested to work efficiently.	• Drop CanSat from 900m - 800m height using a drone and deployer, and check if Descent Control Subsystem will function. • The overall descent of CanSat will be tested with drone to make sure that system functions at corresponding altitude levels. • 3D printed model of gyro system is tested by tilting the CanSat container in a controlled manner.	Pass: All the mechanical subsystems work perfectly. The deployment mechanisms give the desired results and also mechanical gyro control is achieved.

Environmental Test Plan

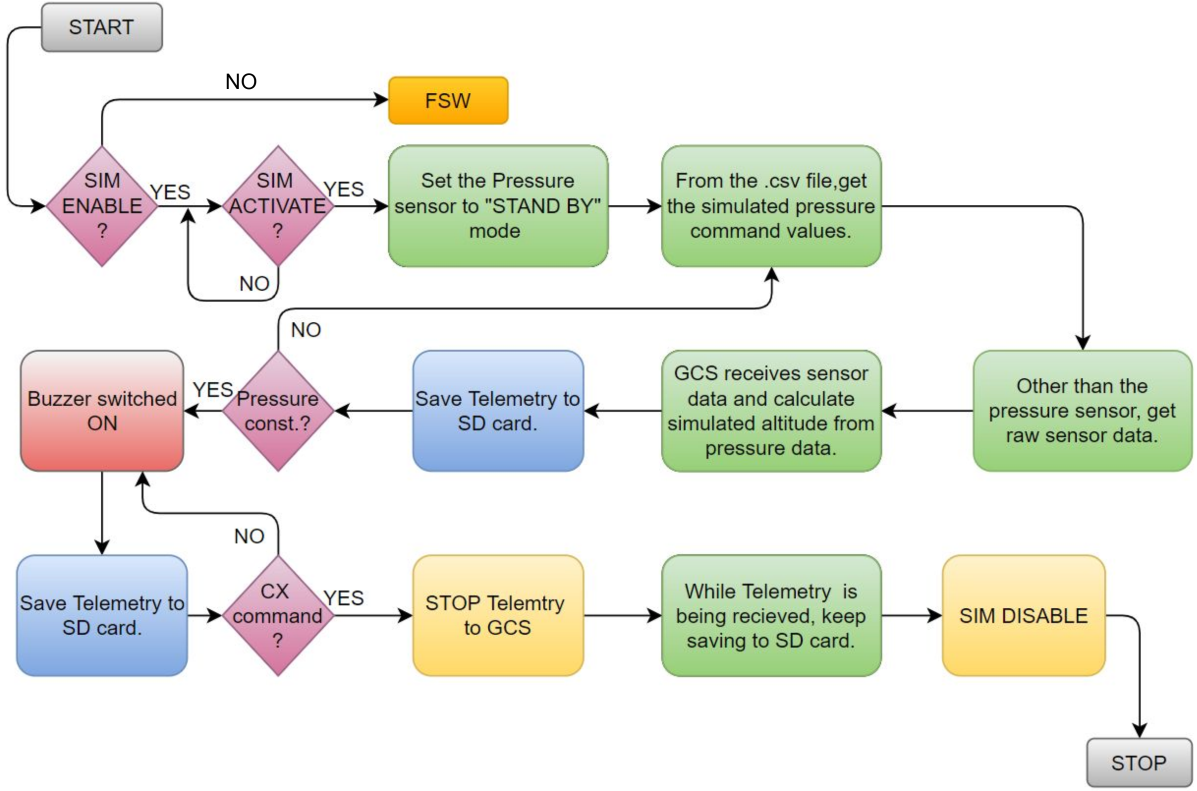
Environmental Test Plan (1/2)

