



---

# CanSat 2023

## Preliminary Design Review (PDR)

**Team 1095**  
**Team Aether**



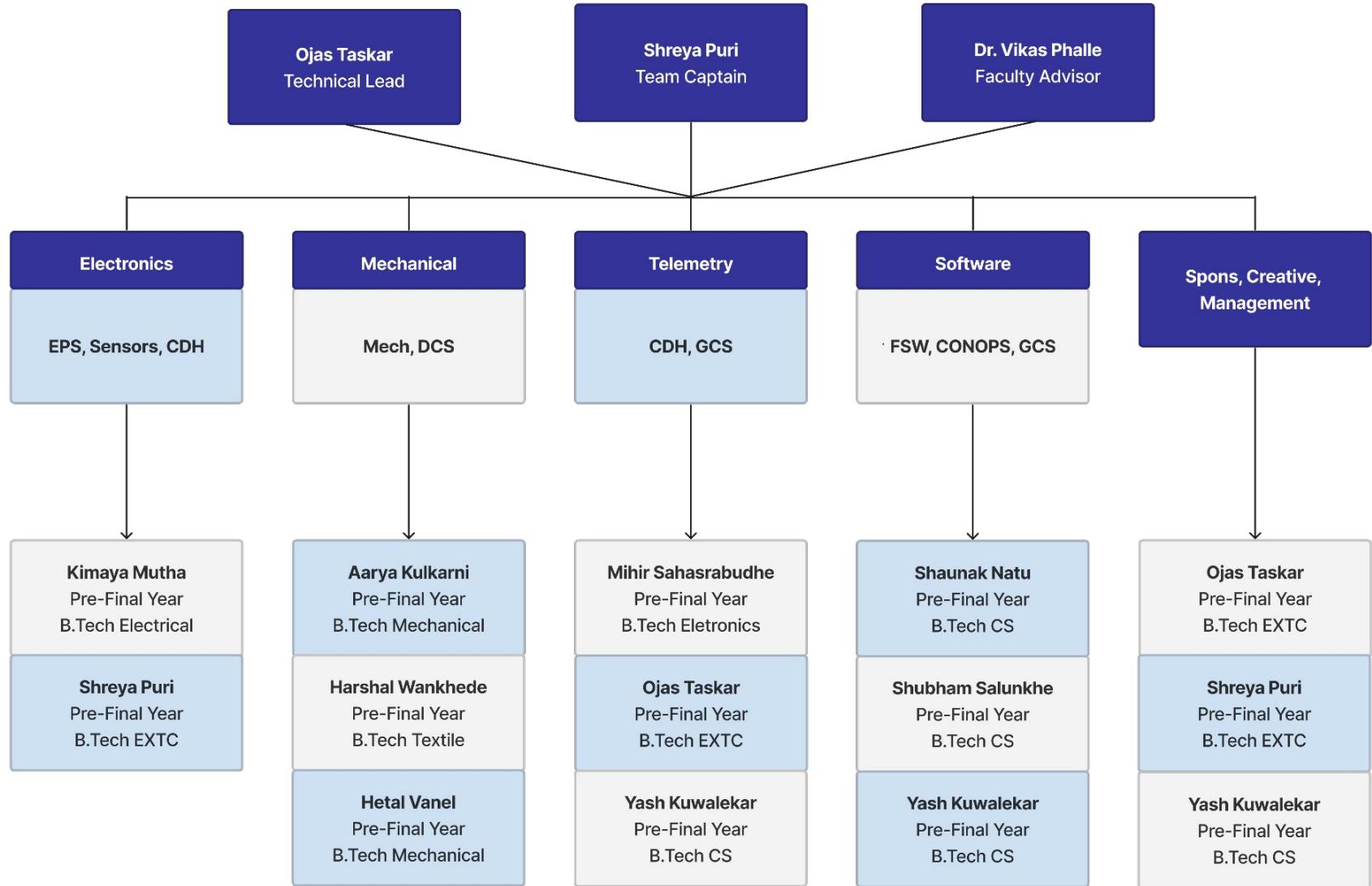
# Presentation Outline



Sr. No	Contents	Presenter	Page No.
1	Introduction	Kimaya Mutha	1
2	Systems Overview	Shreya Puri	6
3	Sensor Subsystem Design	Shreya Puri	27
4	Descent Control Design	Ojas Taskar	36
5	Mechanical Subsystem Design	Hetal Vanel	64
6	Communication and Data Handling (CDH) Subsystem Design	Ojas Taskar	88
7	Electrical Power Subsystem(EPS) Design	Kimaya Mutha	111
8	Flight Software(FSW) Design	Shubham Salunkhe	119
9	Ground Control System (GCS) Design	Yash Kuwalekar	132
10	CanSat Integration and Test	Ojas Taskar	147
11	Mission Operations and Analysis	Shubham Salunkhe	164
12	Requirements Compliance	Mihir Sahasrabudhe	171
13	Management	Shreya Puri	181



# Team Organization





# Acronyms(1/2)



Acronym	Description
EPS	Electrical Power Subsystem
DCS	Descent Control Subsystem
FSW	Flight Software
CDH	Communication and Data Handling
A	Analysis
I	Inspection
T	Testing
D	Demonstration
GCS	Ground Control Station
PFR	Post Flight Review
I <sup>2</sup> C	Inter-Integrated Circuit
dps	Degrees per second

Acronym	Description
hPa	Hectopascal
dBi	Decibels relative to isotropic
RP-SMA	Reverse-Polarity SMA
GHz	GigaHertz
LOS	Line-of-Sight
TX, RX	Transmit, Receive
UART	Universal Asynchronous Receiver-Transmitter
UTC	Coordinated Universal Time
ASCII	American Standard Code for Information Interchange
GPS	Global Positioning System
USB	Universal Serial Bus
FIFO	First In First Out



# Acronyms(2/2)



Acronym	Description
RTC	Real Time Clock
ppm	Parts per Million
PCB	Printed Circuit Board
LED	Light Emitting Diode
AC	Alternating Current
ADC	Analog to Digital Converter
SPI	Serial Peripheral Interface
FIFO	First In First Out
CSI	Camera Serial Interface
GPIO	General Purpose Input/Output
TVL	Television Lines
FPV	First Person View

Acronym	Description
SMA	Sub Miniature A Connector
RAM	Random Access Memory
EEPROM	Electrical Erasable Programmable Read Only Memory
SD	Secure Digital
SOC	State of Charge
IDE	Integrated Development Environment
COTS	Commercial Off the Shelf
CSV	Comma Separated Value
RF	Radio Frequency
LV	Launch Vehicle
TC	Team Captain
TL	Technical Lead



---

# Systems Overview

**Shreya Puri**



# Mission Summary (2/2)



## Bonus Objective

A **video camera** shall be integrated into the container and **point toward the probe**. The camera shall record the event when the probe is released from the container.

Video shall be in color with a minimum resolution of **640x480 pixels** and a minimum of **30 fps**. The video shall be **recorded and retrieved** when the container is retrieved.

This bonus objective has been selected due to **high feasibility** and to help us analyse the **moment of separation** during flight. It additionally provides us with more experience working on incorporating more components into the system.

## External Objectives

Obtain the Institute's **approval** for participation and **secure funding** for as many phases of the competition as possible, and **attain sponsorships**

Achieve a commendable rank for our **first attempt** at the competition

Design and assemble **customised PCBs** for the electronics used

Starting a tradition of participating in the competition, fostering a healthy work environment in the team

Since the participating team is a part of a student club aiming to launch a **student satellite**, we want to gain experience on all phases of the mission on a smaller scale through the competition.



# Mission Summary (1/2)



## Mission Objectives

Design and build a **sturdy** CanSat structure including a **container** and a **probe** for executing the probe lander mission

CanSat shall be deployed from the rocket compartment near the apogee between **670-725 m** and descend at **15 m/s** with a **parachute**.

The structure shall survive all forces incurred at launch and deployment. At **500m**, it shall **deploy a probe** that opens a **heat shield** working as an aerobraking shield with a descent rate of **20 m/s or less**.

When the probe reaches **200 m**, the probe shall deploy a **parachute** and slow the descent rate to **5 m/s**.

After landing, the probe shall attempt to **upright itself** and **raise a flag 500 mm above its base**

A **video camera** shall be included and **point toward the ground during descent** in color and with a minimum resolution of 640x480.

All telemetry shall be displayed and plotted on the **GUI** in real time during **descent** on the ground (**1 Hz**)

Setting up a **portable ground control station** for telemetry to and fro from the ground station to the probe and generate csv files for the received telemetry.



# System Requirement Summary(1/8)



ID	Requirement	Priority	Sub-system	Verification			
				A	I	T	D
1	Total mass of the CanSat (science probe and container) shall be 700 grams +/- 10 grams.	High	All subsystems	✓		✓	
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	High	All subsystems	✓	✓	✓	
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	High	Mechanical	✓	✓	✓	
4	The container shall be a fluorescent color; pink, red or orange.	Medium	Mechanical		✓		
5	The container shall be solid and fully enclose the science probes. Small holes to allow access to turn on the science probes are allowed. The end of the container where the probe deploys may be open.	High	Mechanical, EPS	✓	✓	✓	✓
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	High	Mechanical	✓	✓	✓	
7	The rocket airframe shall not be used as part of the CanSat operations.	High	Mechanical	✓	✓		✓
8	The container's parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	High	Mechanical, DCS	✓	✓	✓	



# System Requirement Summary(2/8)



ID	Requirement	Priority	Sub-system	Verification			
				A	I	T	D
9	The Parachute shall be fluorescent Pink or Orange	Medium	Mechanical		✓		
10	The descent rate of the CanSat (container and science probe) shall be 15 meters/second +/- 5 m/s.	High	Mechanical, DCS	✓		✓	✓
11	0 altitude reference shall be at the launch pad.	High	FSW, CDH			✓	✓
12	All structures shall be built to survive 15 Gs of launch acceleration.	High	Mechanical	✓		✓	✓
13	All structures shall be built to survive 30 Gs of shock.	High	Mechanical	✓		✓	✓
14	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	High	Mechanical, Sensors, CDH		✓	✓	
15	All mechanisms shall be capable of maintaining their configuration or states under all forces.	High	Mechanical			✓	
16	Mechanisms shall not use pyrotechnics or chemicals.	High	Mechanical		✓		
17	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	High	Mechanical		✓		



# System Requirement Summary(3/8)



ID	Requirement	Priority	Sub-system	Verification			
				A	I	T	D
18	Both the container and probe shall be labeled with team contact information including email address.	Medium	Mechanical		✓		
19	Cost of the CanSat shall be under \$1000. Ground support and analysis tools are not included in the cost. Equipment from previous years shall be included in this cost, based on current market value.	High	All subsystems	✓	✓		
20	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	High	CDH, GCS		✓	✓	✓
21	XBEE radios shall have their NETID/PANID set to their team number.	High	CDH, GCS		✓	✓	✓
22	XBEE radios shall not use broadcast mode.	High	CDH, GCS		✓		✓
23	The container(if needed) and probe shall include an easily accessible power switch that can be accessed without disassembling the CanSat and science probes and in the stowed configuration.	High	EPS, Mechanical		✓		✓
24	The probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the cansat and in the stowed state.	High	EPS, Mechanical		✓		✓
25	An audio beacon is required for the probe. It shall be powered after landing.	High	FSW, EPS			✓	✓



# System Requirement Summary(4/8)



ID	Requirement	Priority	Sub-system	Verification			
				A	I	T	D
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	High	Sensors			✓	✓
27	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells. Coin cells are allowed.	Hlgh	EPS	✓	✓		
28	An easily accessible battery compartment shall be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	High	Mechanical, EPS		✓		✓
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Hlgh	Mechanical, EPS		✓		
30	The Cansat shall operate during the environmental tests laid out in Section 3.5.	High	All subsystems	✓	✓	✓	✓
31	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Hlgh	EPS	✓		✓	✓
32	The probe shall be released from the container when the CanSat reaches 500 meters.	Hlgh	Mechanical, FSW, EPS	✓		✓	



# System Requirement Summary(5/8)



ID	Requirement	Priority	Sub-system	Verification			
				A	I	T	D
33	The probe shall deploy a heat shield after leaving the container.	High	Mechanical, FSW			✓	✓
34	The heat shield shall be used as an aerobrake and limit the descent rate to 20 m/s or less.	High	Mechanical, DCS	✓		✓	✓
35	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s +/- 1 m/sec.	High	Mechanical	✓		✓	✓
36	Once landed, the probe shall upright itself.	High	Mechanical			✓	✓
37	After uprighting, the probe shall deploy a flag 500 mm above the base of the probe when the probe is in the upright position.	High	Mechanical			✓	✓
38	The probe shall transmit telemetry once per second.	High	CDH	✓		✓	✓
39	The probe telemetry shall include altitude, air pressure, temperature, battery voltage, probe tilt angles, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	High	CDH			✓	✓
40	The probe shall include a video camera pointing down to the ground.	High	Mechanical, Sensors		✓	✓	



# System Requirement Summary(6/8)



ID	Requirement	Priority	Sub-system	Verification			
				A	I	T	D
41	The video camera shall record the flight of the probe from release to landing.	High	Sensors, FSW			✓	✓
42	The video camera shall record video in color and with a minimum resolution of 640x480.	High	Sensors	✓		✓	✓
44	The flight software shall maintain a count of packets transmitted which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	High	FSW				✓
45	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	High	Sensors, EPS				✓
46	The probe shall have its time set to within one second UTC time prior to launch.	High	FSW			✓	✓
47	The probe flight software shall support simulated flight mode where the ground station sends air pressure values at a one second interval using a provided flight profile csv file.	High	FSW, GCS	✓		✓	✓
48	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the probe altitude.	High	FSW	✓		✓	✓



# System Requirement Summary(7/8)



ID	Requirement	Priority	Sub-system	Verification			
				A	I	T	D
49	The probe flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	High	FSW			✓	✓
50	The ground station shall command the Cansat to start calibrating the altitude to zero when the Cansat is on the launch pad prior to launch.	High	GCS, CDH	✓		✓	✓
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	High	GCS			✓	✓
52	Telemetry shall include mission time with 1 second or better resolution.	High	Sensors, CDH	✓		✓	✓
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	High	FSW	✓		✓	✓
54	Each team shall develop their own ground station.	High	GCS	✓			✓
55	All telemetry shall be displayed in real time during descent on the ground station.	High	CDH, GCS		✓	✓	✓
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	High	CDH, GCS	✓	✓	✓	✓



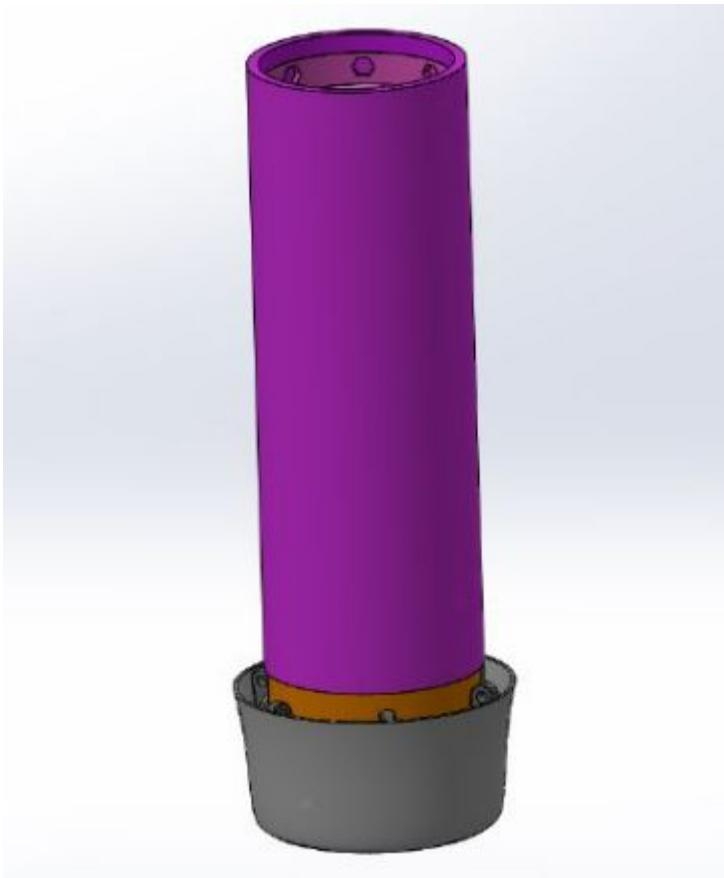
# System Requirement Summary(8/8)



ID	Requirement	Priority	Sub-system	Verification			
				A	I	T	D
57	Teams shall plot each telemetry data field in real time during flight.	High	CDH, GCS			✓	✓
58	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	High	GCS	✓		✓	✓
59	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	High	GCS		✓		✓
60	The ground station software shall be able to command the probe to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	High	GCS	✓		✓	✓
61	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the CanSat.	High	GCS	✓		✓	✓



# System Level CanSat Configuration Trade & Selection(1/5)



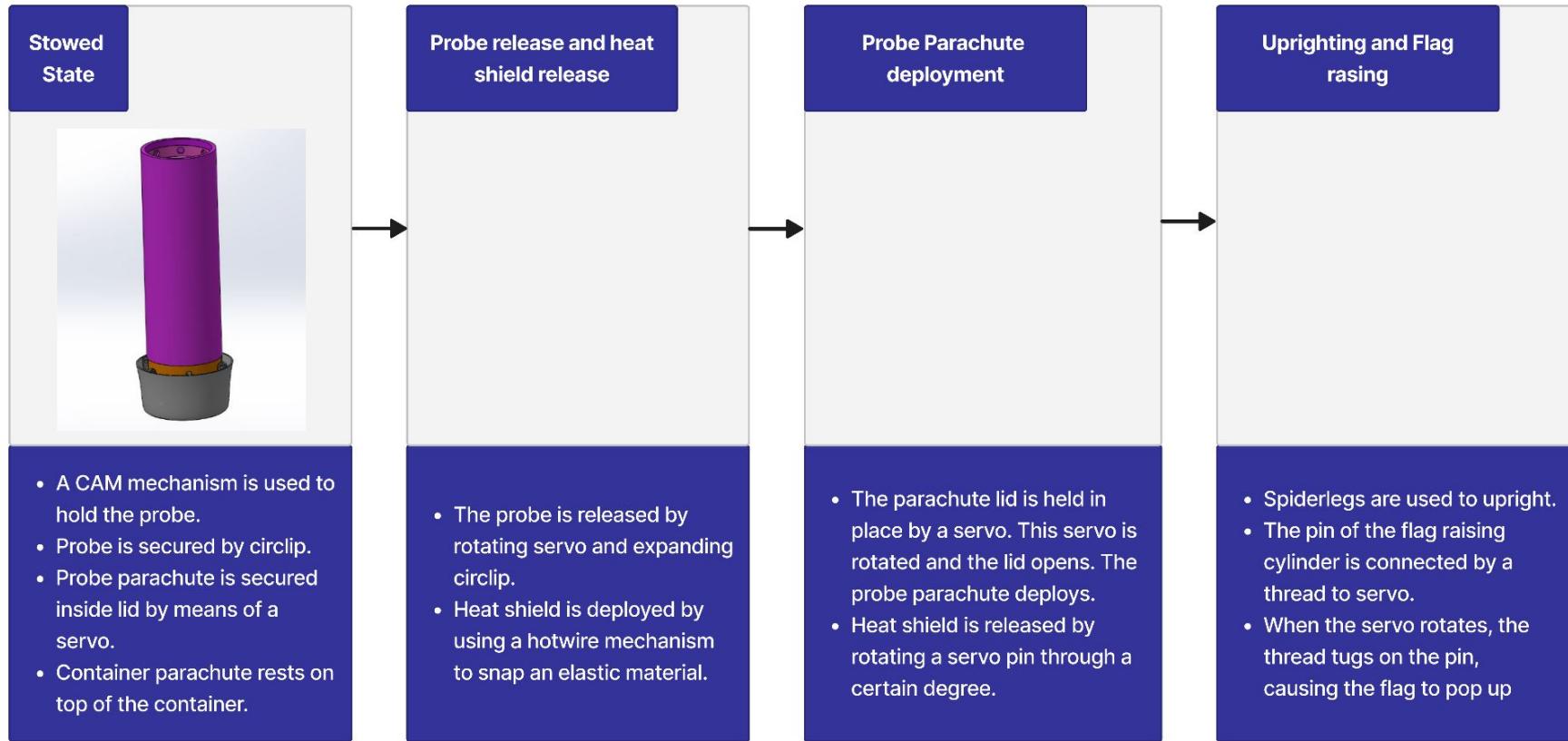
## Configuration A

1. The system is stabilised by passive control.
2. The system components are mounted using standoffs and screws.
3. Parachute is controlled using lid deployment by servo motor.
4. Probe is released using CAM mechanism

Pros	Cons
<ul style="list-style-type: none"><li>1. The CanSat is stable as it descends.</li><li>2. Electronics are reliably secured.</li></ul>	<ul style="list-style-type: none"><li>1. 3D printed material is considerable in volume, increases cost and mass.</li></ul>