TEST	Purpose	Setup	Procedure	Pass/Fail Criteria
Drop Test	To check if the system is able to **withstand a shock of 30Gs**.	One end of a **non-stretching cord** is tied with a parachute and the other end is attached to the cansat firmly.	• Switch on all the systems of cansat and check if telemetry is being received. • **Raise the cansat with sufficient elevation and position it such that it point of attachment of cansat with the cord points upwards and drop it.** • Check the cansat for any damage and confirm if the telemetry is still being received.	Fail: If the cansat suffers from any **structural damage** or if there is a **loss of telemetry**.
Thermal Test	To check if the cansat changes characteristics or **fails to withstand high temperature**	Place the cansat **inside the thermal chamber** making sure that the heat is not directly blown on the cansat.	• Turn on the cansat and place it in the thermal chamber. • **Check if telemetry is being received from cansat and turn on the thermal chamber, raise the temperature and maintain it for some time**. • Turn off the heating chamber and check for any structural damages while the canast is still hot while taking precautions. • Check if the telemetry is still being received and if there is any change in the data being received.	Fail: If there is any **structural damage** or there is a loss in telemetry or large **variations in the data** received from the cansat.
Fit Check	Fit check is performed so that we can make sure that our cansat would be **dispatched properly at the time** it is detached from the rocket and the parachute time would be smooth.	The sat is **fitted properly in the payload region** of the container.	• **Fix in the cansat such that it would be fixed in with the payload and at the time it is detached from the rocket the parachute time will not have any crashes.** • The sat must be fitted properly in the payload section of the rocket and checked for deployability.	Pass: If the sat is **fitted properly** in the payload section of the rocket then it will.

Environmental Test Plan (2/2)

TEST	Purpose	Setup	Procedure	Pass/Fail Criteria
Vibrational Test	This test is designed to verify the **mounting integrity** of all components, mounting connections, structural integrity, and battery connections.	The sander is a handheld power tool where the sanding head moves in a random pattern. One setup for the test is to secure the sander, upside down, via a bench vise; the CanSat should be secured where the sandpaper is installed. The vise cannot be allowed to move freely and the sandpaper cannot be held by hand.	• Power on the CanSat and verify accelerometer data is being collected. • **Power up the sander. Once the sander is up to full speed, wait 5 seconds. Power down the sander to a full stop.** • Repeat step 2 four more times to inspect the CanSat for damage and functionality. • Verify accelerometer data is still being collected and then power down CanSat.	Pass: If all components and parts retain their structure and shape. Fail: If structure deforms or breaks.
Vacuum Test	This test is designed to **verify deployment operation** of the payload.	A lid can be used or thick sheet of polycarbonate can be placed on top of the bucket. A vacuum cleaner or shop vacuum can be used to pull out air and simulate vacuum environment.	• Suspend the fully configured and powered CanSat in the vacuum chamber. • Turn on the vacuum to start pulling a vacuum. • **Monitor the telemetry and stop the vacuum when the peak altitude has been reached.** • Let the air enter the vacuum chamber slowly and monitor the operation of the CanSat. • Collect and save telemetry.	Pass: If all components and parts retain their structure and shape. Fail: If any deformation is observed.

Simulation Test Plan(1/2)