# System Level CanSat Configuration Trade & Selection(2/5)





# System Level CanSat Configuration Trade & Selection(3/5)



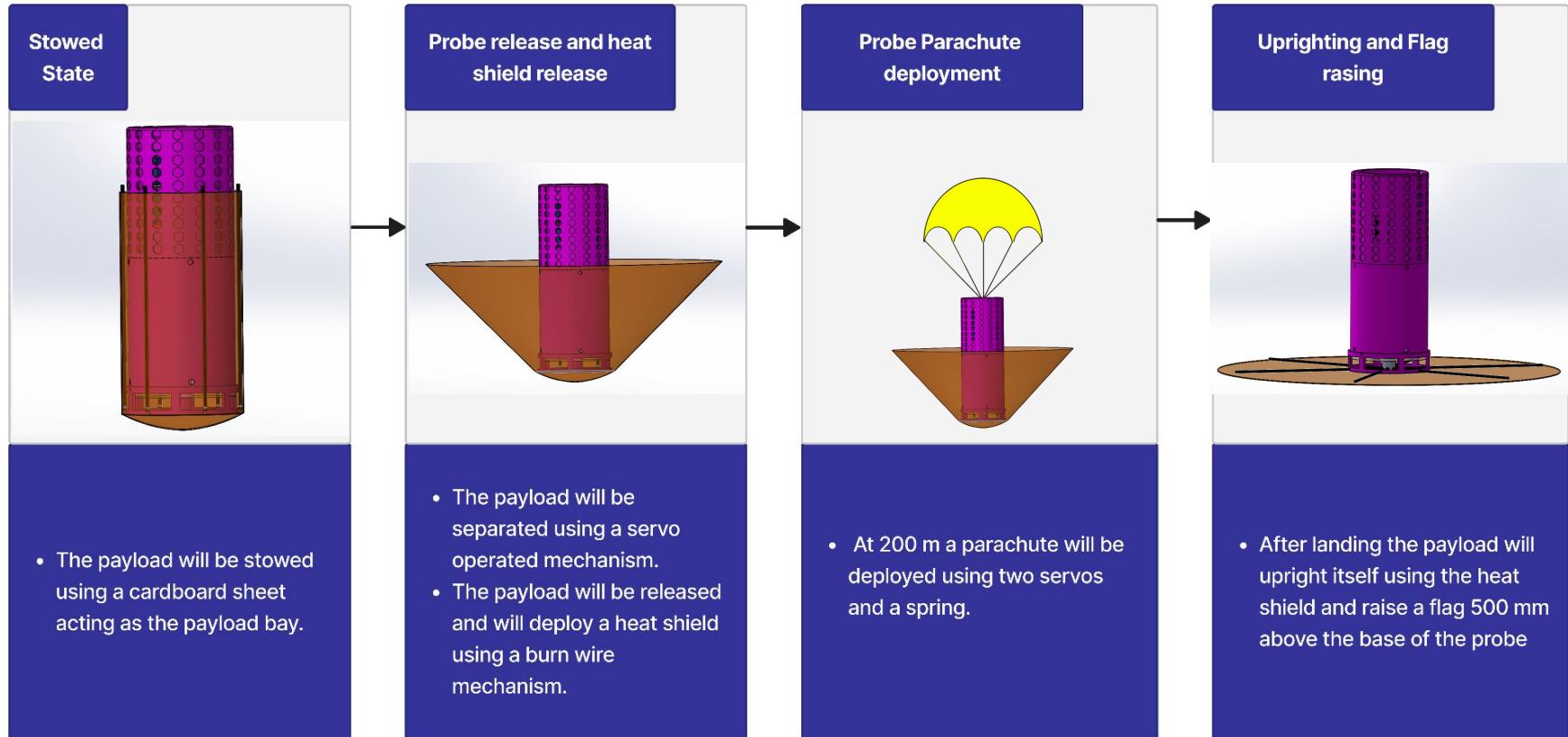
## Configuration B

1. The system will provide descent using only passive control.
2. All the electronic components will be enclosed inside the structure.
3. The payload is stowed using sheet of cardboard.
4. The base of the container is open to allow easier payload deployment.
5. Two servos and a spring will be used to deploy probe parachute.
6. The heat shield is deployed using burn wire mechanism

Pros	Cons
<ol style="list-style-type: none"><li>1. Reduction in mechanism as heat shield is used for uprighting.</li><li>2. Mechanisms are simple.</li></ol>	<ol style="list-style-type: none"><li>1. Reduction in durability due to 3D printed components.</li><li>2. Chance of damage to the heat shield arms due to improper stowing and payload release.</li></ol>



# System Level CanSat Configuration Trade & Selection(4/5)





# System Level CanSat Configuration Trade & Selection(5/5)

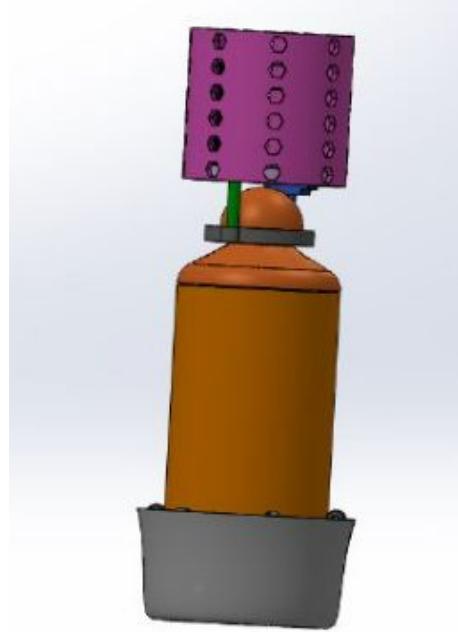


Criteria	Configuration A	Configuration B
<b>Descent stability</b>	Better stability	Chances of variable descent rate.
<b>Durability</b>	Durable structure	Fairly durable
<b>Presence of failsafe</b>	Mechanisms prevent failure due to error	No failsafes
<b>Utilization of space</b>	Better utilization of space	Wastage of space in probe

Selected Configuration	Reasons
Configuration A	<ol style="list-style-type: none"><li>1. This configuration provides better descent stability and durability.</li><li>2. Mechanisms are sound and reduce risk of failures.</li></ol>



# System Level Configuration Selection



Selected Configuration	Rationale
A	<ul style="list-style-type: none"><li>• Easier to stabilize and upright.</li><li>• More utilization of space</li><li>• Provides greater flexibility of other designs.</li></ul>



# Physical Layout



- The goal is to present the physical idea of what the CanSat will look like for reference prior to getting into details of the CanSat design
- Diagram(s) showing physical layout of selected CanSat configuration
- Make sure to include:
  - Dimensioned drawings
  - Placement of major components
    - Sensors, electronics, radio, power, mechanisms
  - Relevant configurations
    - Payload launch configuration, deployed configuration.
- Can be on separate slides.



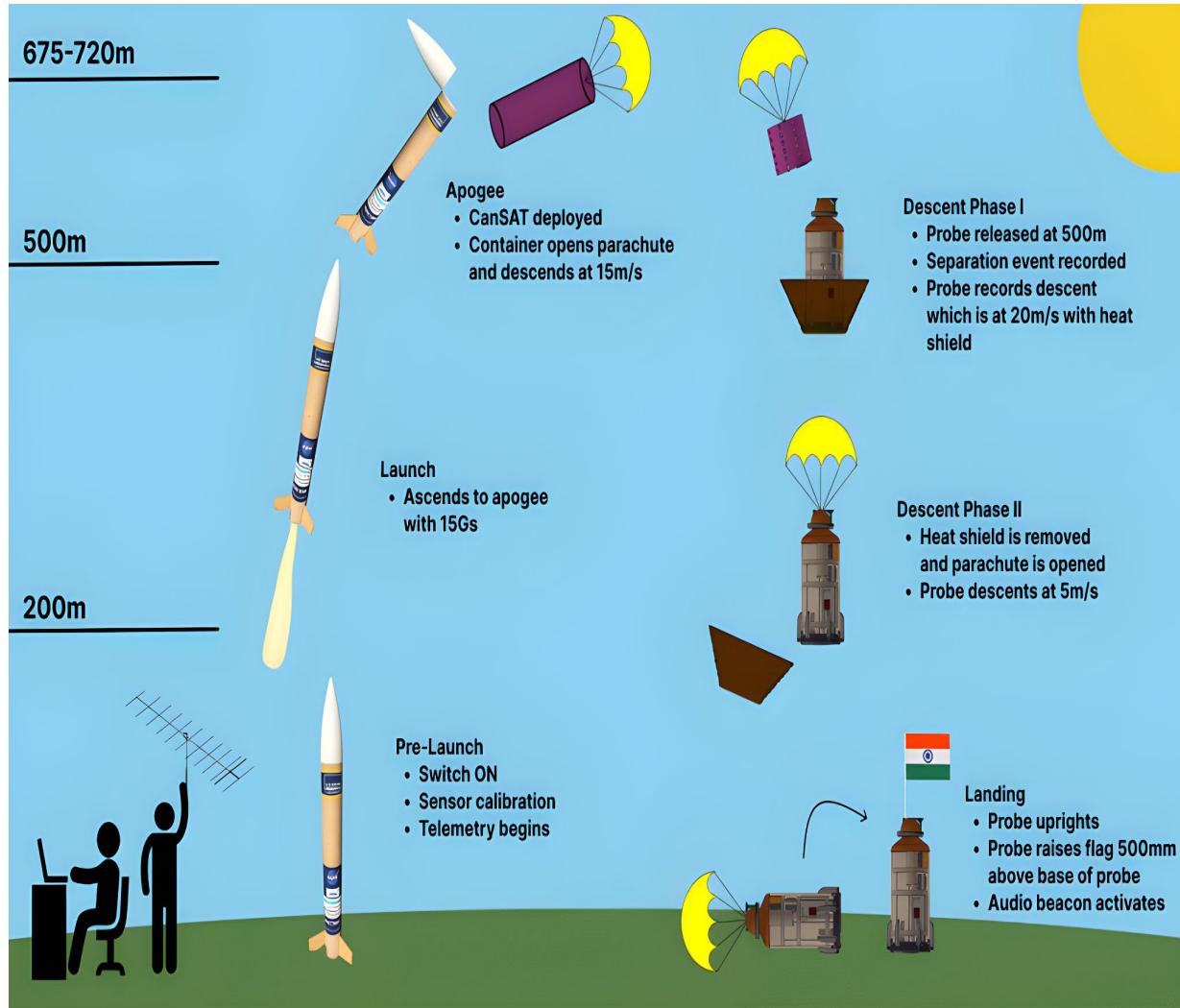
# System Concept of Operations(1/2)



<b>Pre-Launch</b>	<ul style="list-style-type: none"><li>• Arrival at launch site and pre-launch configurations.</li><li>• GCS setup and connection establishment with CanSat.</li><li>• CanSat is switched on, sensors are calibrated and telemetry begins.</li></ul>
<b>Launch</b>	<ul style="list-style-type: none"><li>• CanSat submitted to launch site officials is placed in launch vehicle bay.</li><li>• The launch vehicle is launched and ascends to apogee with 15Gs of acceleration.</li></ul>
<b>Apogee</b>	<ul style="list-style-type: none"><li>• Apogee is attained at 675-720m above launch site.</li><li>• CanSat is deployed from launch vehicle under large shock forces.</li><li>• Container immediately releases a parachute and descends at 15m/s.</li></ul>
<b>Descent Phase - I</b>	<ul style="list-style-type: none"><li>• The altitude of 500 m is sensed.</li><li>• Container video camera starts recording separation event of probe.</li><li>• Container releases a probe.</li><li>• Probe immediately opens a heat shield and descends at 20m/s.</li><li>• Probe camera starts recording descent while pointing towards ground.</li></ul>
<b>Descent Phase - II</b>	<ul style="list-style-type: none"><li>• At an altitude of 200m, probe deploys a parachute.</li><li>• Immediately, the heat shield is detached.</li><li>• Probe descends at a rate of 5m/s.</li></ul>
<b>Landing</b>	<ul style="list-style-type: none"><li>• After the probe lands, it uprights itself.</li><li>• Post uprighting, probe raises flag 500mm above base of probe.</li><li>• Telemetry is stopped and audio beacon activates.</li></ul>
<b>Recovery</b>	<ul style="list-style-type: none"><li>• Container and probe are recovered and switched off.</li><li>• Flight data is recovered, analysed and PFR is made for submission.</li></ul>

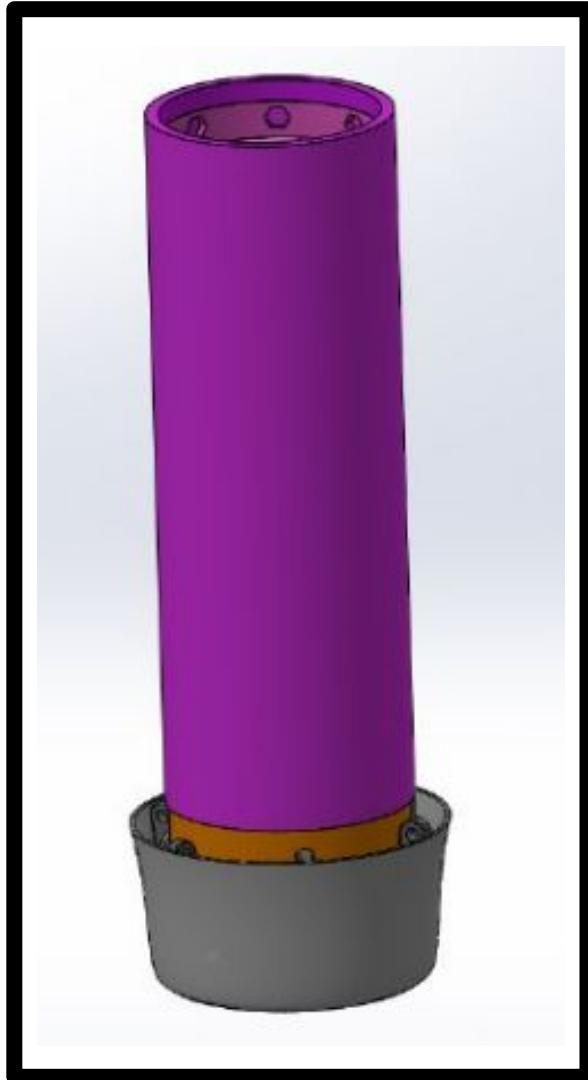


# System Concept of Operations(2/2)





# Launch Vehicle Compatibility



Dimensions	Container	Payload
Length(mm)	100	156
Diameter(mm)	112	112

Particulars	Comments
<b>Clearances</b>	<ul style="list-style-type: none"><li>The CanSat has a clearance of 6.5 mm of on diametrically opposite sides.</li><li>Vertical clearance is</li></ul>
<b>Sharp edges/protrusions</b>	<ul style="list-style-type: none"><li>There are no sharp edges anywhere and no chances of protrusion getting stuck.</li></ul>



---

# Sensor Subsystem Design

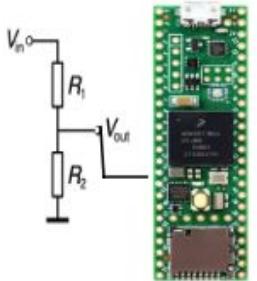
**Shreya Puri**



# Sensor Subsystem Overview



Air Pressure +  
temperature sensor



Battery voltage  
sensor



Tilt sensor



GPS



Camera



Bonus Camera

Sensor Type	Selected Model	Purpose
Air Pressure sensor	MS5611	Measures air pressure and altitude.
Temperature sensor	MS5611	Measures air temperature.
Battery voltage sensor	TeensyADC+ voltage divider	Measures the battery voltage.
Tilt sensor	Adafruit LSM6DS3TR-C	Determines the orientation of the payload.
GPS sensor	Neo-6M	Determines the position and no. of satellites.
Camera	SQ11	Records the video of the descent.
Bonus Camera	ESP-32 CAM	Records the release of the payload.



# Payload Air Pressure Sensor Trade & Selection



Component	Power	Dimensions (mm)	Mass (g)	Pressure range (hPa)	Resolution (hPa)	Interface	Cost (\$)
BMP280	3.3V x 0.0034mA	12 x 9 x 1.5	1	300 - 1100	0.01	I <sup>2</sup> C	0.63
BMP388	3.3V x 0.034mA	13.5 x10.5 x2	1.2	300 - 1250	0.0018	I <sup>2</sup> C,SPI	15
MS5611	3.3V x 0.015mA	19 x 13 x 2	1.5	10 - 1200	0.012	I <sup>2</sup> C	8.15

## Selected Component



**MS5611**

## Rationale

- High Resolution.
- Low power consumption.
- Moderate cost.
- Good pressure range.



# Payload Air Temperature Sensor Trade & Selection



Component	Power	Dimensions (mm)	Mass (g)	Range (°C)	Resolution (°C)	Accuracy (°C)	Interface	Cost (\$)
BMP280	3.3V x 0.0034mA	12 x 9 x 1.5	1	-40~85	0.01	± 1.0	I²C	0.63
BMP388	3.3V x 0.034mA	13.5 x10.5 x2	1.2	-40~85	0.005	± 0.5	I²C,SPI	15
MS5611	3.3V x 0.015mA	19 x 13 x 2	1.5	-40~85	< 0.01	± 0.8	I²C	8.15

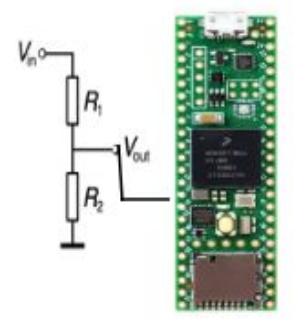
Selected Component	Rationale
 <b>MS5611</b>	<ul style="list-style-type: none"><li>• Better accuracy and resolution.</li><li>• Low power consumption.</li><li>• Moderate cost.</li></ul>



# Payload Battery Voltage Sensor Trade & Selection



Model	Dimensions (mm)	Mass (gm)	Range (V)	Resolution (mV)	Interface	Cost (\$)
Teensy ADC + voltage divider	Embedded	-	0 - 3.3	1.2	Analog	0
INA 219	26 x 22 x 6	3	0 - 26	1.2	I <sup>2</sup> C	3.14
Arduino voltage sensor	40 x 30 x 20	9	0 - 25	4.8	Analog	0.7

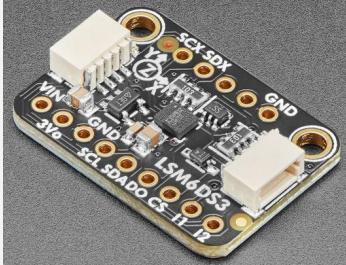
Selected Component	Rationale
 <b>Teensy ADC + voltage divider</b>	<ul style="list-style-type: none"><li>Included ADC in Teensy.</li><li>Easy to implement voltage divider.</li><li>Good resolution.</li></ul>



# Payload Tilt Sensor Trade & Selection



Component	Power	Dimensions (mm)	Mass (g)	Accelerometer range (g)	Gyrometer range (dps)	Interface	Cost(\$)
MPU 6050	3.3 V x 3.9 mA	20.7 x 15.5	2.1	$\pm 2 \pm 4 \pm 8 \pm 16$ g	$\pm 250, 500, 1000, 2000$	I <sup>2</sup> C	2.12
Adafruit LSM6DS3TR-C	3.3 V x 0.9 mA	25.3 x 17.8	1.7	$\pm 2 \pm 4 \pm 8 \pm 16$ g	$\pm 250, 500, 1000, 2000$	I <sup>2</sup> C	9.95
GY-87 10DOF	3.3 V x 4.1 mA	22 x17	5	$\pm 2 \pm 4 \pm 8 \pm 16$ g	$\pm 250, 500, 1000, 2000$	I <sup>2</sup> C	12.24

Selected Component	Rationale
 <b>Adafruit LSM6DS3TR-C</b>	<ul style="list-style-type: none"><li>Low current consumption.</li><li>Moderate cost.</li><li>On-board FIFO Management.</li></ul> <p>We had encountered FIFO overflow error using MPU 6050.</p>



# Payload GPS Sensor Trade & Selection



Component	Power	Dimensions (mm)	Mass (g)	Resolution (m)	Update rate (Hz)	Interface	Cost(\$)
<b>Neo 6M</b>	3.3 V x 40 mA	22x30x4	12	±2.5	1-5	UART	4.91
<b>Neo 8M</b>	3.3 V x 22 mA	27x36x4	17	±2.5	1-10	UART	13.53
<b>MTK3339</b>	3.3 V x 25 mA	16x16x5	4	±1.8	1-10	UART	24.6

Selected Component	Rationale
 <b>Neo 6M</b>	<ul style="list-style-type: none"><li>Moderate size.</li><li>Affordable cost.</li><li>Has the same tracking sensitivity as Neo-8M, but higher than MTK3339.</li></ul>



# Payload Camera Trade & Selection



Component	Dimensions (mm)	Mass (gm)	Operating voltage(V)	Resolution	SD Card	Interface	Cost (\$)
Adafruit 3202	28.5 x 17 x 4.2	2.8	5	640 x 480	Yes	CSI, GPIO	12.5
ESP-32 CAM	43 x 40 x 10	45	5	1600 x 1200	Yes	CSI	7.45
SQ11	23 x 23 x 23	20	5	1280 x 720	Yes	Digital	9.84

## Selected Component



SQ11

## Rationale

- Small size.
- Good resolution.
- Has micro SD card slot.
- In-built battery.



# Bonus Camera Trade and Selection



Component	Dimensions (mm)	Mass (gm)	Operating voltage(V)	Resolution	SD Card	Interface	Cost (\$)
Adafruit 3202	28.5 x 17x 4.2	2.8	5	640 x 480	Yes	CSI, GPIO	12.5
ESP-32 CAM	43 x 40 x 10	45	5	1600 x 1200	Yes	CSI	11
SQ11	23 x 23 x 23	20	5	1280 x 720	Yes	Digital	9.84

Selected Component	Rationale
 <b>ESP-32 CAM</b>	<ul style="list-style-type: none"><li>• Better resolution.</li><li>• Has micro SD card slot.</li><li>• Separate processor.</li></ul>



---

# Descent Control Design

Ojas Taskar



# Descent Control Overview



The descent control strategy of the CanSat is as follows:

1. At an altitude of **670-725 m**, the CanSat is deployed from the rocket. Immediately, the **first parachute** stowed inside the container deploys and reduces the entire CanSat descent rate to **15m/s**.
2. At an altitude of **500m**, the container releases the probe. The probe immediately opens a **dome shaped heat shield** with which probe descends at **20m/s**. A **() mechanism** is used to stabilize the probe when the heat shield is open. Container with the first parachute descends at \_\_\_\_ .
3. At a height of **200m**, probe releases the heat shield and immediately opens the **second round parachute** stowed inside it. This parachute reduces the probe descent rate to **5m/s**.

Altitude	Configuration	Components required
675-720m	<b>First round parachute</b>	Yellow ripstop nylon parachute attached by nylon strings.
500m	<b>Probe with heat shield and stabilization</b>	Servo-lever movable mechanism with hotwire for nylon heat shield deployment. () for stabilization of probe.
200m	<b>Probe parachute.</b>	Lid opening servo mechanism for stowed ripstop nylon parachute.

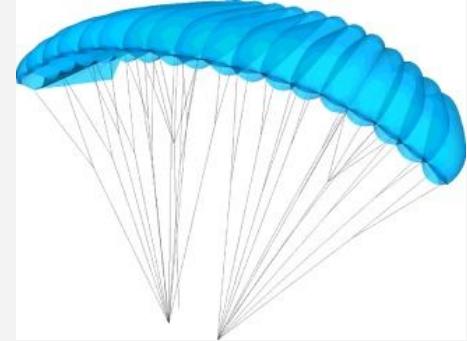


# Container Descent Control Strategy

## Selection and Trade(1/7)



### Container Parachute Design Trade (1/2)

Features	Round Parachute	X-form Parachute	Ram-air Parachute
Visual Description			
PROS	<ul style="list-style-type: none"><li>• Easy to fabricate</li><li>• More stability per unit area of parachute material</li><li>• Short opening time</li></ul>	<ul style="list-style-type: none"><li>• Reduces required area and material cost</li><li>• Less possibility of swaying</li><li>• Reduces horizontal drift</li></ul>	<ul style="list-style-type: none"><li>• Provide greater control over direction</li><li>• Spread stress evenly over area</li></ul>
CONS	<ul style="list-style-type: none"><li><input type="checkbox"/> Possibility of greater stress on connecting points when deployed.</li></ul>	<ul style="list-style-type: none"><li><input type="checkbox"/> Rope entanglement is likely.</li><li><input type="checkbox"/> Harder to fabricate.</li><li><input type="checkbox"/> Chances of stress.</li></ul>	<ul style="list-style-type: none"><li><input type="checkbox"/> Descent rate may vary if control is not active.</li><li><input type="checkbox"/> Complexity increases because of more number of threads</li></ul>

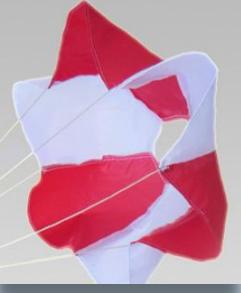


# Container Descent Control Strategy

## Selection and Trade(2/7)



### Container Parachute Design Trade (2/2)

Selected Parachute Type	Rationale
 <b>Round Parachute with spill holes</b>	<ul style="list-style-type: none"><li>• Spill holes improve stability</li><li>• Easier to fabricate</li><li>• Descent Rate can be easily verified</li><li>• Experience of use on previous occasions</li></ul>



# Container Descent Control Strategy

## Selection and Trade(3/7)



### Container Parachute Material Trade (1/1)

Features	Ripstop Nylon	Kevlar
Cost(\$) / meter	2.5	15
PROS	<ul style="list-style-type: none"><li>Widely verified as a reliable option for making parachutes.</li><li>Commercially available parachutes of this material.</li></ul>	<ul style="list-style-type: none"><li>Strongest fabric commercially available.</li><li>Light material per unit area.</li></ul>
CONS	<ul style="list-style-type: none"><li>Heavier material per unit area.</li><li>Can melt when exposed to high temperatures.</li></ul>	<ul style="list-style-type: none"><li>Very Expensive.</li><li>Not easily available in India.</li></ul>

Selected Material	Rationale
Ripstop Nylon	<ul style="list-style-type: none"><li>Documentation is available online for designing own parachute of this material.</li><li>Easy of supply in India.</li><li>We have experience using this material previously.</li><li>Reliable material at lesser cost.</li></ul>



# Container Descent Control Strategy

## Selection and Trade(4/7)



### Container Parachute Stowed Configuration Selection(1/3)

#### Configuration A

##### Description

- The parachute is attached to the attachment plate using nylon strings of 1 feet length.
- The nylon strings are attached to an eye-bolt made of metal which is attached to the plate by means of screws.
- The nylon strings are attached to metal welded holes in the parachute.
- The parachute rests loosely on top of the container.



# Container Descent Control Strategy

## Selection and Trade(5/7)



### Container Parachute Stowed Configuration Selection(2/3)

#### Configuration B

##### Description

- The parachute is tightly wound and kept on the topmost plate of the container.
- The parachute is kept secured by two threads running at 90° across its folded shape.
- The threads are attached to a point which is beside a servo motor with a sharp edge glued to it.
- The servo motor rotates, cuts the thread and the parachute is released due to airflow.



# Container Descent Control Strategy

## Selection and Trade(6/7)



### Container Parachute Stowed Configuration Selection(3/3)

Configuration	Advantages	Disadvantages
A	<ul style="list-style-type: none"><li>• Easy to design</li><li>• No complex mechanisms</li><li>• Recommended by mission guidelines</li></ul>	<input type="checkbox"/> Possibility that the parachute may get stuck when deploying.
B	<ul style="list-style-type: none"><li>• Complex</li><li>• Probability of late release of parachute/no release at all.</li><li>• Increases components and mass requirement.</li></ul>	<input type="checkbox"/> Parachute is kept compact <input type="checkbox"/> Uniformly released parachute means there will be no unbalanced force from one side at the point of contact.

Selected Configuration	Rationale
Configuration A	<ul style="list-style-type: none"><li>→ Saves power and mass.</li><li>→ Complies to all mission requirements</li><li>→ Easier to assemble and disassemble.</li></ul>



# Container Descent Control Strategy

## Selection and Trade(7/7)



### Container Descent Control Deployment Process

Just before release	Deployment	Post Deployment
<ul style="list-style-type: none"><li>The CanSat rests on the parachute in the launch vehicle bay.</li></ul>	<ul style="list-style-type: none"><li>As soon as the CanSat starts descending, the parachute opens naturally due to airflow. The eyebolt experiences shock force but stays in place as it is surrounded by a thin layer of rockwool.</li></ul>	<ul style="list-style-type: none"><li>The container is stabilised against swaying by 1ft length of cord and <b>slightly thickened lower walls</b>. This keeps the mass concentrated at bottom and acts as a passive control mechanism.</li></ul>



# Payload Aerobraking Descent Control Strategy Selection and Trade(1/5)



## Payload Aerobraking Device Design Trade(1/3)

### Configuration A - Hexagonal Heat Shield with interconnected panels

#### Stowed Configuration

- The two halves of the heat shield are connected by torsional springs.
- Shield folds inward forming a star-shape.
- Each panel of the shield is joined together by elastic cords.
- Entire shield is wound tight by a rubber connected to hotwire.



#### Deployed Configuration

- At 500m, the hotwire is given current from a MOSFET. The rubber band snaps open.
- The spring force pushes the panels outward and elastic cords force the panels to open up.



# Payload Aerobraking Descent Control Strategy Selection and Trade(2/5)



## Payload Aerobraking Device Design Trade(2/3)

### Configuration B - Umbrella shape heat shield with metal links

#### Stowed Configuration

- Metal links are placed in holes on a ring held in place by servo latch mechanism.
- One end of the links is held by torsional spring. Heat shield material is held within links.
- Upper part of link has a through-hole for a rubber to pass through.



#### Deployed Configuration

- To deploy, rubber is burnt using current.
- Torsional spring force pushes the links outward and heat shield opens.



# Payload Aerobraking Descent Control Strategy Selection and Trade(3/5)



## Payload Aerobraking Device Design Trade(3/3)

### Configuration Selection

Selected Configuration	Rationale
Configuration B	<ul style="list-style-type: none"><li>• Eliminates possibility of uprighting mechanism and heat shield interfering.</li><li>• Descent rate can be easily calculated.</li><li>• Reliability is high and mechanism is relatively less complex.</li><li>• Easier to time for deployment</li></ul>



# Payload Aerobraking Descent Control Strategy Selection and Trade(4/5)



## Payload Aerobraking Device Material Trade(1/1)

Features	Ripstop Nylon	Silica Fabric	Carbon Fabric
<b>PROS</b>	<ul style="list-style-type: none"><li>• Less expensive.</li><li>• Has durability.</li><li>• Easily available..</li></ul>	<ul style="list-style-type: none"><li>• Highly thermal resistant (operating temperatures &gt; 982°C)</li><li>• Tear proof.</li></ul>	<ul style="list-style-type: none"><li>• Heat and shock proof.</li><li>• Used as insulating and heat shield material by space agencies as well.</li></ul>
<b>CONS</b>	<ul style="list-style-type: none"><li><input type="checkbox"/> Heavier material per unit area.</li><li><input type="checkbox"/> Can melt when exposed to high temperatures.</li></ul>	<ul style="list-style-type: none"><li><input type="checkbox"/> Very expensive.</li><li><input type="checkbox"/> Not very easily available in India.</li></ul>	<ul style="list-style-type: none"><li><input type="checkbox"/> High cost.</li><li><input type="checkbox"/> Slight trace of carbon particles are left behind by it, may interfere with electronics.</li></ul>

Selected Material	Rationale
Silica Fabric	<ul style="list-style-type: none"><li>• Best material for price range.</li><li>• Prevents risk of 3D material melting due to heat when descending.</li></ul>



# Payload Aerobraking Descent Control Strategy Selection and Trade(5/5)



## Payload Aerobraking Device Deployment Description(1/1)

- Initially, the heat shield is held in place by the rubber, which resists the force of the torsional springs.
- At deployment point, the rubber is burnt by providing current through a MOSFET.
- The tension on the links is now provided by the torsional spring, which force it backward and heat shield opens.

- ★ At 200m, heat shield is needed to be released. To achieve this, the servo link is rotated and the heat shield ring is now free to move.
- ★ Due to airflow, the heat shield moves up and gets separated.
- ★ Slight delay is added between this release and parachute release to avoid entanglement.



# Payload Aerobraking Descent Stability Control Strategy Selection and Trade(1/3)



## Payload Aerobraking Stability Design Trade(1/3)

### Configuration A - Passive Control

Strategy	Effect and Advantage
PCBs and electronics are placed at the bottom.	The mass is concentrated at the bottom and there is minimal swaying due to torque of airflow.
Heat Shield is attached as close as possible to COM.	The air flowing past the heat shield generates torque on the shield. In case of unstable air flow, the torque generated by that force will be very less <b>owing to a very small moment arm.</b>



# Payload Aerobraking Descent Stability Control Strategy Selection and Trade(2/3)



## Payload Aerobraking Stability Design Trade(2/3)

### Configuration B - Active Control

Strategy	Effect and Advantage
4 servo controlled aerofoils are placed on the lowest plate.	It is possible to control the orientation of CanSat.
PID is used to determine position of aerofoil.	Using this, we can control the CanSat from twisting into the wind direction and becoming unstable due to windy conditions.



# Payload Aerobraking Descent Stability Control Strategy Selection and Trade(3/3)



## Payload Aerobraking Stability Design Trade(3/3)

Selected configuration	Rationale
Configuration A	<ul style="list-style-type: none"><li>• Eliminates the need for additional circuitry and additional mass.</li><li>• Initial testing in windy conditions suggests this is a sufficient mechanism.</li></ul>



# Payload Parachute Descent Control Strategy Selection and Trade(1/7)



## Probe Parachute Trade (1/2)

Features	Round Parachute	Flat Circular Parachute	Ram-air Parachute
Visual Description			
PROS	<ul style="list-style-type: none"><li>• Easy to design</li><li>• Descent rate can be easily modified</li><li>• Less chance of error</li></ul>	<ul style="list-style-type: none"><li>• No complexity</li><li>• Opens very fast</li><li>• Uses less material</li></ul>	<ul style="list-style-type: none"><li>• Provide greater control over direction</li><li>• Spread stress evenly over area</li></ul>
CONS	<ul style="list-style-type: none"><li><input type="checkbox"/> Possibility of greater stress on connecting points when deployed.</li></ul>	<ul style="list-style-type: none"><li><input type="checkbox"/> May sway and control provided is very less</li></ul>	<ul style="list-style-type: none"><li><input type="checkbox"/> Descent rate may vary if control is not active.</li><li><input type="checkbox"/> Complexity increases because of more number of threads</li></ul>



# Payload Parachute Descent Control Strategy Selection and Trade(2/7)



## Probe Parachute Trade (2/2)

Selected Parachute Type	Rationale
 <b>Round Parachute</b>	<ul style="list-style-type: none"><li>• Spill holes reduce building of air pressure and hence, chance of tearing.</li><li>• Can be easily woven by nylon strings to improve shock strength.</li><li>• Familiarity of design.</li></ul>



# Payload Parachute Descent Control Strategy Selection and Trade(3/7)



## Probe Parachute Material Trade (1/1)

Features	Ripstop Nylon	Kevlar
<b>Cost(\$)/meter</b>	2.5	15
<b>PROS</b>	<ul style="list-style-type: none"><li>Widely verified as a reliable option for making parachutes.</li><li>Commercially available parachutes of this material.</li></ul>	<ul style="list-style-type: none"><li>Strongest fabric commercially available.</li><li>Light material per unit area.</li></ul>
<b>CONS</b>	<ul style="list-style-type: none"><li>Heavier material per unit area.</li><li>Can melt when exposed to high temperatures.</li></ul>	<ul style="list-style-type: none"><li>Very Expensive.</li><li>Not easily available in India.</li></ul>

Selected Material	Rationale
Ripstop Nylon	<ul style="list-style-type: none"><li>Documentation is available online for designing own parachute of this material.</li><li>Easy of supply in India.</li><li>We have experience using this material previously.</li><li>Reliable material at lesser cost.</li></ul>



# Payload Parachute Descent Control Strategy Selection and Trade(4/7)



## Container Parachute Stowed Configuration Selection(1/3)

### Configuration A

#### Description

- The parachute is stowed inside the upper section of the probe.
- The section is held in place by a lid controlled by a servo motor.
- To release the parachute, the servo motor rotates and the lid opens.
- Small holes provided at the side of the section provide airflow entry which forces the parachute to open.
- Parachute is attached to an eyebolt secured to a 3D printed PLA plate by nylon cords.



# Payload Parachute Descent Control Strategy Selection and Trade(5/7)



## Container Parachute Stowed Configuration Selection(2/3)

### Configuration B

#### Description

- The parachute is tightly wound into a small 'pack' by threads.
- This is placed over a rectangular slot on a small plate.
- This plate keeps a spring under compression. The entire mechanism is fit under the vertical length of a servo motor.
- To release, the servo motor rotates 90° and the parachute is thrown into the air and deploys.



# Payload Parachute Descent Control Strategy Selection and Trade(6/7)



## Container Parachute Stowed Configuration Selection(3/3)

Configuration	Advantages	Disadvantages
A	<ul style="list-style-type: none"><li>• Easy to design</li><li>• Does not rely on high level circuitry.</li><li>• Can be controlled by a single digital pin</li></ul>	<input type="checkbox"/> Possibility that the parachute may not deploy due to airflow.
B	<ul style="list-style-type: none"><li>• Complex</li><li>• The launch forces may trigger the spring causing premature deployment.</li><li>• Difficult to time exact deployment.</li></ul>	<input type="checkbox"/> Parachute is kept compact in shape. <input type="checkbox"/> Uses up less space inside the probe.

Selected Configuration	Rationale
Configuration A	<ul style="list-style-type: none"><li>➔ Simple and highly reliable.</li><li>➔ Initial testing has suggested that these descent rates can be achieved with high accuracy.</li></ul>



# Payload Parachute Descent Control Strategy Selection and Trade(7/7)



## Container Descent Control Deployment Process

### Just before release

- The probe descends with the heat shield open at a rate of 20m/s.

### Deployment

- At 200m, the heat shield is removed. At the same time, the servo mechanism releases the lid by rotating.
- To mitigate deployment risk, the parachute(nylon) and lid will be rubbed with a plastic before assembling CanSat. This ensures that the parachute is pulled out with lid

### Post Deployment

- The probe descends to ground at the rate of 5 m/s.
- As mass of probe is contained at bottom, it is stabilised against swaying.
- Passive stabilising mechanism prevents shaking during descent.



# Descent Rate Estimates(1/4)



## Descent Rate for CanSat with Payload

$$\frac{1}{2}mv^2 = mgh \text{ (Total Energy conservation)}$$

$$\therefore v = \sqrt{2gh}$$

Now,  $h$  can be between 675 – 720 m

$$h_{avg} = 697.5m$$

$$\therefore v = \sqrt{2gh_{avg}}$$

$\therefore v = 116.92 \text{ m/s}$  of CanSat just after deployment.

Immediately, parachute will deploy,

$$\sqrt{\frac{8mg}{p(v_{max})^2\pi C_d}} \leq D_p \leq \sqrt{\frac{8mg}{p(v_{min})^2\pi C_d}}$$

$$D_{spill} = 4\% \text{ of diameter}$$

$$D_{side} = 2\% \text{ of diameter}$$

### Data

$$m = 0.65 \text{ kg}$$

### Assumptions

$$\rho = 1.225 \text{ kg/m}^3$$

$$g = 9.8 \text{ m/s}$$

$$\pi = 3.14$$

$$C_d = 1.5$$

Part	Chosen Diameter(m)
First Parachute	0.198
Spill Hole	0.0079
Side Hole	0.004



# Descent Rate Estimates(2/4)



## Descent Rate for Probe with Aerobraking Shield

To determine the required diameter for the heat shield, we calculate the diameter range using a maximum and minimum range of velocities.

Data

$$m =$$

Assumptions

$$\rho = 1.225 \text{ kg/m}^3$$

$$g = 9.8 \text{ m/s}$$

$$\pi = 3.14$$

$$C_d = 1.5$$

Part	Chosen Diameter(m)
Heat Shield	



# Descent Rate Estimates(3/4)



## Descent Rate for Probe with Parachute

$$\sqrt{\frac{8mg}{p(v_{max})^2\pi C_d}} \leq D_p \leq \sqrt{\frac{8mg}{p(v_{min})^2\pi C_d}}$$

Data

m =

$D_{spill} = 4\% \text{ of diameter}$

$D_{side} = 2\% \text{ of diameter}$

Assumptions

$\rho = 1.225 \text{ kg/m}^3$

$g = 9.8 \text{ m/s}$

$\pi = 3.14$

$C_d = 1.5$

Part	Chosen Diameter(m)
Second Parachute	0.483
Spill Hole	0.019
Side Hole	0.009



# Descent Rate Estimates(4/4)



## Final Result

Summary	
Altitude range	Description and Descent Rates
From 675-720m to 500m	
500m - 200m	
200m - ground	

Section	Overview of entire descent journey
Container	
Probe	



---

# Mechanical Subsystem Design

## Hetal Vanel



# Mechanical Subsystem Overview



Section	Components required
Container structures(plates, rods)	PLA, Polypropylene, steel screws and nuts
Container Parachute plate	PLA and steel eyebolt
Probe structure	PLA, ABS plastic and carbon fibre
Electronics bays	Carbon fibre rods, FR-4, steel screws and nuts, epoxy glue



# Container Mechanical Layout of Components Trade & Selection



- **Key trade issues related to mechanical layout and component selection**
  - Show structure of Container
  - Identify location of electrical components
  - Identify major mechanical parts
    - mechanisms such as springs, hinges, etc.
- **Show at least two mechanical layouts**
- **Indicate selection and reasons for selection**
- **Show structural material selection(s)**

**See slide discussing trade studies at the end of this PowerPoint**



# Container Mechanical Layout of Components Trade & Selection (1/



## Information

1. The container has 2 hinges and they are located at the bottom.



# Container Mechanical Layout of Components Trade & Selection (1/



## Selection

1. The container has 2 hinges and they are located at the bottom.
- 2.



# Container Parachute Attachment Mechanism



(parachute bay w  
parachute)

(eyebolt and threads)

Upper part of  
container

- The parachute will be made of nylon. It will have small holes through which metal rings will be fixed.
- These metal rings will hold the connecting parachute threads.
- The threads are one feet in length.

- The nylon threads are attached to a steel eyebolt by a standard knot. The steel eyebolt is held tightly to the mounting plate by using screws inserted into plate.
- The plate is secured in place by carbon fibre rods.

- Prior to deployment, the parachute is kept on top of the container. It rests on the top without any hindrance.
- The parachute strings are placed inside the parachute area to avoid entanglement



# Payload Mechanical Layout of Components Trade & Selection



- **Key trade issues related to mechanical layout and component selection**
  - Show structure of Payload
  - Identify location of electrical components
  - Identify major mechanical parts
    - mechanisms such as springs, hinges, etc.
- **Show at least two mechanical layouts**
- **Indicate selection and reasons for selection**
- **Show structural material selection(s)**

**See slide discussing trade studies at the end of this PowerPoint**



# Payload Aerobraking Pre Deployment Configuration Trade & Selection



## STOWED

- The payload is secured into the container by means of a CAM mechanism.
- The configuration is kept locked by a circlip which is controlled by a servo motor.
- In locked configuration, the diameter of circlip is lesser than the upper ball part and hence there is no swaying of payload



## SECURING

- The CAM mechanism is held together by two rods coming down from the container.
- These rods connect to the ring surrounding the probe and ensure that the probe does not sway due to horizontal forces on it.



# Payload Aerobraking Deployment Configuration Trade & Selection



## TRANSITION

- The heat shield is held together by an elastic cord touching a metal wire.
- To deploy, the elastic cord is snapped by heating it.
- The links of the heat shield are connected to a torsional spring each. This spring force now pushes the shield outward.