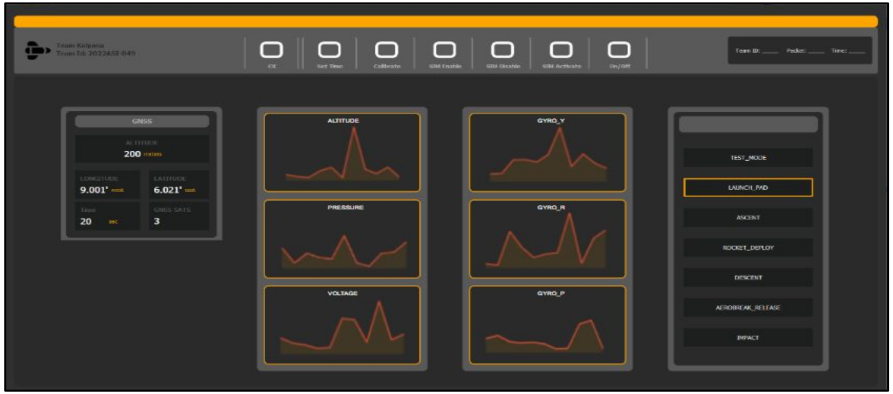


OVERALL SIMULATION TEST PLAN

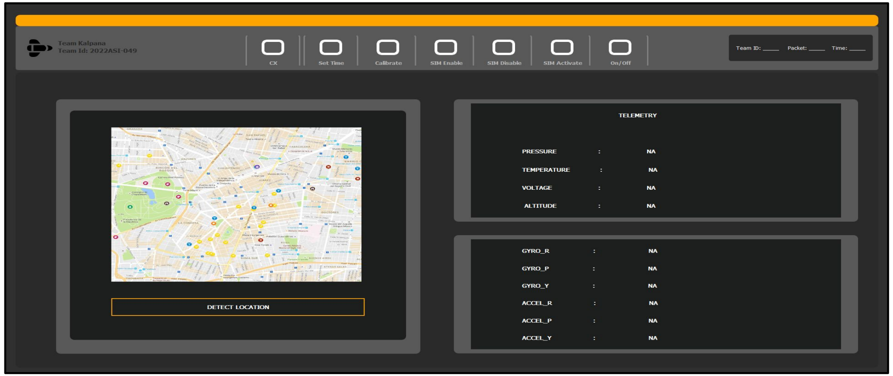
Both GCS and FSW states have been evaluated while switching between FLIGHT MODE and SIMULATION MODE.

The telemetry packets that were received were checked for any errors or delays.

Simulation Test Plan(2/2)



<TEAMID>	<TIME STAMPING>	<PACKET C	ALTITUDE	PRESSURE	TEMP	VOLTAGE	GNSS TIMI	GNSS LAT
49	10:12:42	1	0	86.70127	50.9891	7.4	10:12:42	29.312
49	10:12:43	2	9.9	64.7535	49.8398	7.4	10:12:43	29.312
49	10:12:44	3	19.3	84.0923	82.6615	7.4	10:12:44	29.312
49	10:12:45	4	29.9	45.2376	46.5844	7.4	10:12:45	29.312
49	10:12:46	5	40	41.187	29.0767	7.4	10:12:46	29.312
49	10:12:47	6	51	22.6727	34.6789	7.4	10:12:47	29.312
49	10:12:48	7	62.3	38.8354	43.2868	7.4	10:12:48	29.312
49	10:12:49	8	71.9	68.58084	39.7871	7.4	10:12:49	29.312
49	10:12:50	9	80	44.05676	43.9384	7.4	10:12:50	29.312
49	10:12:51	10	90.9	83.89752	74.9527	7.4	10:12:51	29.312
49	10:12:52	11	100.8	53.0932	55.1895	7.4	10:12:52	29.312



GNSS TIMI	GNSS LAT	GNSS LON	GNSS ALT	GNSS SATS	GYRO_R	GYRO_P	GYRO_Y	ACCEL_R	ACCEL_P	ACCEL_Y
10:12:42	29.312	77.0642	0	9	0.01	-0.03	0.01	1.58	0.36	1.25
10:12:43	29.312	77.0642	9.9	9	-0.03	0.01	0.02	1.58	0.36	1.25
10:12:44	29.312	77.0642	19.3	9	0.02	-0.03	0.01	1.58	0.36	1.25
10:12:45	29.312	77.0642	29.9	9	0.03	0.02	-0.03	1.58	0.36	1.25
10:12:46	29.312	77.0642	40	9	-0.01	0.01	0.02	1.58	0.36	1.25
10:12:47	29.312	77.0642	51	9	0.02	0.03	0.01	1.58	0.36	1.25
10:12:48	29.312	77.0642	62.3	9	0.03	0.01	0.02	1.58	0.36	1.25
10:12:49	29.312	77.0642	71.9	9	-0.01	0.03	0.03	1.58	0.36	1.25
10:12:50	29.312	77.0642	80	9	-0.02	0.02	-0.02	1.58	0.36	1.25
10:12:51	29.312	77.0642	90.9	9	0.01	-0.03	0.01	1.58	0.36	1.25
10:12:52	29.312	77.0642	100.8	9	0.03	0.01	-0.03	1.58	0.36	1.25

Mission Operations & Analysis

Mission Operations & Analysis (1/4)

<table>
<tr><td>Arrival</td><td colspan="2">

- **Integrity** of CanSat will be **checked** for any damage or unexpected malfunctioning that might occur during flight and travelling.
- **Assembly of the CanSat** will be done.

</td><td>1</td></tr>
<tr><td rowspan="5">Pre Launch</td><td colspan="2">

- Work in accord with **checklist** for **Pre-launch procedures.**

</td><td rowspan="5">2</td></tr>
<tr><td>GCS Setup</td><td>

- Initiate and test **Laptop - XBEE (Radio) serial connection**.
- Initiate and test handheld **(GCS) antenna's functionality.**
- Verify that **flight software** is **uploaded** onto the **MCU** and **functioning appropriately** in **expected parameters.**

</td></tr>
<tr><td>GCS Testing</td><td>

- Establish and verify **Laptop - Antenna communications.**
- Establish and verify **Antenna - CanSat communications.**
- Implement **communications setup** and verify that the **GCS is receiving telemetry**. Also **authenticate correct IDs.**

</td></tr>
<tr><td>CanSat Setup</td><td>

- **Fully charge** all batteries and check if **batteries and sensors** are **fully installed and correctly integrated** in CanSat.
- **Calibrate** and test all sensors.
- Check **connections and fastenings** to ensure that there are **no loose connections.**
- Check **dimensions and weight** of CanSat.

</td></tr>
<tr><td>CanSat Testing</td><td>

- **Inspect Mechanical Systems** and verify if all mechanisms are functioning properly.
- Conduct **fit and clearance** tests.
- Carry out **parachute checks** i.e. if or not parachute is correctly **loaded** and **folded** for **easy deployment.**
- Test **electronic** components as an **integrated system.**

</td></tr>
</table>

Mission Operations & Analysis (2/4)

Installation	• **Final inspection and clearance** before integration into Container. • Ensure **communication** of **CanSat** with **GCS.** • Ready for launch. • CanSat will be **switched on** prior to installation into rocket. • **Wireless Communication** with **GCS** will be confirmed for **continuity**. • **Rocket** will be **delivered** to team members.	**3**
Launch	• Rocket will be **launched after** Mission Control team **completes launch procedures.** • When the rocket reaches **apogee**, CanSat will begin to **descend with parachute.**	**4**
Mid - Air	• The **first parachute** immediately **deploys**;CanSat will **continue descending.** • The **second parachute** will be **deployed** at **500 m**. • Container will **measure telemetry** data and **transmit to GCS** during descent. • **Flight** is **monitored.** • **Recovery** team is **prepared.**	**5**
Recovery	• Container will **land with parachute**. • The **latest coordinates** will be used to **locate the touchdown** locations with help of audio beacon. • **Recovery Team** will start **searching** when all launches are completed, and the area is safe. • **Retrieve** data from **SD Card.**	**6**
Data Analysis and PFR	• Backup flight data post CanSat recovery. • Acquire and analyse telemetry (GCS) data. • Damage Inspection will be done. • PFR is prepared and CSV Flight Data delivered to judges.	**7**

Mission Operations & Analysis (3/4)