## DEPLOYED STATE

- The heat shield gets pushed out until the links reach their maximum length. The force exerted by the links is on the supporting ring which is made of steel for resistance.
- The heat shield stays open and provides aerobraking. To release it, a servo motor pin rotates through an angle of 14°, which leaves the ring free to slide and shield moves up.



# Payload Parachute Deployment Configuration Trade & Selection



(parachute section)

(transition from stowed to deploying)

Deployed parachute

- The parachute is rolled tightly and stored in the uppermost part of the probe.
- The lid is controlled using a servo motor which moves to release the parachute.

- The lid opens and the parachute is pulled out due to airflow and the static electric charge on the parachute.
- The threads are connected to the eyebolt which is firmly secured to the plate.

- Parachute gets fully deployed and achieves a descent rate of 5m/s.
- The payload is passively stabilized due passive stability control.

# Payload Uprighting Configuration Trade & Selection



- Key trade issues related to how the payload is made upright.
- Identify the upright orientation
- Explain mechanisms used to make the payload upright.

**See slide discussing trade studies at the end of this PowerPoint**



# Electronics Structural Integrity



All PCBs shall be mounted using stand-off screws around threaded carbon rods.

The bolts shall be covered with electrical insulation tape to avoid cross conductivity.

PCBs shall be covered inside the body by laminated paper on both sides.

All components, including through-hole and surface-mounted, shall be carefully soldered on the PCBs.

Through-hole components shall be attached using header connectors and not directly on the PCBs.

Heat sinks shall be used over MOSFETS and ICs

The antenna shall be taped around the wedge to secure it.

Container's descent rate shall be controlled by a parachute.

The probe parachute shall be deployed using servo motor opening the lid

PCBs shall be covered inside the body by laminated paper on both sides.



# Mass Budget(1)



## CONTAINER

### Structure

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Container outer body	PLA	1	10.597	10.597	Calculated
Parachute Plate	PLA	1	78.54	78.54	Calculated
Container rods	Carbon fiber	3	3.77	11.31	Calculated

Summary Container Structure Mass

100.447 g



# Mass Budget(2)



## CONTAINER

## Mechanisms

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Servo Motor	SG90 Servo	1	9	9	Datasheet
Cam Rods	PLA	2	2.493	4.986	Datasheet

Summary Container Mechanisms Mass

13.986 g



# Mass Budget(3/



## CONTAINER

### Electronics

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Tilt Sensor	Adafruit LSM6DS3TR-C	1	1.7	1.7	Datasheet
Memory Card	SanDisk Ultra microSD 32GB	1	2.0	2.0	Datasheet
Buzzer	92 dB Buzzer	1	22.0	22.0	Estimate
LED	Green LED	1	0.3	0.3	Datasheet
ON/OFF Switch	Switch	1	4.2	4.2	Estimate
Bonus Camera	ESP32 CAM	1	10.0	10.0	Datasheet
Air Temperature and Pressure Sensor	MS5611	1	1.2	1.2	Datasheet
Battery	Orange ICR18650-20C	1	47.0	47.0	Estimate



# Mass Budget(4)



## CONTAINER

### Electronics

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Custom PCBs	FR-4	1	25.62	25.62	Calculated

Summary Container Electronics Mass

114.02 g



# Mass Budget(5/



## PROBE

### Structure

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Base Plate	PLA	1			
Central Plates	PLA	3			
Hinges for Servo	PLA	2	17.046	34.092	Calculated
Probe outer body	PLA	1	198.4	198.4	Calculated
Probe upper holder	PLA	1			
Probe rods	Carbon fiber	3	2.337	7.012	Calculated

Summary Probe Structures Mass

239.504 g



# Mass Budget(6/



## PROBE

### Mechanisms

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Servo	SG90 Servo Motor	2	9	18	Datasheet
Spider legs	PLA	6	5.02	30.12	Calculated
Flag stick	Deployable Safety Stick	1	7.5	7.5	Datasheet
Heat Shield Cloth	Silica Fabric	1			
Heat Shield links	Metal rods	6	7	42	Estimate
Torsional Springs	Steel springs	12	3	36	Estimate

Summary Probe Mechanisms Mass

133.62 g



# Mass Budget(7)



## PROBE

### Electronics

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Microcontroller	Teensy 4.1	1	10.0	10.0	Estimated
Air Pressure and Temperature Sensor	MS5611	1	1.2	1.2	Datasheet
Tilt Sensor	Adafruit LSM6DS3TR-C	1	1.7	1.7	Datasheet
GPS Sensor	UBLOX Neo 6M	1	12	12	Datasheet
Camera	SQ11 Mini Camera	1	18	18	Datasheet
Memory Card	Sandisk Ultra uSD 32GB	2	2	4	Datasheet
Coin Battery and holder	Duracell DL2032 3V	1	4.5 + 4.2	8.7	Estimate
92dB Buzzer	GoodLife 92Buzzer	1	5.35	5.35	Datasheet



# Mass Budget(8/



## PROBE

### Electronics

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Battery Power Indicator	SMD 3 Colour LED module	1	1.2	1.2	Datasheet
LED	5mm LED	1	0.3	0.3	Datasheet
Radio	XBee Pro S2C	1	4	4	Datasheet
Antenna	Molex 214415-0011	1	7.7	7.7	Datasheet
SMA Cable	SMA-M to SMA-M	1	4.64	4.64	Estimate
Custom PCBs	Printed Circuit Board	2	27.32	27.32	Estimate
ON/OFF Switch	Switch	1	4.2	4.2	Estimate
Battery	Orange ICR 18650-20C	1	47	47	Datasheet



# Mass Budget(9)



## PROBE

### Electronics

Component	Material / Part name	Quantity	Mass/unit (g)	Mass summary (g)	Source
Battery Holder	18650 SMD/SMT Holder	1	8	8	Datasheet

Summary Probe Electronics Mass

165.310 g



# Mass Budget





---

# Communication and Data Handling (CDH) Subsystem Design

Ojas Taskar



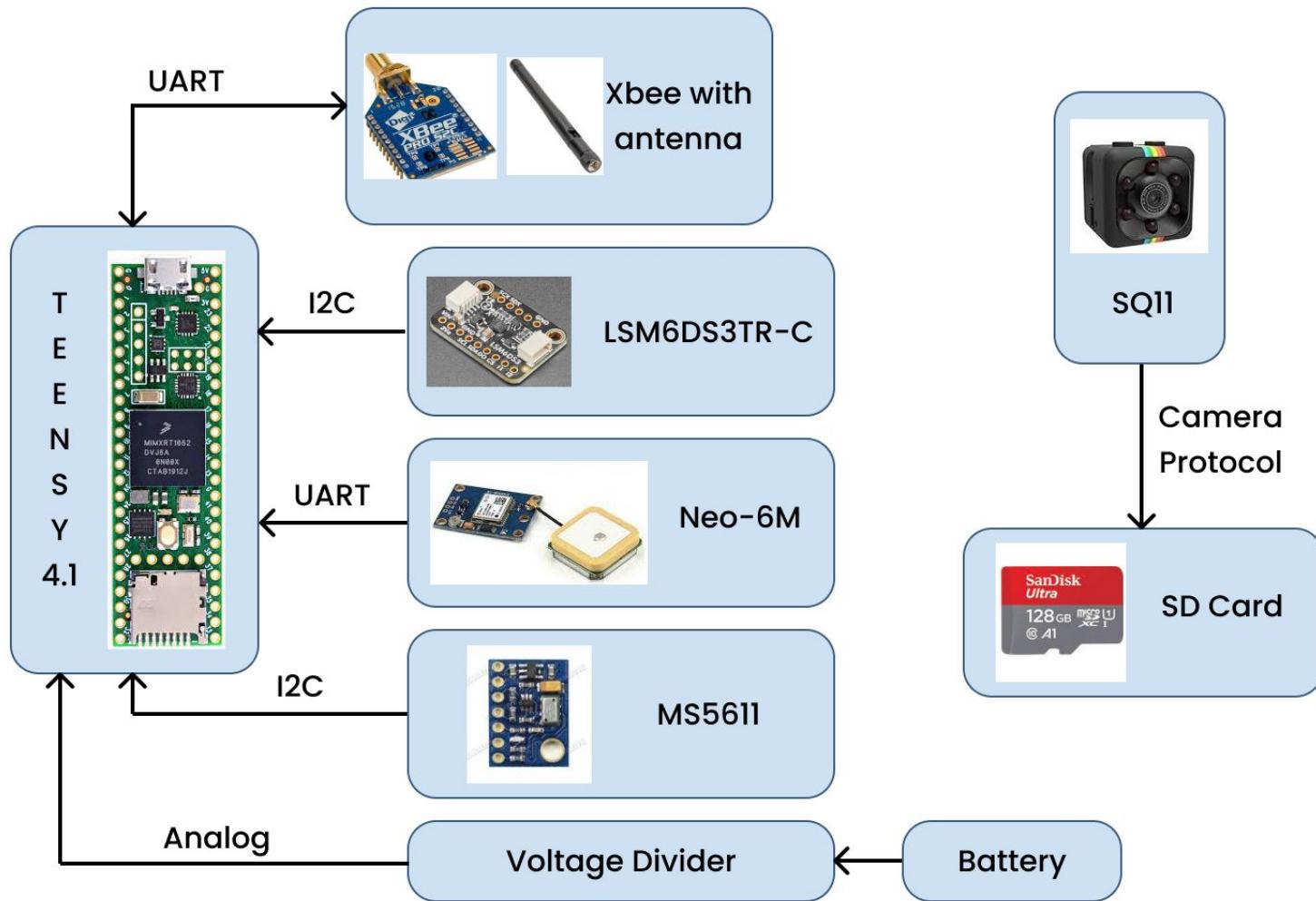
# Payload Command Data Handler (CDH) Overview (1/2)



Component	Selected Model	Purpose
Processor	<b>IMXRT1062DVJ6 on Teensy v4.1</b>	Collecting and processing data from the sensors, bidirectional communication with the ground station, control over CanSat mechanisms.
Storage	<b>Sandisk Ultra micro SD Card</b>	Stores backup telemetry data.
Radio Module	<b>XBee Pro S2C</b>	Transmitting to and receiving data from GCS.
Antenna Payload-GCS	<b>Molex 214415-0011</b>	Increases gain of XBee and amplifies the signal range.
Sensors	<b>Adafruit LSM6DS3TR-C, MS5611, Neo-6M</b>	Sending respective data fields.
RTC	<b>Built-in</b>	Measures mission time.
Camera	<b>SQ11 Mini Camera</b>	Records the video of descent in separate SD card.



# Payload Command Data Handler (CDH) Overview (2/2)





# Payload Processor & Memory Trade & Selection (1/2)



Model	Size (mm)	Clock speed (MHz)	Boot time (ms)	Operating voltage (V)	Memory (kB)			Interface
					RAM	FLASH	EEPROM	
Teensy 4.1	61 x 18	600	5	3.3	1024	7936	4	UART(8), I <sup>2</sup> C(3), SPI(3)
Teensy 4.0	36 x 18	600	5	3.3	1024	1984	1	UART(7), I <sup>2</sup> C(3), SPI(3)
Raspberry-Pi Pico	51 x 21	133	>300	1.8 - 3.3	264	2000	0	UART(2), I <sup>2</sup> C(2), SPI(2)

Selected Component	Rationale
 <b>Teensy 4.1</b>	<ul style="list-style-type: none"><li>Very high clock speed.</li><li>Large flash memory compared to other boards.</li><li>In-built SD card slot and RTC.</li><li>More number of GPIO pins.</li></ul>



# Payload Processor & Memory Trade & Selection (2/2)



SD Card	Memory storage(GB)	Data Transfer Speed(MB/S)		Interface	Cost (\$)
		Read	Write		
SanDisk Ultra	32	120	98	SPI, SD	4.38
HP microSD HC	32	80	30	SPI, SD	4.75
SAMSUNG Evo Plus	32	100	90	SPI, SD	5.63

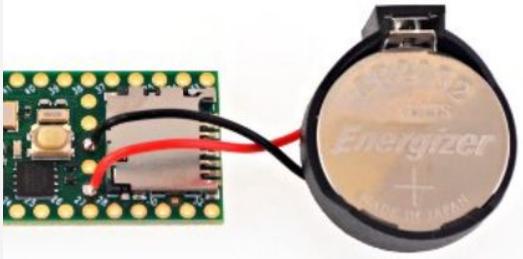
Selected payload memory	Rationale
 <b>SanDisk Ultra</b>	<ul style="list-style-type: none"><li>Sufficient memory storage.</li><li>Faster data transfer speed.</li><li>Moderate cost.</li><li>High availability.</li></ul>



# Payload Real-Time Clock



Model	Size(mm)	Supply voltage (V)	Accuracy (ppm)	Interface	Reset Tolerance	Cost (\$)
<b>Teensy 4.1 built in RTC</b>	Embedded in Teensy 4.1	3.3	~5	Internal bus	Continues to track time due to external battery.	0
DS3231	38 x 22 x 14	3.3	2	I <sup>2</sup> C	Continues to track time due to external battery.	3

Selected Component	Rationale
 <b>Teensy 4.1 built in RTC</b>	<ul style="list-style-type: none"><li>• Eliminates the need for additional circuitry.</li><li>• Can be provided external power from a coin battery</li></ul>



# Payload Antenna Trade & Selection(1/6)



Model	Range(km)	Dimensions(cm)	Frequency(GHz)	Peak Gain(dBi)	Connection type	Weight(g)	Cost(\$)
Taoglas GW.20.A151	~ 12	8.95 x 0.95	2.4GHz, 5.8GHz	2	RP-SMA	7	5.46
Pulse Electronics W5029RPG	~ 8.3	7.6 x 0.79	2.4GHz, 5.15-7.125GHz	0.4	RP-SMA	7.82	5.52
Molex 214415-0011	~ 11	10.8 x 0.935	2.4GHz	5.3	RP-SMA	7.715	4.63

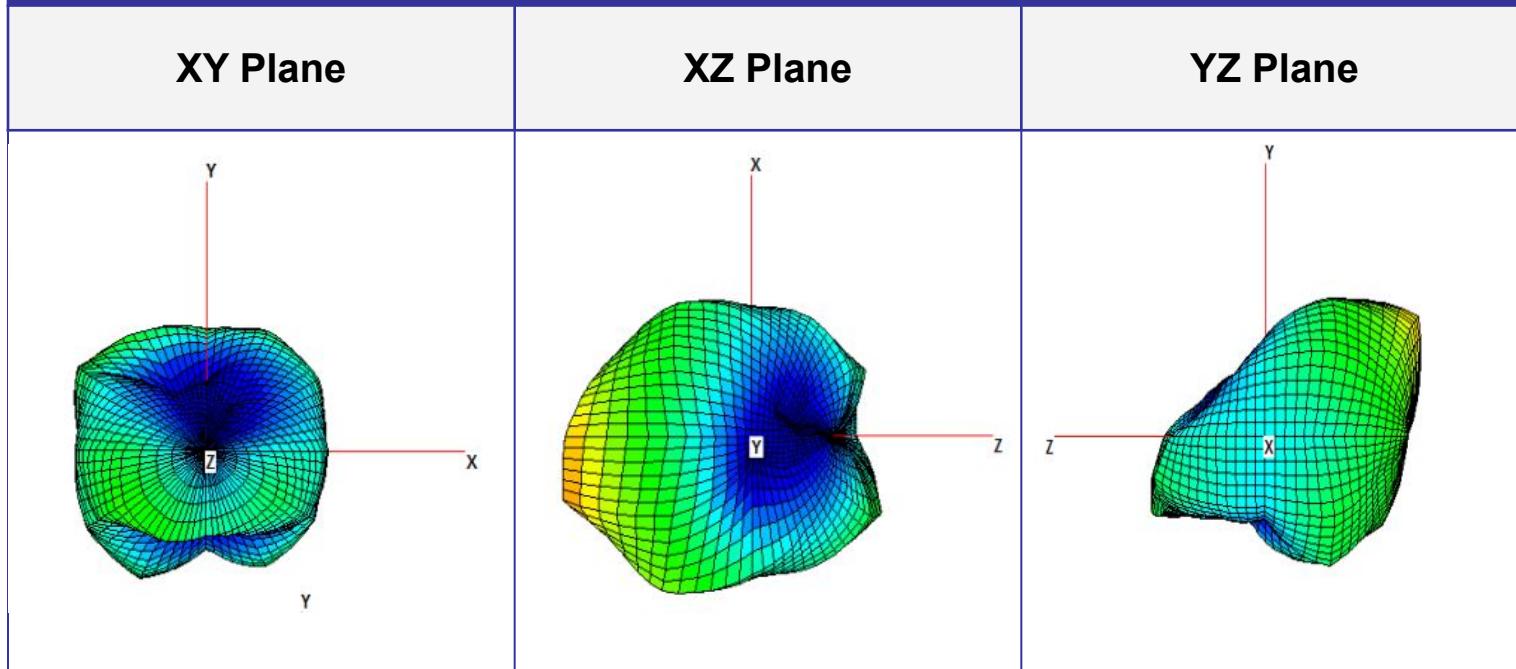


# Payload Antenna Trade & Selection(2/6)



## Radiation Patterns:

**Radiation Pattern of Molex 214415-001115**



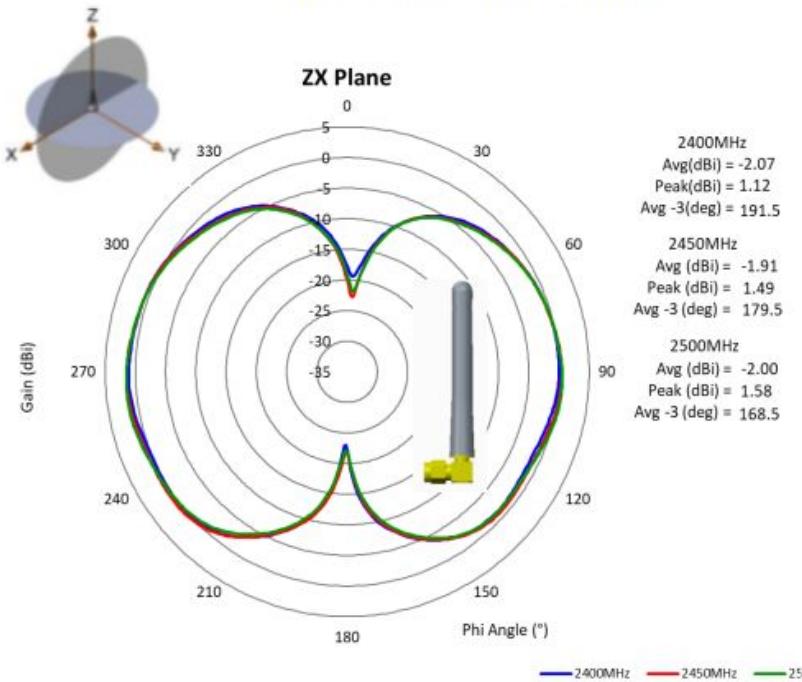


# Payload Antenna Trade & Selection(3/6)

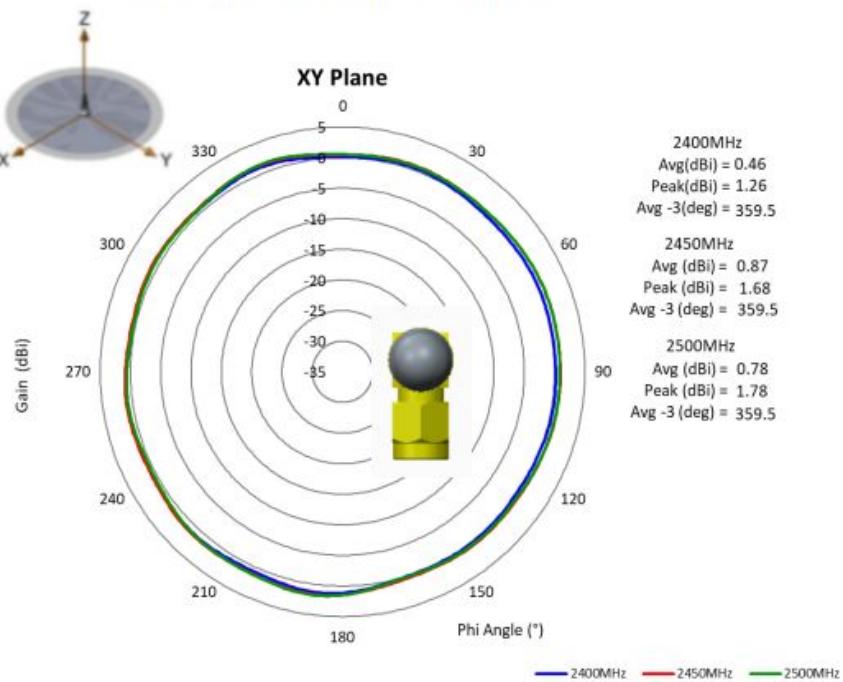


## Pulse Electronics W5029RPG

### Elevation Plane



### Horizontal Plane





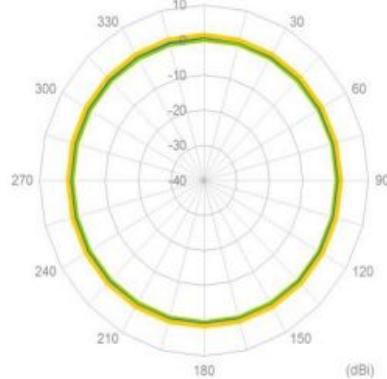
# Payload Antenna Trade & Selection(4/6)



Taoglas GW.20.A151

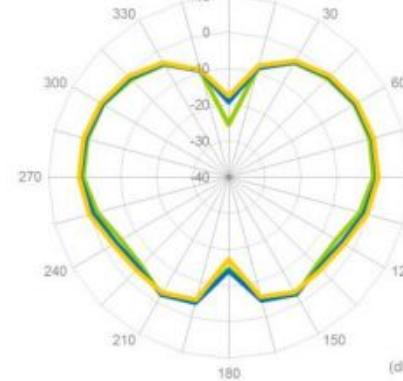
XY Plane

X



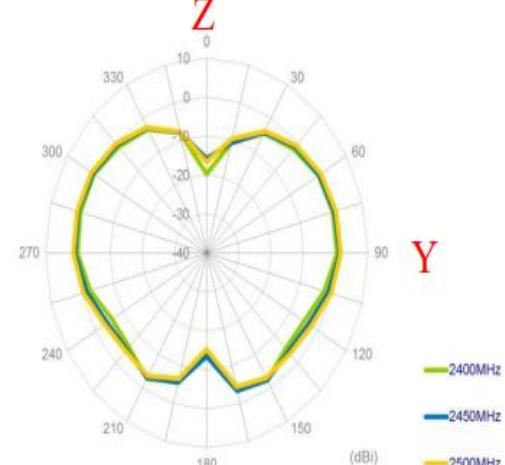
XZ Plane

Z



YZ Plane

Z





# Payload Antenna Trade & Selection(5/6)



Selected Antenna	Reason
 <b>Molex 214415-0011</b>	<ul style="list-style-type: none"><li>• High gain at comparatively lesser price and medium weight.</li><li>• Single band-tuned antenna, less likely to face interference from other bands.</li><li>• Relatively uniform radiation pattern in all three planes.</li><li>• High efficiency over all frequency bands.</li></ul>



# Payload Antenna Trade & Selection(6/6)





# Payload Radio Configuration(1/5)



## Payload to GCS XBee Selection

Model	Zigbee XBee Pro S2C 802.15.4	XBee S2C 2.4GHz	Digi XBee 3 Pro 2.4GHz
Frequency	2.4GHz	2.4GHz	2.4GHz
Range(km)	3.2km	1.2km	3.2km
Sensitivity( dBm)	-101	-100	-103
Supply voltage and currents	2.1-3.6V & 120mA(TX), 31mA(RX)	2.1-3.6V & 33mA(TX), 28mA(RX)	2.1-3.6V & 135mA(TX), 17mA(RX)
Connection type	RP-SMA	U.FL	RP-SMA
Dimensions	2.438 x 3.294 cm	2.438 x 2.761 cm	2.438 x 3.294 cm
Cost (\$)	<b>28.90</b>	<b>22.90</b>	<b>42.87</b>



# Payload Radio Configuration(2/5)



## Selected Component



## Rationale

- Best range and sensitivity for price.
- Omnidirectional antenna can be easily used with RP-SMA connector.
- Good transmit power to ensure safe communication.