Name	Roles / Responsibility	Role Description
Vansh Kumar Goel	Mission Control Officer	Supervision of all CanSat tasks. This is the person in charge of informing the Flight Coordinator when the crew and their CanSat is ready to launch.
Muskan	CanSat Crew	It is their responsibility to prepare the CanSat, integrate it into the rocket, and verify its status.
Vidushi	CanSat Crew	
Divya	CanSat Crew	
Khush Ahuja	Ground Station Crew	They are in charge of monitoring telemetry reception at the ground station and issuing commands to the CanSat. They will transmit calibration commands and execute other responsibilities as directed by the Mission Officer.
Arnav Dev	Ground Station Crew	
Yuvraj	Recovery Crew	Responsible for tracking and going out into the field for recovery and interacting with the field officer.
Yash	Recovery Crew	

Mission Operations & Analysis (4/4)

Antenna Construction	GCS Operations	CanSat Assembly and Test
• Connection is established between Xbee and Antenna. • Xbee is connected to GCS laptop via Serial port. • Sampling data is sent to Xbee and plotted to examine connectivity and flow of information.	• Install sun umbrella & setup laptop GCS. • Setup GCS software and external connections including laptop, XBee and handheld antenna. • Test the communication between CanSat and GCS. • Check GCS software connectivity. • Final check on communication after installation into the rocket. • The assigned team members will have to prepare and stock required equipment, setup the ground station (Umbrella, GCS Software, Connections), and test the communication of Container.	• Inspect all electronics components, connections & mounting. • Check whether all integrated subsystems are functional. • Fold the parachute & assemble CanSat. • Make a full system and processor reset & perform a final check with GCS whether the system is working properly or not. • Fit check & weight measurement. • CanSat Delivery at check-in point.

CanSat Location and Recovery

Cansat Location And Recovery

- The last data/position from GNSS will help us to estimate the location of the Payload.
- An Audio Beacon which is installed on the Cansat will play a high pitch and loud(92dB+) sound upon landing which will help the recovery team to the Cansat.
- The recovery team will follow the descent trajectory by observing the descent and Payload's last GNSS location to estimate its position.
- Fluorescent Orange colour of the cansat and the Pink colour of the parachutes will help us locate the cansat very easily after landing.
- A label will be attached to the CanSat displaying the team ID, contact phone number and Email address in case of failed recovery.

Program Schedule Overview

Program Schedule Overview

S No.	Name	Start Date (DD/MM/YY)	End Date (DD/MM/YY)	Percentage Completion	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
1	The mission statement was analysed and preparation for the competition started.	13/08/22	16/08/22	100%											
2	Team Member Recruitment	17/08/22	21/08/22	100%											
3	A presentation was prepared based on the CanSat mission requirements and competition guide, and presented to the faculty in-charge	22/08/22	22/08/22	100%											
4	Ideation on several mechanism and sensors selection started	23/08/22	28/08/22	100%											
5	FSW logic was ideated and selected	28/08/22	31/08/22	100%											
6	Class Tests of Team Members	01/09/22	07/09/22	100%											
7	Shortlisted mechanical designs were simulated and electronic components were selected and ordered	08/09/22	15/09/22	100%											
8	Basic GCS requirements were fulfilled and Electronic circuit developed and tested	16/09/22	18/09/22	100%											
9	Mid Semester Exams	19/09/22	24/09/22	100%											
10	PCB design begins. GCS front end development completely designed and started working on PDR .	25/09/22	29/09/22	100%											
11	PDR compiled and mailed	29/09/22	30/09/22	100%											
12	Preparation of PDR Presentation	5/10//22	10/10/22	0%											
13	Preliminary Design Review Completion	10/10/22	31/10/22	0%											
14	PCBs will be soldered	10/10/22	15/10/22	0%											
15	The fabrication of CANSAT shall begin	1/11/22	10/11/22	0%											
16	End Semester Exams	12/11/22	14/12/22	0%											
17	Final testing of software shall be done.Solutions to any failures will be quickly assimilated into our design. Full scale fabrication of the CanSat shall be completed.	16/12/22	15/01/23	0%											
18	The CDR shall be compiled and mailed.	16/01/23	31/01/23	0%											
19	Critical Design Review Completion	01/02/23	28/02/23	0%											
20	Final Models Printed and complete CANSAT assembly is done	01/03/23	12/04/23	0%											
21	Flight Readiness Review & Launch Window	15/04/23	15/06/23	0%											
22	Post Flight Review and Results Declaration	15/06/23	30/06/23	0%											