**Zigbee XBee Pro S2C 802.15.4**

We have already started prototyping and testing the above XBee radios in various configurations.

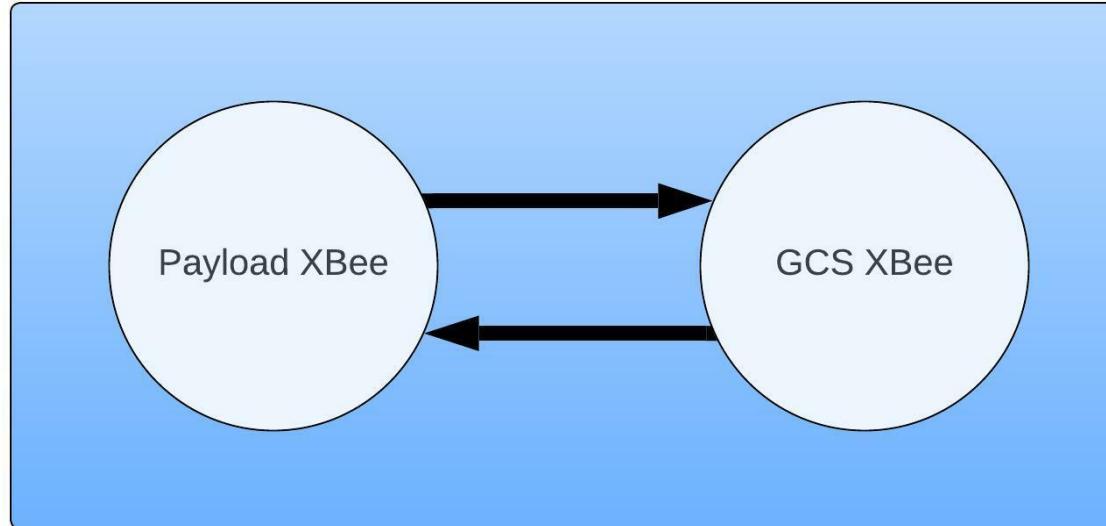


# Payload Radio Configuration(3/5)



## Description of transmission control

### XBEE Radio Connection Architecture



NET ID 1095



# Payload Radio Configuration(4/5)



<b>Communication Description</b>	<p>There are two XBee radios on the communications link. One XBee is present on the payload, the other on the ground control station.</p> <p>XBee radios operate in <b>AT(transparent)</b> mode on <b>Zigbee</b> protocol.</p> <p>The GCS XBee is configured as a <b>Coordinator</b> and the payload XBee as a <b>Router</b>.</p> <p>Data transmission between payload microcontroller and onboard XBee is done using <b>UART</b>.</p>
<b>Transmission Control</b>	<p>When the payload receives the <b>CMD,1095,CX,ON</b> command from ground station, it starts sending telemetry data.</p> <p>The payload collects the data and formats it into a packet. It sends the packet to the GCS. This process will be conducted once per sec, i.e 1 Hz.</p> <p>For avoidance of collision, a special character, '\$' is added to the end of each packet.</p> <p>Once the payload flag is raised,, it will stop sending the telemetry.</p>



# Payload Radio Configuration(5/5)



## NET ID - For XCTU Configuration

Radio Configuration [Ground Station - 0013A20041BB7AD0]

Read Write Default Update Profile Parameter + -

Product family: XB3-24      Function set: Digi XBee3 Zigbee 3.0 TH      Firmware version: 1010

Networking

Parameters which affect the Zigbee network

i CE Device Role	Form Network [1]	
i ID Extended PAN ID	1095	
i ZS Zigbee Stack Profile	0	
i CR PAN Conflict Threshold	3	
i NJ Node Join Time	FE	x 1 sec
i NW Network Watchdog Timeout	0	x 1 minute
i JV Coordinator Verification	Disabled [0]	
i JN Join Notification	Disabled [0]	
i DO Device Options	40	Bitfield
i DC Joining Device Controls	0	Bitfield
i C8 Compatibility Options	0	

Discovery Options

Configuration of network discovery options

i NI Node Identifier	Ground Station	
i DD Device Type Identifier	120000	
i NT Node Discovery Backoff	3C	x 100 ms
i NO Node Discovery Options	0	Bitfield



# Payload Telemetry Format(1/4)



Data Field	Description	Resolution	Example
TEAM_ID	The assigned team ID.	N/A	1095
MISSION_TIME	UTC time in format hh:mm:ss.ss, where hh is hours, mm is minutes, and ss.ss is seconds (including 1/100th of a second).	hh:mm:ss:ss	03:12:57:35
PACKET_COUNT	The total count of transmitted packets, which is to be maintained through processor reset.	N/A	53
MODE	The ASCII character 'F' for flight (the default mode upon system start) and 'S' for Simulation mode.	'F' or 'S'	F
STATE	This is the operating state of the software. Operating states are team defined.	Human readable description	DESCENT



# Payload Telemetry Format(2/4)



Data Field	Description	Resolution	Example
ALTITUDE	The altitude in units of meters, relative to ground level.	0.1 m	283.5
HS_DEPLOYED	Indicates whether the probe with heat shield has been deployed, or not.	'P' or 'N'	P
PC_DEPLOYED	Indicates whether the probe parachute is deployed, or not.	'C' or 'N'	C
MAST_RAISED	Indicates whether the flag has been raised or not.	'M' or 'N'	M
TEMPERATURE	The temperature in degrees Celsius.	0.1 °C	29.1
VOLTAGE	The voltage of the CanSat power bus.	0.01 V	3.05
PRESSURE	Air pressure reading from the pressure sensor	0.1kPa	91.3
GPS_TIME	The time generated by the GPS receiver in UTC.	1 sec	07:33:09



# Payload Telemetry Format(3/4)



Data Field	Description	Resolution	Example
<b>GPS_ALTITUDE</b>	The altitude generated by the GPS receiver in meters above mean sea level.	0.1 m	107.8
<b>GPS_LATITUDE</b>	The latitude generated by the GPS receiver in decimal degrees.	0.0001 North	19.0759
<b>GPS_LONGITUDE</b>	The longitude generated by the GPS receiver in decimal degrees.	0.0001 West	72.8776
<b>GPS_SATS</b>	The number of GPS satellites being tracked by the GPS receiver.	Integer	5
<b>TILT_X, TILT_Y</b>	The angles of the CanSat X and Y axes in degrees.	0.01 °	5.02, 78.09
<b>CMD_ECHO</b>	The fixed text command name and value field of the last received command with no commas.	N/A	CXON
<b>[,OPTIONAL_DATA]</b>	If required, additional necessary data fields added by the team.	-	-



# Payload Telemetry Format(4/4)



## Packet Data Format

- The data field are separated by a comma and a space after the comma, i.e, “,”.
- The entire packet format is given as:  
TEAM\_ID, MISSION\_TIME, PACKET\_COUNT, MODE, STATE, ALTITUDE,  
HS\_DEPLOYED, PC\_DEPLOYED, MAST\_RAISED, TEMPERATURE,  
VOLTAGE, PRESSURE, GPS\_TIME, GPS\_ALTITUDE, GPS\_LATITUDE,  
GPS\_LONGITUDE, GPS\_SATS, TILT\_X, TILT\_Y, CMD\_ECHO  
[,,OPTIONAL\_DATA]

## Example Packet

1095, 03:12:57:35, 53, F, ASCENT, 283.5, P, C, M, 29.1, 91.3, 3.05, 07:33:09,  
107.8, 19.0759, 72.8776, 5, 5.02, 78.09, CXON\$

## Description

- The payload takes the values from the peripheral devices and formats them into the required packet format in the microcontroller.
- The character ‘\$’ is added at the end of frame for collision detection and resolving frames.
- The formatted frame(packet) is sent to the GCS.



# Payload Command Formats(1/2)



Command	Description	Example	Use
CX	Turning the payload telemetry ON/OFF.	CMD,1095,CX,OFF\$	Can be used to turn on telemetry at the start of the mission.
ST	Sets mission time in UTC format to GPS time or any given time.	CMD,1095,ST,05:30:12\$	Used to set mission time before take-off.
SIM	Activate the simulation mode.	CMD,1095,SIM,ENABLE\$	Used to activate simulation command. It has 3 values: 'ENABLE', 'ACTIVATE' and 'DEACTIVATE'.
SIMP	In simulation mode, sends simulated pressure data.	CMD,1095,SIMP,101010\$	Provides a simulated pressure reading to the container.
CAL	Calibrate altitude to zero.	CMD,1095,CAL\$	Sets altitude to zero. Can be used as a processor reset command.



# Payload Command Formats(2/2)



Field	Description
<TEAM_ID>	The assigned team identification number.
<ON_OFF>	ON turns on the payload telemetry, OFF turns it off.
<UTC_TIME>	UTC time in hh:mm::ss. It can be taken from GCS UTC time or GPS module
<MODE>	'ENABLE' and 'ACTIVATE' when sent one after the other, activate the simulation mode for the CanSat. 'DEACTIVATE' instructs the CanSat to exit simulation mode.
<PRESSURE>	The simulated atmospheric pressure data in units of pascals with a resolution of one Pascal.

- The commands are sent from the ground station to the CanSat.
- The character '\$' is used for separation in case two commands collide.

**The above format matches the Competition Guide requirements**



---

# Electrical Power Subsystem (EPS) Design

**Kimaya Mutha**



# EPS Overview(1/2)



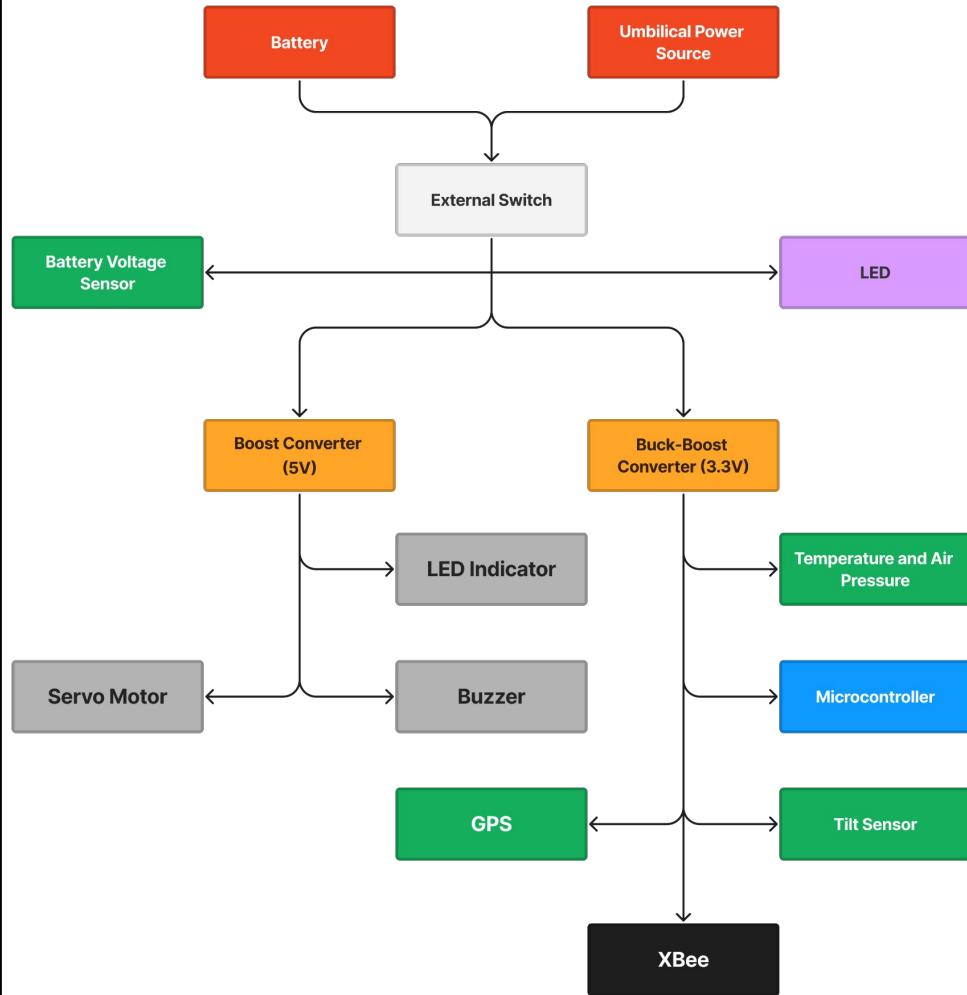
Component	Description
<b>Orange ICR18650-20C</b>	Main Power Source.
<b>Voltage divider</b>	To monitor battery voltage (Also the feed to the RGB indicator)
<b>5V Boost Converter</b>	Power supply for components which require 5V as input power.
<b>3.3V Buck - Boost Converter</b>	Power supply for components which require 3.3V as input power.
<b>External switch</b>	The switch which turns off the main power bus.
<b>LED Indicator (SOC)</b>	Power and battery SOC indicator.



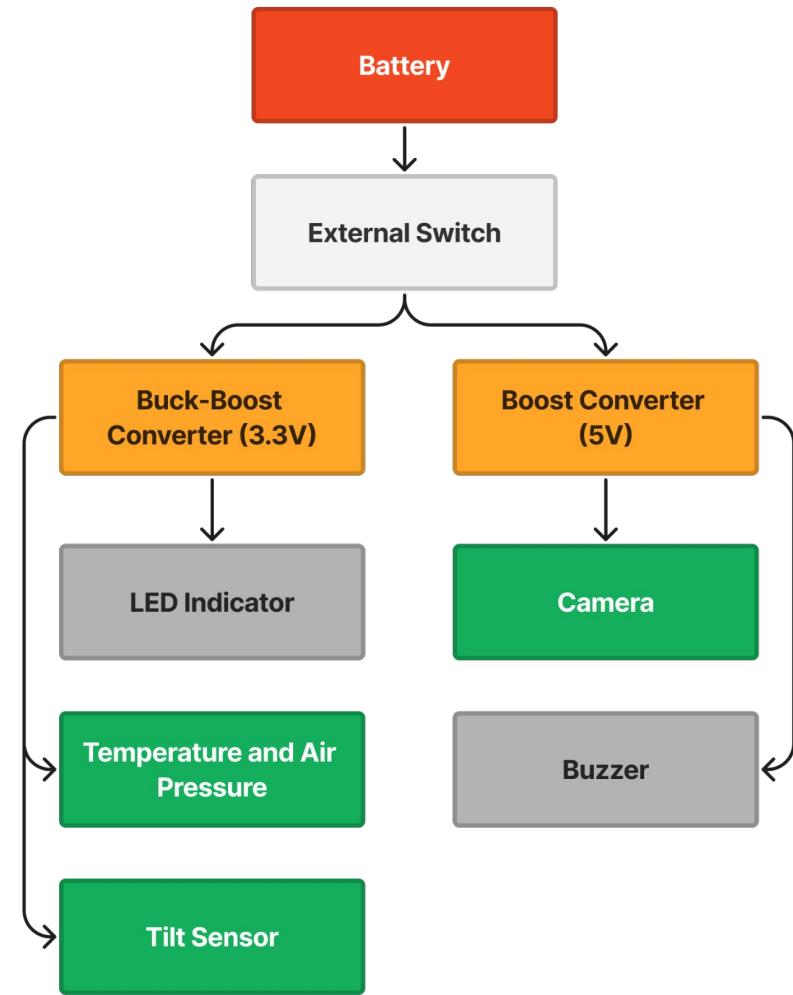
# EPS Overview(2/2)



## Probe Diagram

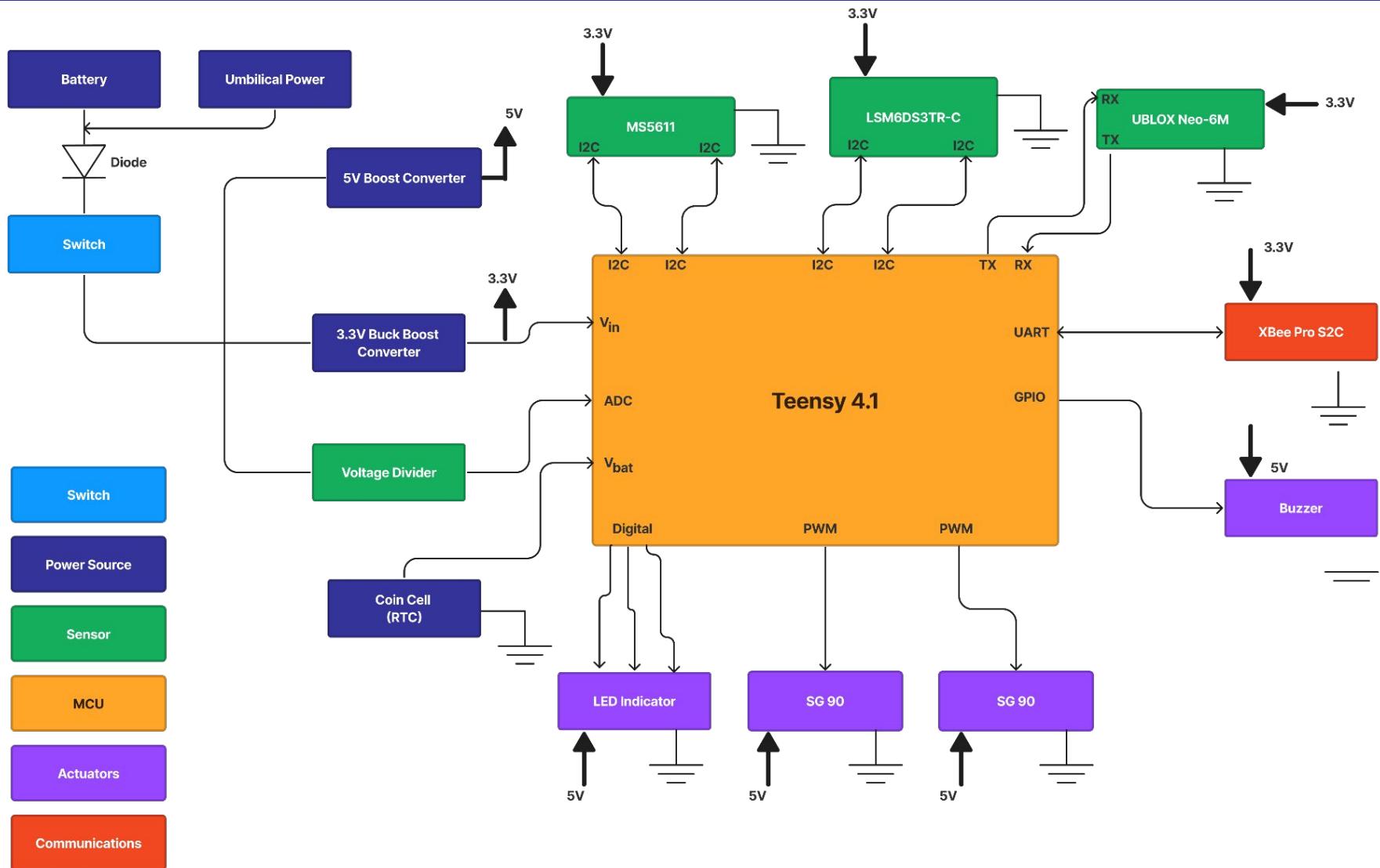


## Container Diagram



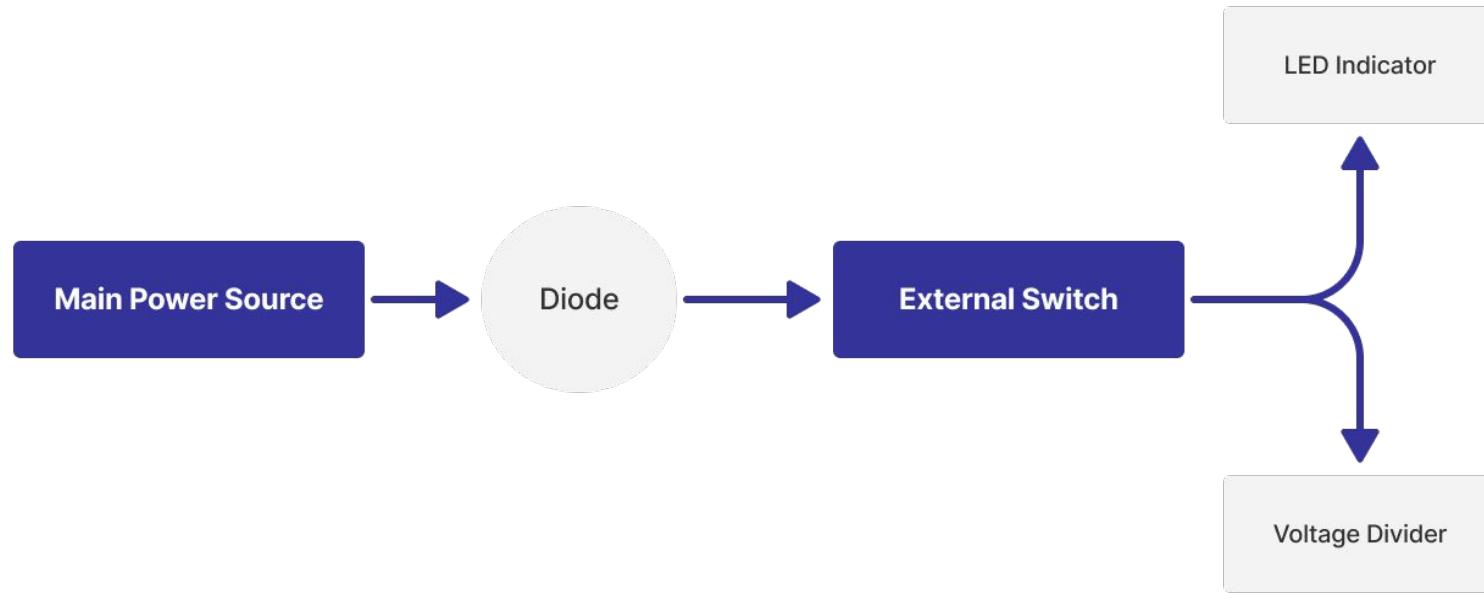


# Payload Electrical Block Diagram(1/2)





# Payload Electrical Block Diagram(2/2)



Features	Power Verification
<ul style="list-style-type: none"><li>External switch is connected between the main power source and the rest of the circuitry.</li><li>The remaining circuitry is powered only if the switch is turned on.</li></ul>	<ul style="list-style-type: none"><li>The LED indicator will glow only if the external switch is turned on.</li><li>In this way, presence of power can be verified by sight.</li></ul>



# Payload Power Trade & Selection



Battery Model	Dimensions (mm)	Mass (g)	Voltage (V)	Charge(mAh)	Max current capacity(A)	Type	Cost(\$)
<b>Panasonic NCR18650B</b>	65 x φ18	45	3.7	3400	8	Li-ion	9.93
<b>Orange ICR18650-20C</b>	65 x φ18.2	50	3.7	2000	4	Li-ion	2.5

Selected Component	Rationale
 	<ul style="list-style-type: none"><li>Satisfies requirement of providing power for at least two hours.</li><li>Lesser max current capacity prevents chance of over-current damage.</li><li>Sufficient energy available at less cost and mass.</li><li>Higher number of charge cycle lifetimes and higher charge rate.</li></ul> <p><b>The battery is mounted in the holder shown, which is secured into a slot made on a PCB.</b></p>



# Payload Power Budget(1/2)



Component	Model	Voltage(V)	Current(mA)	Power(mW)	Duty Cycle(s)	Duty Cycle in %	Required Energy(mWh)	Source
Air Temperature and Pressure Sensor	MS5611	3.3	0.015	0.0495	7200	100	0.099	Datasheet
Tilt Sensor	Adafruit LSM6DS3TR-C	3.3	100	330	7200	100	660	Datasheet
GPS Module	UBLOX NEO- 6M	3.3	45	148.5	7200	100	297	Datasheet
Microcontroller + Memory	Teensy 4.1	3.3	100	330	7200	100	660	Datasheet
Radio	XBee Pro S2C	3.3	120	396	7200	100	792	Datasheet
Buzzer	92dB Buzzer	5	20	100	1200	16.67	33.34	Datasheet
Servo Motors	SG90	5	40	200	20	0.28	1.12	Datasheet
Camera	SQ11	5	310	1550	120	1.67	51.77	Datasheet
LED indicator	SMD RGB LED	5	30	150	7200	100.00	300.00	Datasheet
Total						2795.329 mWh		

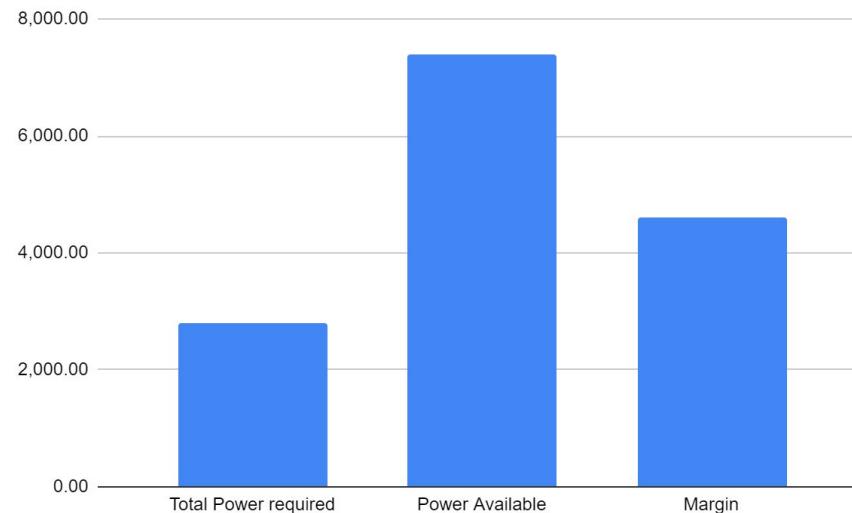


## Payload Power Budget(2/2)



Total Power required	2795.329 mWh
Total Power Available in Battery	7400 mWh
Margin	$7400 - 2795.329 = 4604 \text{ mWh}$
Percent Margin	$(4604/7400)*100 = 62.21\%$

Using the given battery, the CanSat can operate for approximately **5.29 hours** when integrated into the launch vehicle.





---

# Flight Software (FSW) Design

**Shubham Salunkhe**



# FSW Overview(1/4)



## Brief Summary of FSW Tasks

- **Probe FSW** will evaluate through different states based on data collected by the sensors.
- These states are responsible for tasks such as data processing, telemetry packet creation and sending it to GCS via XBEE, performing the operations as per commands received from GCS, and deployment & uprighting mechanisms.
- It is also responsible for recording the probe's descent using the camera at the bottom of the probe.
- **Container FSW** is responsible for carrying out the bonus mission objective to record the probe's deployment.

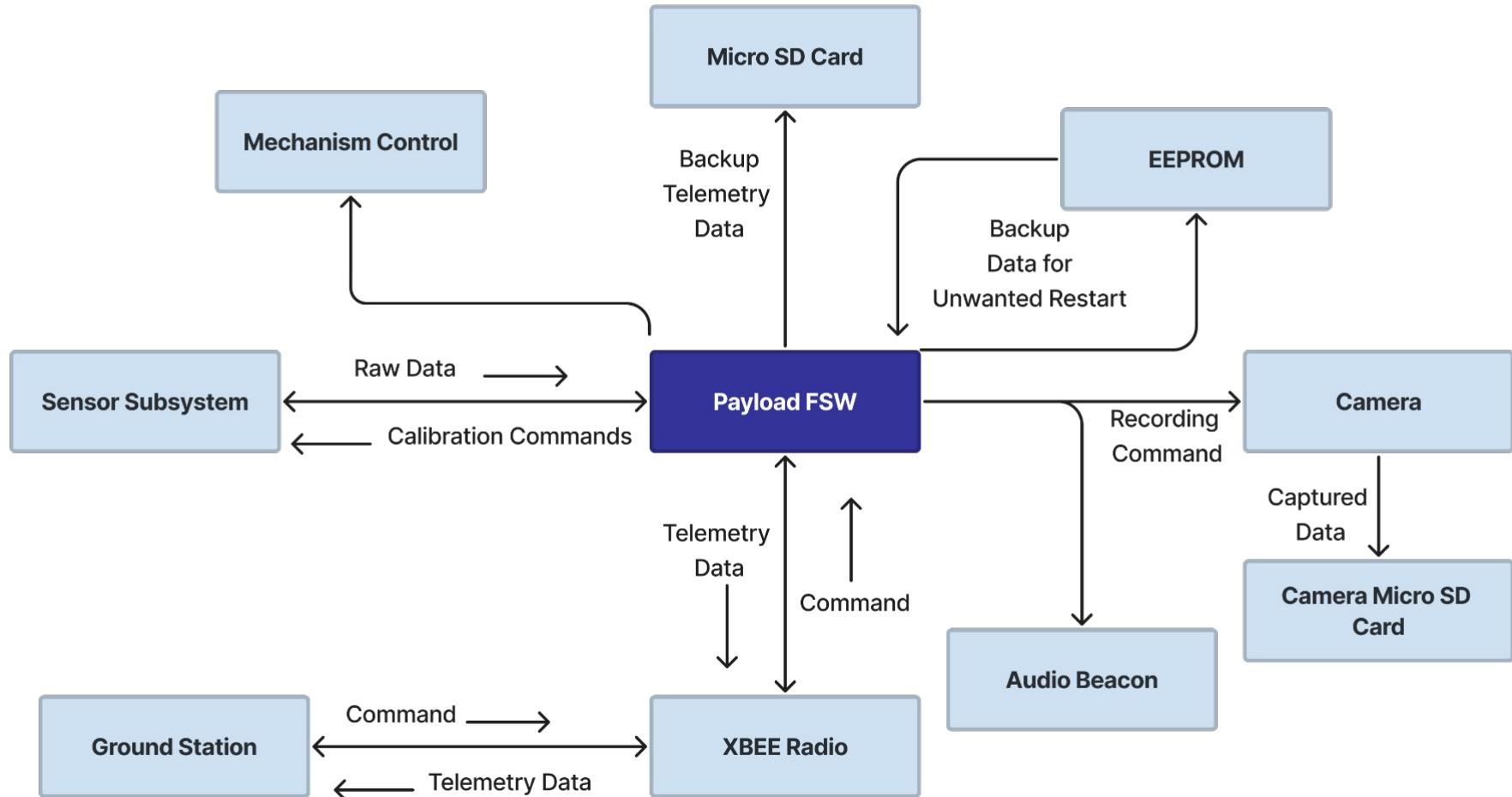
Development Environments	Programming Languages
<ul style="list-style-type: none"><li>• Arduino IDE</li><li>• Visual Studio Code</li></ul>	<ul style="list-style-type: none"><li>• C/C++</li></ul>



# FSW Overview(2/4)



## Probe FSW Architecture

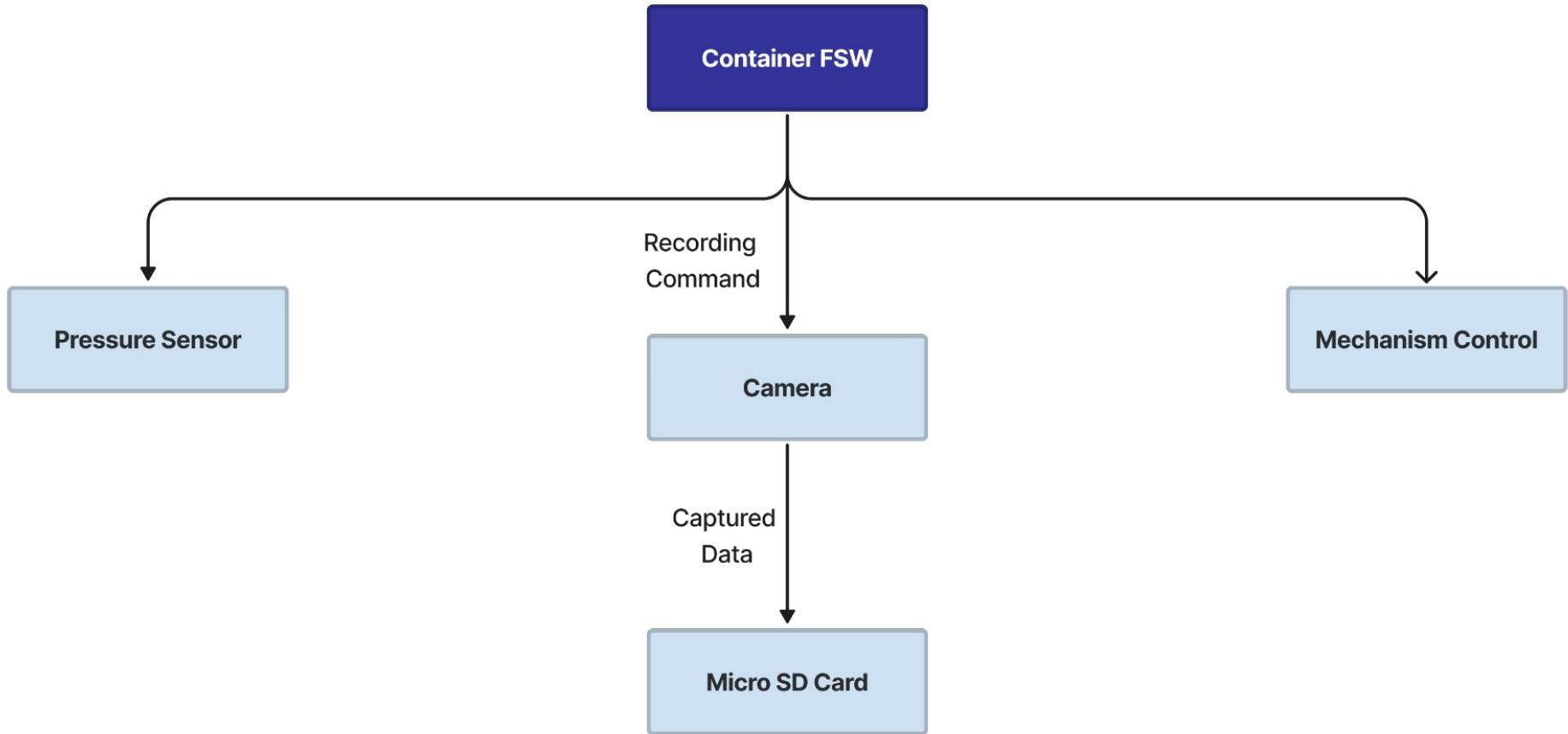




# FSW Overview(3/4)



## Container FSW Architecture





# FSW Overview(4/4)



## Summary of FSW Tasks

### Container FSW

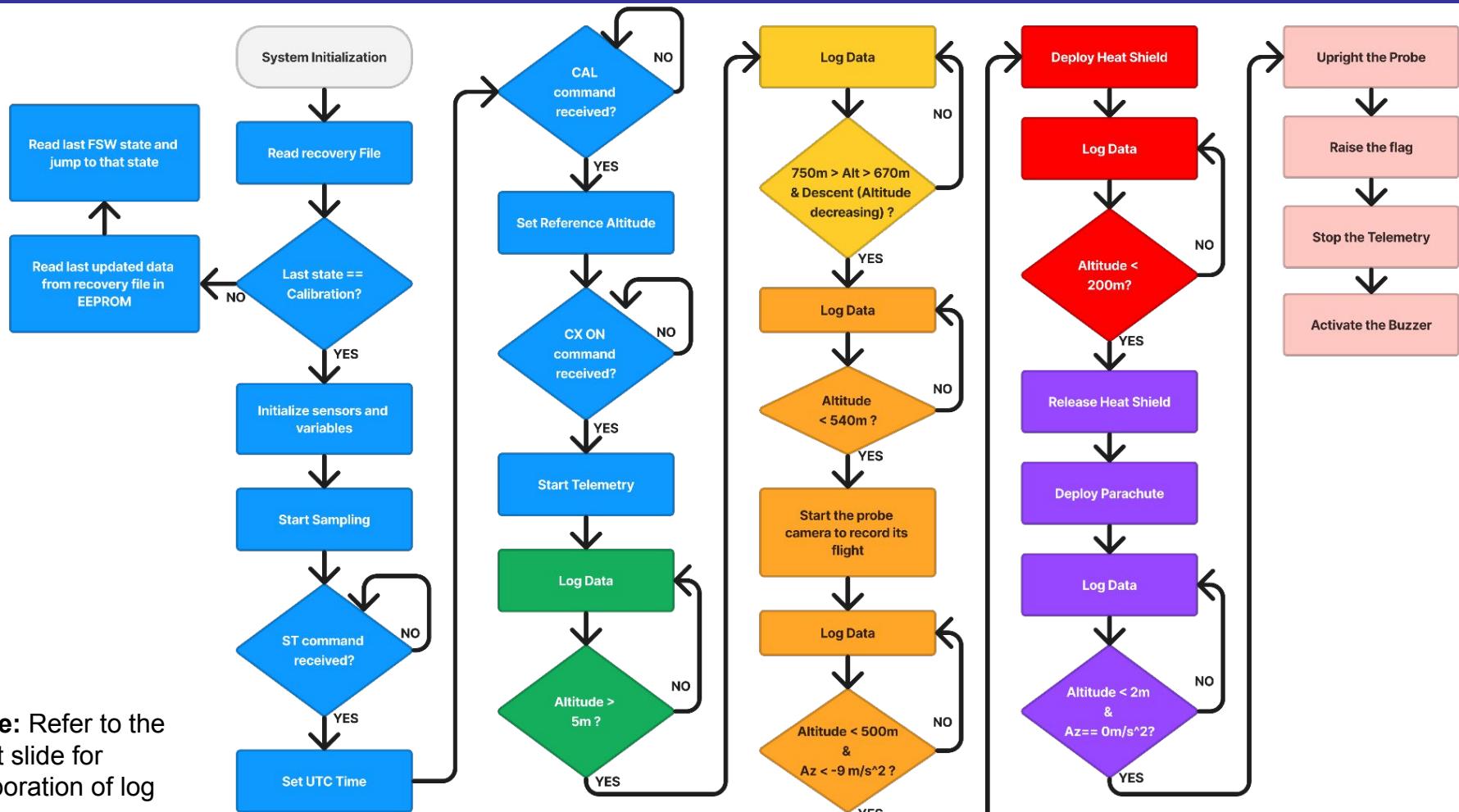
- Electronics system will be activated via a switch which will be indicated by blinking of LED.
- Initialize and calibrate pressure sensor.
- Start the camera to record the deployment of the probe.
- Release the probe at 500m altitude.
- Activate the audio beacon on landing.

### Probe FSW

- Electronics system will be activated via a switch which will be indicated by blinking of LED.
- Initialize sensors and calibrate system when ST command to Set Time and CAL command to calibrate altitude is received.
- Activate telemetry when CXON command is received.
- Create the telemetry packet according to the given format.
- Save sensor data to SD card and send it to GCS via XBee.
- Keep on updating recovery data in EEPROM.
- Start the probe camera to record its descent.
- Deploy the heat shield as soon as the probe is released.
- Release the probe parachute at 200m altitude.
- Upon landing, upright the probe, raise the flag, and activate the audio beacon.



# Payload FSW State Diagram(1/4)



Note: Refer to the next slide for elaboration of log data process.

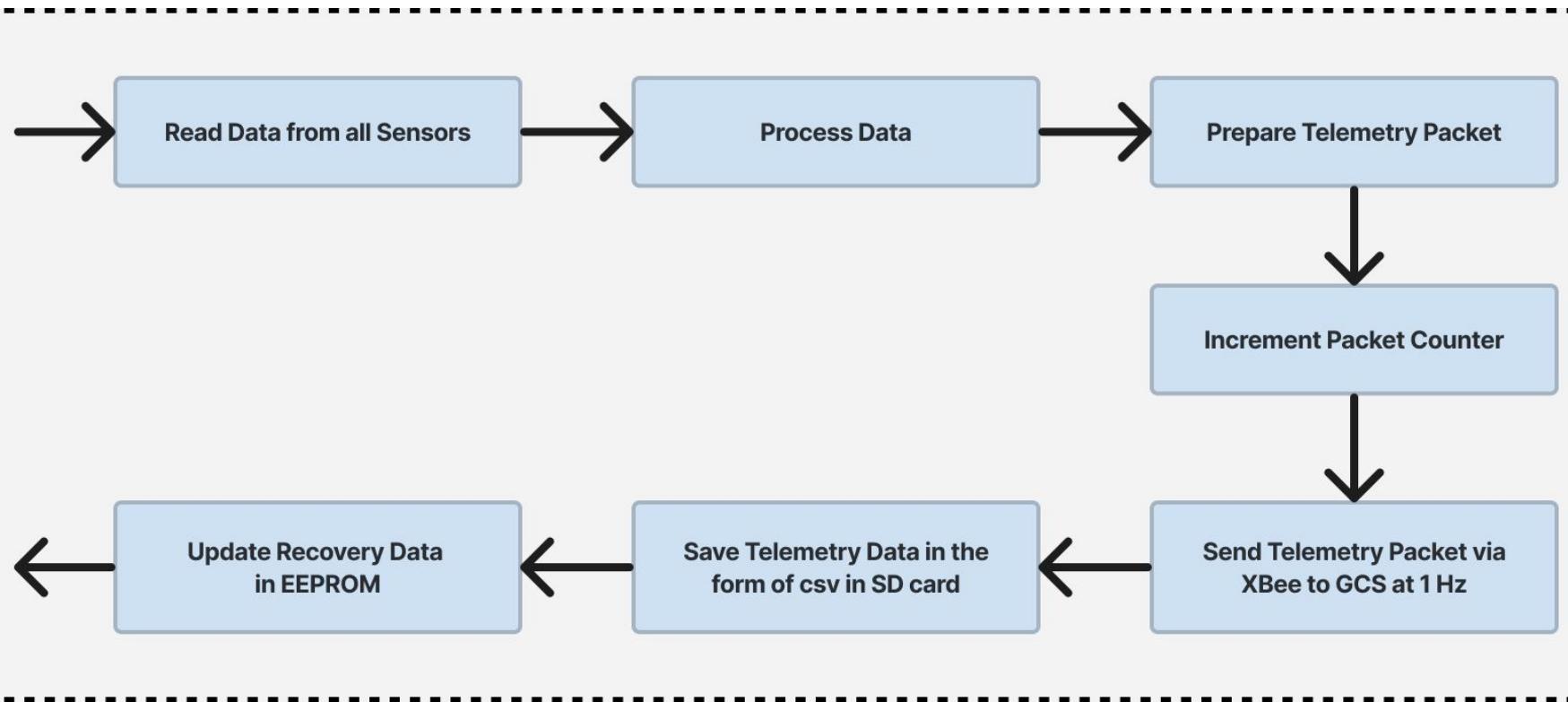




# Payload FSW State Diagram(2/4)



## LOG DATA PROCESS





# Payload FSW State Diagram(3/4)



## Mechanism Activations

At 540m i.e. just before the probe is launched, the Probe FSW will command the camera module to start recording.