CanSat Work

College Work

CanSat Work To be Done

PFR Work

Detailed Program Schedule

S No.	Start Date	End Date	Name	Assigned To
1	13/08/22	16/08/22	The mission statement was analysed and preparation for the competition started.	Vansh
2	17/08/22	21/08/22	Team Member Recruitment.	Vansh
3	22/08/22	22/08/22	A presentation was prepared based on the CanSat mission requirements and competition guide, and presented to the faculty in-charge.	Full Team
4	23/08/22	28/08/22	Ideation on several mechanism and sensors selection started.	Vansh, Yuvraj, Divya, Vidushi,Muskan,Yash
5	28/08/22	31/08/22	FSW logic was ideated and selected.	Khush, Arnav

Detailed Program Schedule

S No.	Start Date	End Date	Name	Assigned To
6	01/09/22	07/09/22	Class Tests of Team Members.	Full Team
7	08/09/22	15/09/22	Shortlisted mechanical designs were simulated and electronic components were selected and ordered.	Vansh, Yuvraj, Vidushi, Divya,Muskan, Yash
8	16/09/22	18/09/22	Basic GCS requirements were fulfilled and Electronic circuit developed and tested.	Khush, Arnav, Muskan, Yash
9	19/09/22	24/09/22	Mid Semester Exams.	Full Team
10	25/09/22	29/09/22	PCB design begins. GCS front end development completely designed and started working on PDR.	Full Team
11	29/09/22	30/09/22	PDR compiled and mailed.	Full Team

Detailed Program Schedule

S No.	Start Date	End Date	Name	Assigned To
12	5/10//22	10/10/22	Preparation of PDR Presentation.	Full Team
13	10/10/22	31/10/22	Preliminary Design Review Completion.	Full Team
14	10/10/22	15/10/22	PCBs will be soldered.	Muskan, Yash
15	1/11/22	10/11/22	The fabrication of CANSAT shall begin.	Yuvraj,Divya,Vidushi
16	16/12/22	15/01/23	Final testing of software shall be done.Solutions to any failures will be quickly assimilated into our design. Full scale fabrication of the CanSat shall be completed.	Full Team
17	16/01/23	31/01/23	The CDR shall be compiled and mailed.	Full Team

Detailed Program Schedule

S No.	Start Date	End Date	Name	Assigned To
18	01/02/23	28/02/23	Critical Design Review Completion.	Full Team
19	01/03/23	31/03/23	Final Models Printed and complete CANSAT assembly is done.	Full Team
20	15/04/23	15/06/23	Flight Readiness Review & Launch Window.	Full Team
21	15/06/23	30/06/23	Post Flight Review and Results Declaration.	Full Team

Conclusion

Conclusions

MAJOR ACCOMPLISHMENTS	MAJOR UNFINISHED WORK	PREPARATION FOR NEXT STAGE
• Mechanisms were ideated and finalized along with the primary design. • Descent rate estimates and reaction wheel calculations were done, and material selection for major parts was done. • Container sensors and telemetry were tested and finalized, radio module was configured and basic CDH diagrams were made along with starting codes. • GUI, FSW, GCS, and recovery software state were completed.	• Models to be finalised based on printability and structural integrity. • More iteration will be done on reaction wheel calculation for max accuracy. • PCB designing to be done, to establish communication over a range(antenna test), perform environment tests. • Backend remaining with some front-end modifications.	• We have toiled hard as a team in prototyping, developing, testing and troubleshooting the design and are dedicated to do so in the near future.Therefore we feel that we are absolutely ready to refine our systems further in the competition and face the challenges ahead.