Below 500m and upon detecting free fall through the accelerometer, the Probe FSW will deploy the heat shield.

At 200m, the heat shield is released and the parachute is deployed.

Once the probe is landed which is detected by low altitude and 0 acceleration, the spider-legs mechanism is activated to make it upright and then the flag is raised.

Sampling of sensors	Communications
The sensors are sampled.	Telemetry packet is sent from probe XBee to GCS once per second. The correct packet format is created by probe FSW.
Data storage	Major Decision Points
EEPROM is used to store recovery data, needed in case of unwanted resets. Telemetry Data is backed up onto the SD card. Video Recording is stored into the SD card which is only connected to the camera.	Most of the decisions are based on conditions of Altitude and that to open the heat shield is based on altitude and acceleration to indicate free fall once probe is deployed.



# Payload FSW State Diagram(4/4)



## Tackling Unwanted Processor Resets Problem

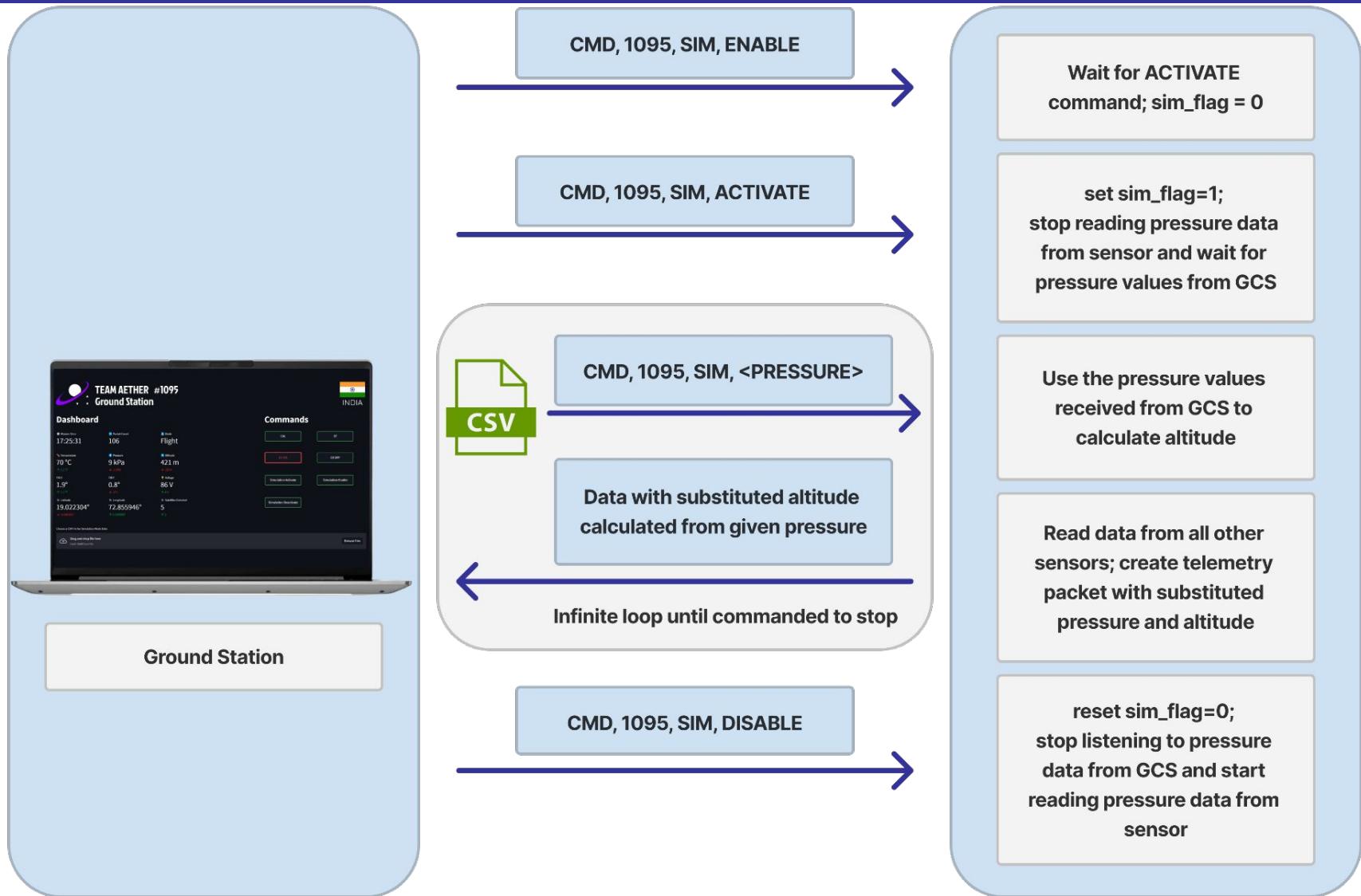
What data is used to recover?	Reasons for Resets?
<ol style="list-style-type: none"><li>1. FSW State No. (integer)</li><li>2. Packet Count (integer)</li><li>3. Reference Altitude (to calibrate pressure sensor) (float)</li><li>4. Simulation Active (boolean)</li><li>5. Container Camera started (boolean)</li><li>6. Probe Camera started (boolean)</li><li>7. Heat Shield deployed (boolean)</li><li>8. Parachute deployed (boolean)</li></ol>	<ol style="list-style-type: none"><li>1. G-Force impact</li><li>2. PCB being exposed to high temperatures.</li><li>3. Runtime error</li><li>4. Temporary power failure</li><li>5. Voltage drop</li></ol>

### Methods of Recovery

Once the microcontroller restarts, it will read the recovery file in the EEPROM. It will read the last active FSW State and jump to that state and continue thereafter with the context of other crucial data like reference altitude, packet count, etc.



# Simulation Mode Software





# Software Development Plan(1/3)



## Late Software Development Problem

To reduce this risk and avoid prolonged delays, we started our software development earlier. The testing and development of code for sensors began as soon as they had arrived. Proper development plan was constructed with strict deadlines in order to monitor the progress continuously. Also, GitHub is being made use of for code storage, management and review.

## Prototyping and Prototyping Environments

Subject	Environment	Procedure
<b>ESP-32 (Container) and Teensy 4.1 (Probe)</b>	Arduino IDE	The process of programming and identifying issues are carried out using the Arduino IDE and data will be observed through the serial monitor.
<b>Sensors</b>	Breadboard & PCB	Sensors are verified one by one using a breadboard and microcontrollers.



# Software Development Plan(1/3)



## Late Software Development Problem

To reduce this risk and avoid prolonged delays, we started our software development earlier. The testing and development of code for sensors began as soon as they had arrived. Proper development plan was constructed with strict deadlines in order to monitor the progress continuously. Also, GitHub is being made use of for code storage, management and review.

## Prototyping and Prototyping Environments

Subject	Environment	Procedure
<b>ESP-32 (Container) and Teensy 4.1 (Probe)</b>	Arduino IDE	The process of programming and identifying issues are carried out using the Arduino IDE and data will be observed through the serial monitor.
<b>Sensors</b>	Breadboard & PCB	Sensors are verified one by one using a breadboard and microcontrollers.



# Software Development Plan(2/3)



## Software Subsystem Development Sequence

Subsystem	Development Sequence
Sensors	<ol style="list-style-type: none"><li>1. Selecting sensors and choosing appropriate libraries.</li><li>2. Sensor-wise programming : write code for each sensor to process the raw data into required format.</li></ol>
State Switching Mechanism	<ol style="list-style-type: none"><li>1. Integrate all sensors.</li><li>2. Check whether states are switched automatically under proper conditions.</li></ol>
Xbee Telemetry	<ol style="list-style-type: none"><li>1. Write code to gather various sensor data and other fields required in the telemetry packet.</li><li>2. Testing GCS and Probe Connection: Test whether probe is able to send the required telemetry packet to GCS at 1Hz via XBEE.</li></ol>
Probe Uprighting Mechanism	<ol style="list-style-type: none"><li>1. Develop the code to recognise that the probe has landed and when landing is recognised, signal the MOSFET to pass the current in the metallic wire and heat it, which in turn will snap the elastic material and release the spider legs.</li><li>2. Test whether MOSFET is able to heat the metallic wire enough when necessary conditions are met.</li></ol>
Deployment Mechanisms	<ol style="list-style-type: none"><li>1. Write the code for releasing mechanisms</li><li>2. Test the code using microcontroller and actuator.</li></ol>
Integration	<ol style="list-style-type: none"><li>1. A significant amount of time will be dedicated for integration of separate software and hardware components.</li><li>2. It will be carried out in a <i>test-fail-repeat</i> manner to make debugging more efficient.</li><li>3. Afterwards, the system will be tested as a whole. (This is mentioned in the Testing part.)</li></ol>



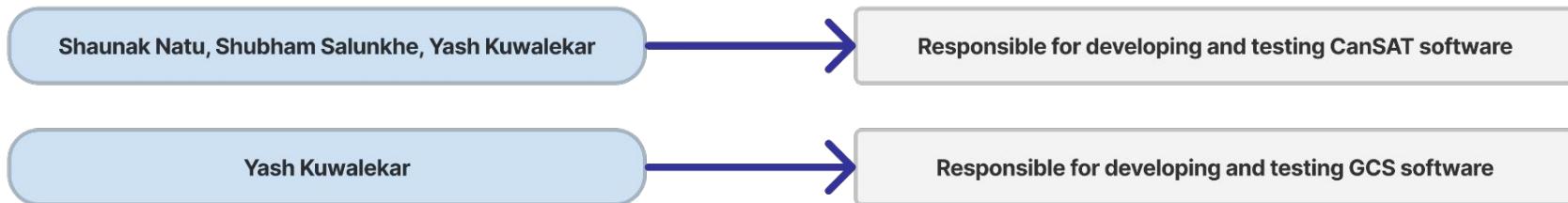
# Software Development Plan(3/3)



## Test Methodology

1. All sensors and electrical components are first tested individually before integrating them into a prototype.
2. Telemetry software is assessed by simulating it using the XCTU tool.
3. Test the state switching mechanism for the probe.
4. Test the recovery software for the probe.
5. Test the probe deployment mechanism to be used in container.
6. Test GCS software by sending simulated telemetry packets from processor which is integrated with required sensors and XBee.
7. Test Flight Mode and Simulation Mode implementations with GCS.
8. Check whether FSW complies with requirements stated in the mission guide.

## Development Team





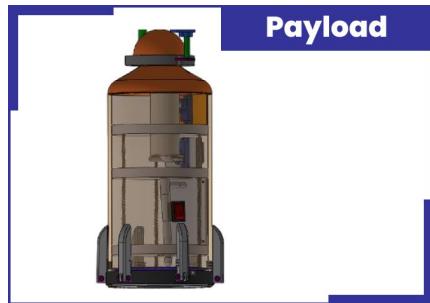
---

# Ground Control System (GCS) Design

**Yash Kuwalekar, Ojas Taskar**



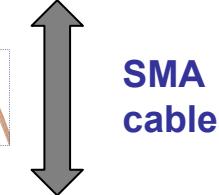
# GCS Overview



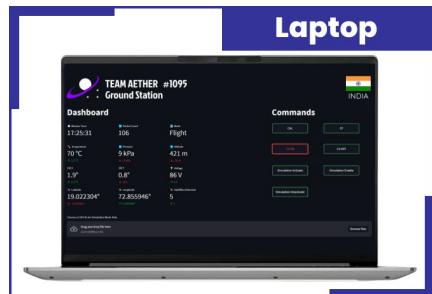
Radio Frequency



LPRS Yagi



SMA  
cable



Mini USB  
to USB



XBee Adapter



UART



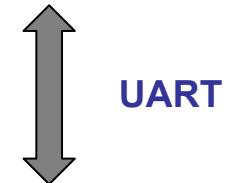
XBee PRO S2C



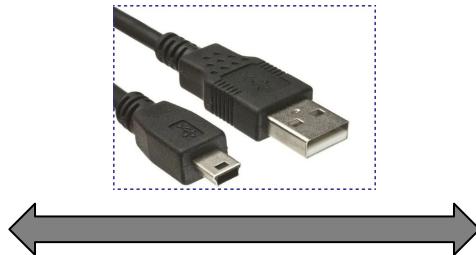
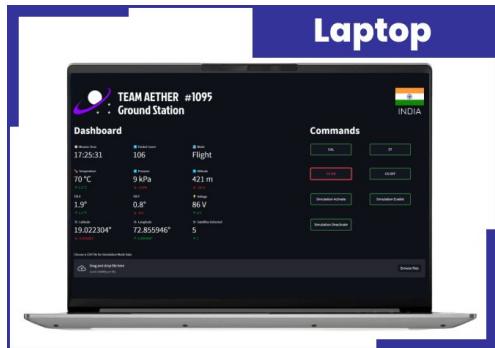
# GCS Design(1/2)



## SMA to SMA connector



## UART



## Mini USB to USB cable





## Specifications

<b>Laptop battery</b>	GCS will be run on a laptop with more than 2 hours of battery life.
<b>Over-heating</b>	The team will use an umbrella to shield the computer from the sun, and a small fan to provide cooling.
<b>Auto-update feature</b>	All other programs will be switched off. Automatic update feature will be turned off. Internet connectivity is turned off.



# GCS Antenna Trade & Selection(1/5)

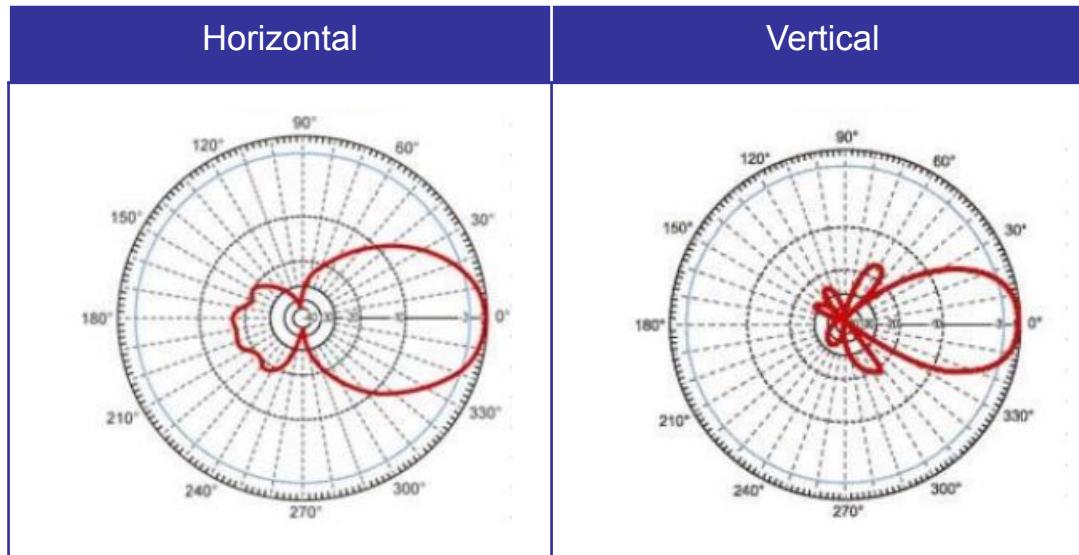


Selection Criteria	LPRS 16-2.4G YAGI	NPC Parabolic Grid Antenna 2.4GHz
Frequency (MHz)	2400 MHz	2348 MHz
Gain (dBi)	14	24
Weight (g)	320	2990
Antenna Type	Directional	Directional
Radiation Pattern	(next slide)	(next slide)
Dimensions (mm)	590 x 85 x 45	933 x 396 x 600
Cost	38.21	97.39

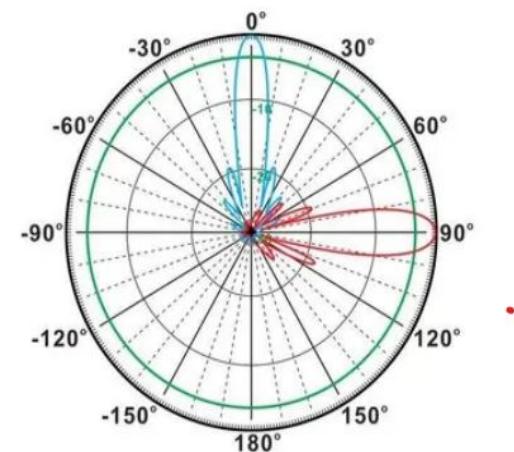


## Radiation Patterns

LPRS 16-2.4G YAGI



NPC Parabolic Grid Antenna



Vertical



# GCS Antenna Trade & Selection(3/5)



Selection Criteria		Options for Selection			
		LPRS 16-2.4G YAGI		NPC Parabolic Grid Antenna	
Criteria	Value	Score	Criteria score	Score	Criteria score
Frequency (MHz)	2	5	10	4	8
Gain (dBi)	5	4	20	5	25
Weight (g)	4	5	20	2	8
Antenna Type	2	4	8	4	8
Radiation Pattern	4	4	16	3	12
Dimensions (mm)	4	5	20	2	8
Cost	3	5	15	2	6
Total		109		75	



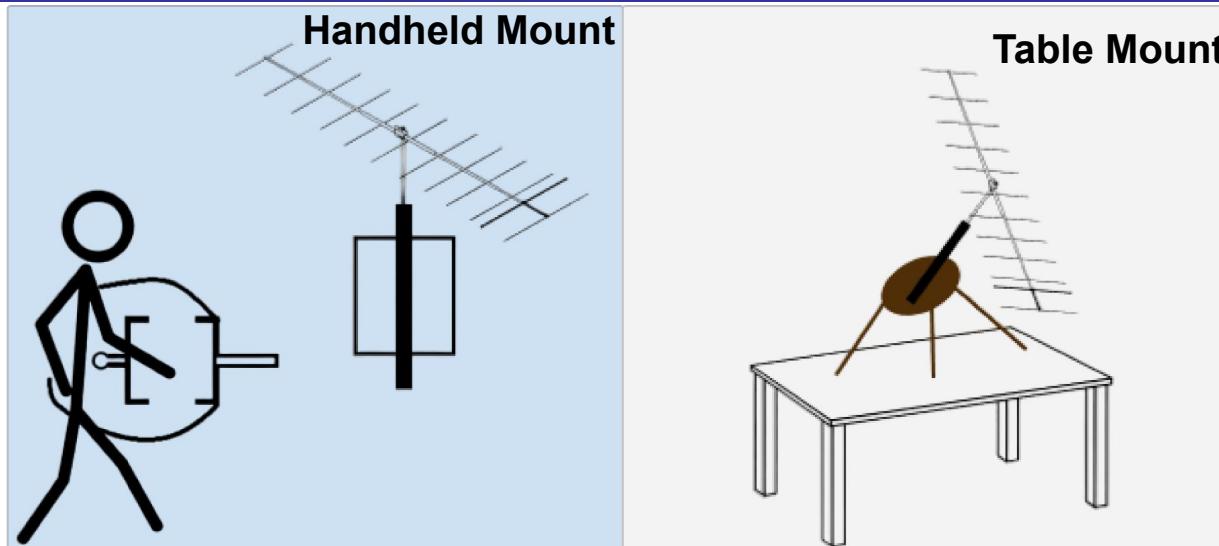
# GCS Antenna Trade & Selection(4/5)



Selected antenna	Rationale
<b>YAGI-14-2.4</b>	<ul style="list-style-type: none"><li>• Relatively high gain for lesser mass and cost.</li><li>• Wider horizontal and vertical beamwidth allows greater range and lesser scope for error.</li><li>• The dimensions of antenna are feasible for transporting from India to the U.S.A.</li></ul>



# GCS Antenna Trade & Selection(5/5)



- A 3D printed bracket will be designed to hold the Yagi Antenna.
- The bracket shall include a handle and wearable band which can be put around the shoulders of the operator.
- It shall also include a view finder of a circular shape in which the CanSAT can be aimed at to maintain connection with the Ground Station.
- This configuration enables greater success of communication and maximal use of Ground Station crew.

- It is kept on a table.
- The laptop is placed beside the setup on the same table.
- The antenna is rigidly mounted.
- It will be aimed in the general direction of the flight fields.

## Selection: Handheld Mount

- Provides greater success rate.
- Easier for error debugging



## Telemetry Display Prototypes

- Telemetry data from the probe will be received and processed by the Ground Station Computer and will be saved in the form of a .csv file.
- This data will be plotted in real-time using graphs and a map. Updating raw telemetry csv data will also be displayed using table. Dashboard is also used to provide a live overview of the data.

## Commercial Off The Shelf (COTS) Software Packages Used

- Visual Studio Code
- Anaconda Navigator
- XCTU
- Arduino IDE

## Real-time Plotting Software Design

- **streamlit** framework library in Python is used for Ground Station design along with **plotly** library for real-time plotting and maps.

## Command Software And Interface

- There will be buttons in the Ground Station GUI which will be used as command executioners.



## Telemetry Data Recording And Media Presentation To Judges For Inspection

Received Telemetry data in a .csv file and screenshots of the GCS dashboard, graphical visualizations and map will be submitted to the judging table in the thumb drive provided.

### Description of .csv Telemetry File Creation For Judges

All the telemetry data received at the Ground Station will be saved in .csv (Comma Separated Value) file format which contains each telemetry field separated with a comma and ending every line with a carriage return character.

### Simulation Mode Description

GCS will send two commands, SIMULATION ENABLE and SIMULATION ACTIVATE to the probe, and then GCS will read the row of the .csv file which contains the barometric pressure values and it will be transmitted to flight software at a frequency of 1Hz by Simulated Pressure Data (SIMP) Command.



# GCS Software(3/6)



INDIA

## TEAM AETHER #1095 Ground Station

### Dashboard

Mission Time: 17:25:31 | Packet Count: 106 | Mode: Flight

Temperature: 70 °C	Pressure: 9 kPa	Altitude: 421 m
Tilt X: 1.9°	Tilt Y: 0.8°	Voltage: 86 V
Latitude: 19.022304°	Longitude: 72.855946°	Satellites Detected: 5

Choose a CSV File for Simulation Mode Data

Drag and drop file here | Limit 200MB per file | Browse files

### Commands

CAL | ST | CX ON | CX OFF | Simulation Activate | Simulation Enable | Simulation Deactivate

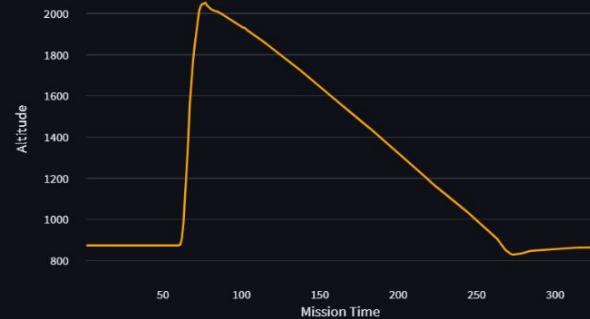


# GCS Software(4/6)

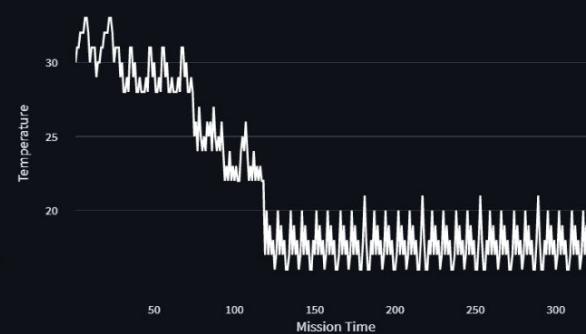


## Real Time Telemetry Plotting

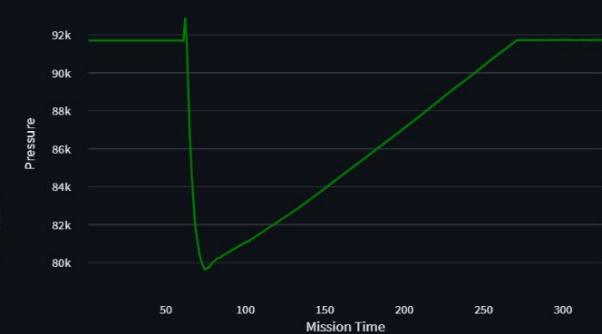
Altitude Plot



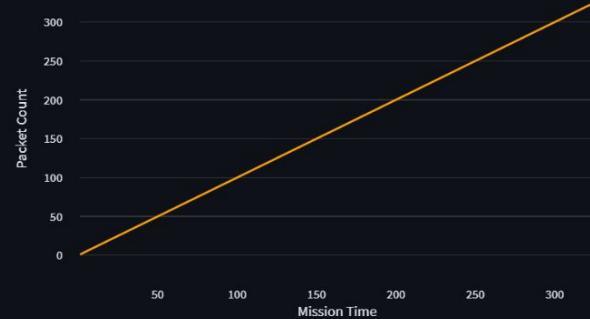
Temperature Plot



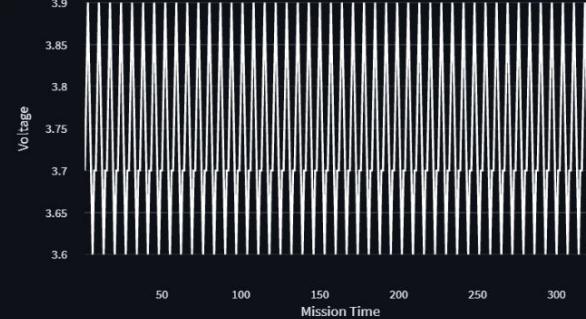
Pressure Plot



Packet Count Plot



Voltage Plot



GPS Plot





# GCS Software(5/6)



## Telemetry Data CSV

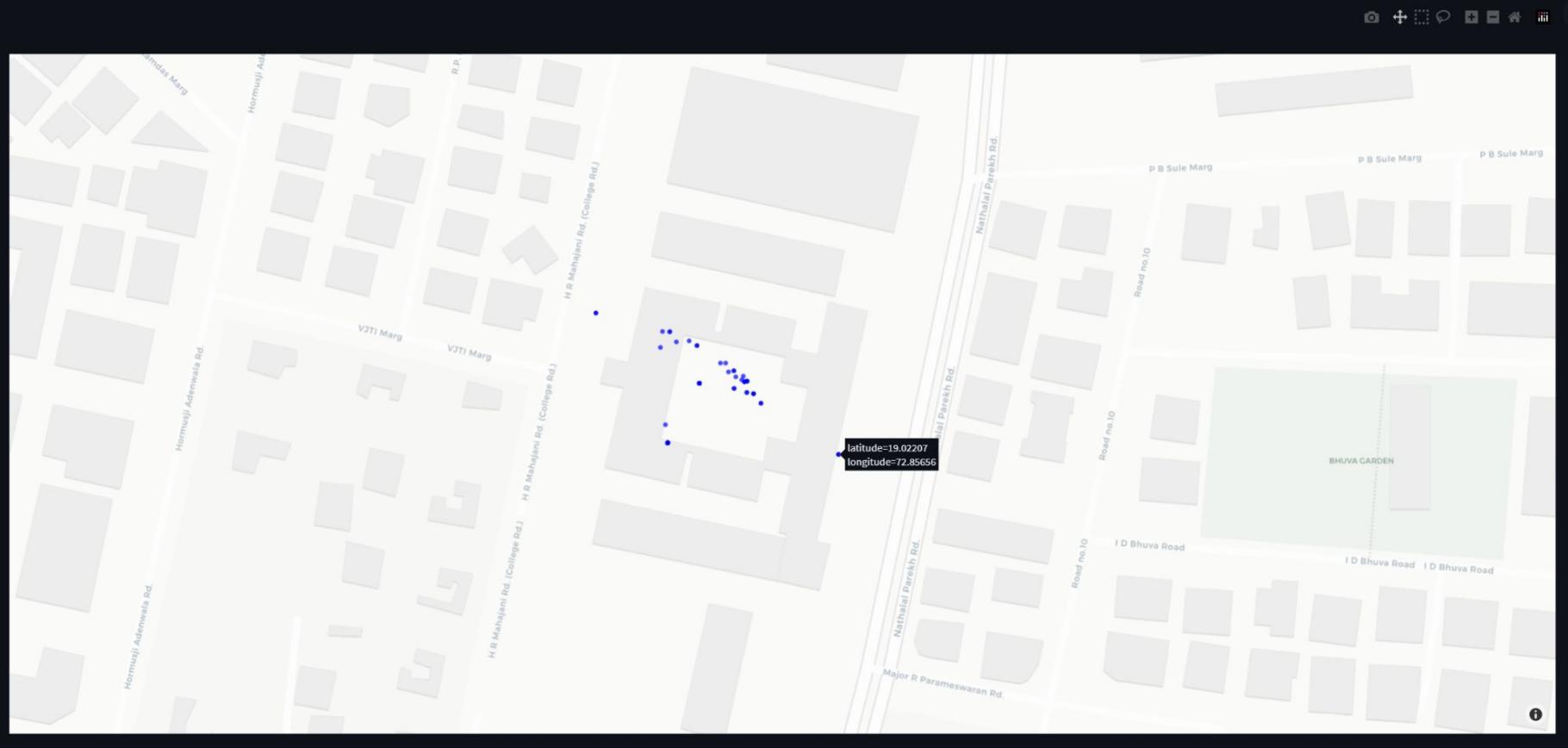
	TEAM_ID	MISSION_TIME	PACKET_COUNT	MODE	STATE	ALTITUDE	HS_DEPLOYED	PC_DEPLOYED	MAST_RAISED	TEMPERATURE	VOLTAGE	PRESSURE	GPS_TIME	GPS_ALTITUDE	GPS_LATITUDE	GPS_LONGITUDE	GPS_SATS	TILT_X	TILT_Y	C
0	1,095.0000	03:12:57	53.0000	F	ASCENT	202.0000	P	C	N	29.1000	91.3000	3.0500	07:33:09	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
1	1,095.0000	03:12:58	54.0000	F	ASCENT	205.0000	P	C	N	29.1000	91.3000	3.0500	07:33:10	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
2	1,095.0000	03:12:59	55.0000	F	ASCENT	206.0000	P	C	N	29.1000	91.3000	3.0500	07:33:11	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
3	1,095.0000	03:13:01	57.0000	F	ASCENT	209.0000	P	C	N	29.1000	91.3000	3.0500	07:33:12	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
4	1,095.0000	03:13:02	58.0000	F	ASCENT	211.0000	P	C	N	29.1000	91.3000	3.0500	07:33:13	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
5	1,095.0000	03:13:03	59.0000	F	ASCENT	212.0000	P	C	N	29.1000	91.3000	3.0500	07:33:14	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
6	1,095.0000	03:13:04	60.0000	F	ASCENT	213.0000	P	C	N	29.1000	91.3000	3.0500	07:33:15	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
7	1,095.0000	03:13:05	61.0000	F	ASCENT	215.0000	P	C	N	29.1000	91.3000	3.0500	07:33:16	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
8	1,095.0000	03:13:06	62.0000	F	ASCENT	216.0000	P	C	N	29.1000	91.3000	3.0500	07:33:17	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
9	1,095.0000	03:13:07	63.0000	F	ASCENT	217.0000	P	C	N	29.1000	91.3000	3.0500	07:33:18	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
10	1,095.0000	03:13:08	64.0000	F	ASCENT	219.0000	P	C	N	29.1000	91.3000	3.0500	07:33:19	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
11	1,095.0000	03:13:09	65.0000	F	ASCENT	219.0000	P	C	N	29.1000	91.3000	3.0500	07:33:20	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
12	1,095.0000	03:13:11	67.0000	F	ASCENT	221.0000	P	C	N	29.1000	91.3000	3.0500	07:33:21	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
13	1,095.0000	03:13:13	69.0000	F	ASCENT	222.0000	P	C	N	29.1000	91.3000	3.0500	07:33:22	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
14	1,095.0000	03:13:15	71.0000	F	ASCENT	224.0000	P	C	N	29.1000	91.3000	3.0500	07:33:23	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
15	1,095.0000	03:13:16	72.0000	F	ASCENT	225.0000	P	C	N	29.1000	91.3000	3.0500	07:33:24	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
16	1,095.0000	03:13:17	73.0000	F	ASCENT	227.0000	P	C	N	29.1000	91.3000	3.0500	07:33:25	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
17	1,095.0000	03:13:18	74.0000	F	ASCENT	229.0000	P	C	N	29.1000	91.3000	3.0500	07:33:26	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
18	1,095.0000	03:13:19	75.0000	F	ASCENT	230.0000	P	C	N	29.1000	91.3000	3.0500	07:33:27	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
19	1,095.0000	03:13:20	76.0000	F	ASCENT	230.0000	P	C	N	29.1000	91.3000	3.0500	07:33:28	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
20	1,095.0000	03:13:21	77.0000	F	ASCENT	232.0000	P	C	N	29.1000	91.3000	3.0500	07:33:29	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C
21	1,095.0000	03:13:22	78.0000	F	ASCENT	233.0000	P	C	N	29.1000	91.3000	3.0500	07:33:30	107.8000	19.0759	72.8776	5.0000	5.0200	78.0900	C



# GCS Software(6/6)



## GPS Map



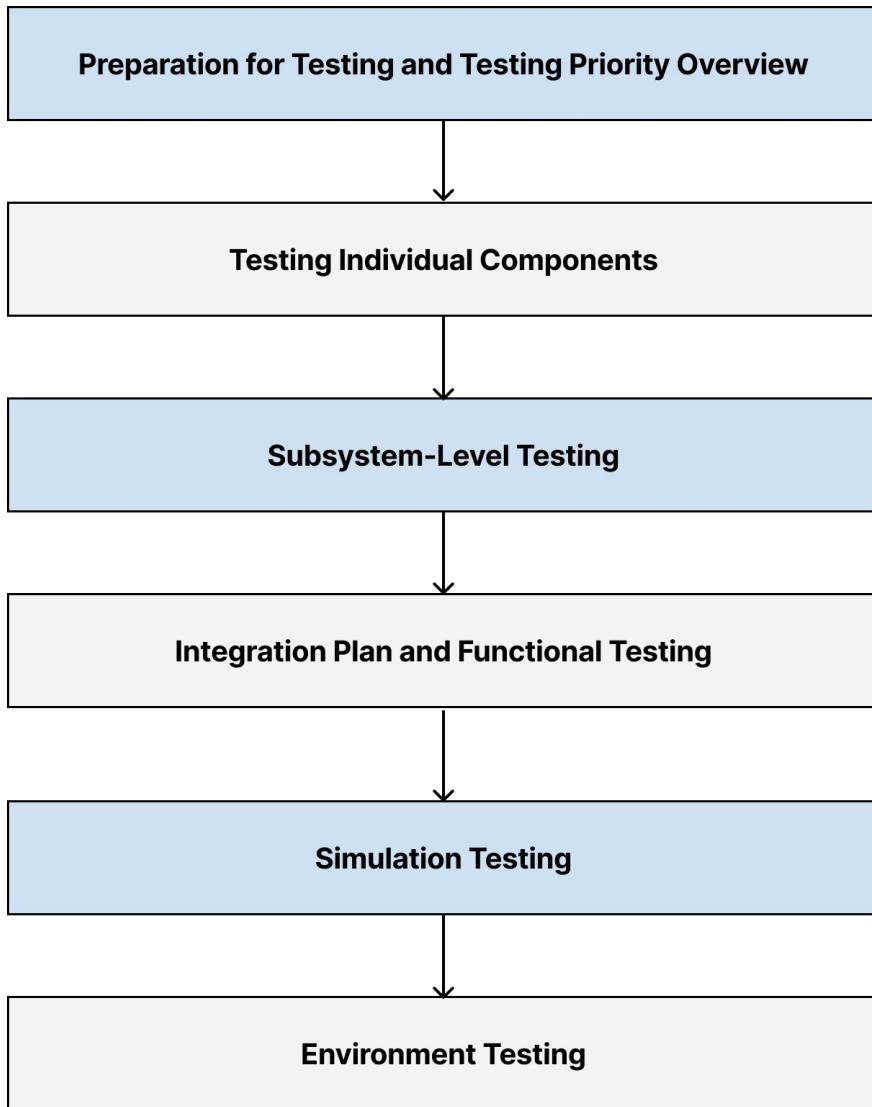


# CanSat Integration and Test

**Yash Kuwalekar**



# CanSat Integration and Test Overview(1/2)



## Description of Integration and Testing Flow:

- Initially, the **body** of container and payload will be tested along with **mechanisms**.
- Next, the components in working order will be **integrated together** and checked for reliable output.
- These components will then be combined together and tested as a **whole unit**.
- Once the **reliability of electronics** has been verified, they will be put into the mechanical structures.
- The **simulation mode** will be activated as a safe method to verify whether critical flight software algorithms are functioning properly.
- Finally, CanSat will be tested in **environmental conditions** which it will be subject to during the **mission**.



# CanSat Integration and Test Overview(2/2)



Phase	Description	Aspects tested
<b>Subsystem level</b>	The working components of subsystem will be checked for functionality in subsystem configuration.	Sensors, CDH, EPS, Radio Communications, FSW, Mechanical, Descent Control
<b>Integration level</b>	Subsystems will be integrated, two or three at a time, and capacity to perform overall tasks will be verified.	Descent Testing, Communications, Mechanisms, Deployment
<b>Simulation level</b>	CanSat will be operated in simulation mode and required critical point mechanisms will be verified for their working.	Flight mode and Simulation mode
<b>Environmental level</b>	Fully assembled CanSat will be tested for sustenance against environmental effects.	Drop test, Thermal test, Vibration test, Fit check, Vacuum test



# Subsystem Level Testing Plan(1/7)



Subsystem	Test protocol	Pass criteria	Test status
Sensors	Sensor initialization	Sensor readings start to appear on the screen.	TBT
	Sensor calibration to give zero values when on ground	Readings from the sensor are very close to zero.	TBT
	Testing pressure sensor.	Pressure and altitude values are accurate.	TBT
	Temperature sensor testing	Temperature reading is precise.	TBT
	Tilt angle measurement	Tilt angles are measured accurately.	TBT
	Power bus voltage verification	Voltage value is correct.	TBT
	GPS data reception	All expected data (time,latitude,longitude,altitude,number of satellites) is received with good accuracy.	TBT
	Camera recording	Complete video is recorded with expected video quality.	TBT



# Subsystem Level Testing Plan(2/7)



Subsystem	Test protocol	Pass criteria	Test status
CDH	Transmission and receiving of data by the processor	Data is sent/received with expected speed and accuracy.	TBT
	Storage of data in the SD card	All the sensor data is stored in the file created in the SD card.	TBT
	Reading data from the SD card	Data can be read from the SD card successfully.	TBT
	Time stamping by Real Time Clock	Time stamping by RTC synchronize with the ground station.	TBT
	Timing of packet sending to ground station	The telemetry packet should be transmitted once every second.	TBT



# Subsystem Level Testing Plan(3/7)



Subsystem	Test protocol	Pass Criteria	Test status
EPS	All sensors are powered	Voltage across the pins of various components is measured according to their respective values.	TBT
	PCB is Soldered properly and has no shorts	Voltage is checked across various points where components are to be connected.	TBT
	Battery withstands high current	Battery works properly when the maximum current is flowing through it.	TBT
	Custom built Buck and Buck -Boost converter	On powering the PCB voltages are measured at all points.	TBT
	Voltage Divider Circuit	Voltage at the point which is connected to Teensy must be checked and verified.	TBT
	To ensure voltage and current supplied to various components are sufficient to function	If all components work properly with the supplied Voltage and also the Current flowing through it is sufficient.	TBT
	All servo motors are powered and working properly	Connecting the motors to the PCB and running them if they work properly at expected speed verified.	TBT
	CanSat can operate for 2 hours	All components must remain on for 2 hours	TBT



# Subsystem Level Testing Plan(4/7)



Subsystem	Test protocol	Pass Criteria	Test status
Radio communications	Basic XBee transmission	Data sent by transmitter should be visible at receiver.	Passed
	XBee transmit mode verification	XBee should not be in broadcast mode.	Passed
	Antenna Alignment Test	Minimal loss of packets in selected antenna orientation.	TBT
	Range test	Successful packet transmission at 1km separation.	TBT
	Interference test	Acceptable throughput in presence of external 2.4GHz signal.	TBT
	Ground Control Station csv creation	GCS should store all telemetry in csv file without delay.	TBT
	Simultaneous transmission & reception	Commands sent by GCS must be received in addition to normal telemetry being sent.	TBT



# Subsystem Level Testing Plan(5/7)



Subsystem	Test protocol	Pass criteria	Test status
Flight Software	Recovery Data Test	Recovery data is backed up regularly and can be accessed after processor resets.	TBT
	Processor Resets	The recovery data must be utilized by the processor to restore it to the correct previous state.	TBT
	FSW State Testing	FSW is able to change states automatically at specified altitudes.	TBT
	Telemetry Packet Test	Telemetry Packet is created properly with correct fields and sensor values.	TBT
	Camera Test (for container and Probe camera)	Video has been properly stored on the SD card without any errors.	TBT



# Subsystem Level Testing Plan(6/7)



Subsystem	Test protocol	Pass Criteria	Test status
Mechanical	Mass Requirement	The container and probe should weigh under 700g.	TBT
	Structural Integrity	CanSat should survive shocks and vibrations.	TBT
	Electronic Components Attachment	Electronic components survive vibrations and attachment points are intact.	TBT
	Payload Separation Mechanism	Payload separates without any damage or entanglement.	TBT
	Probe Parachute Deployment	The securing lid should be removed and parachute should deploy.	TBT
	Uprighting Mechanism	Probe should upright itself regardless of orientation.	TBT
	Flag Raising Mechanism	The flag is raised without entanglement 500mm above the base of the probe.	TBT
	Mass Requirement	The container and probe should weigh under 700g.	TBT



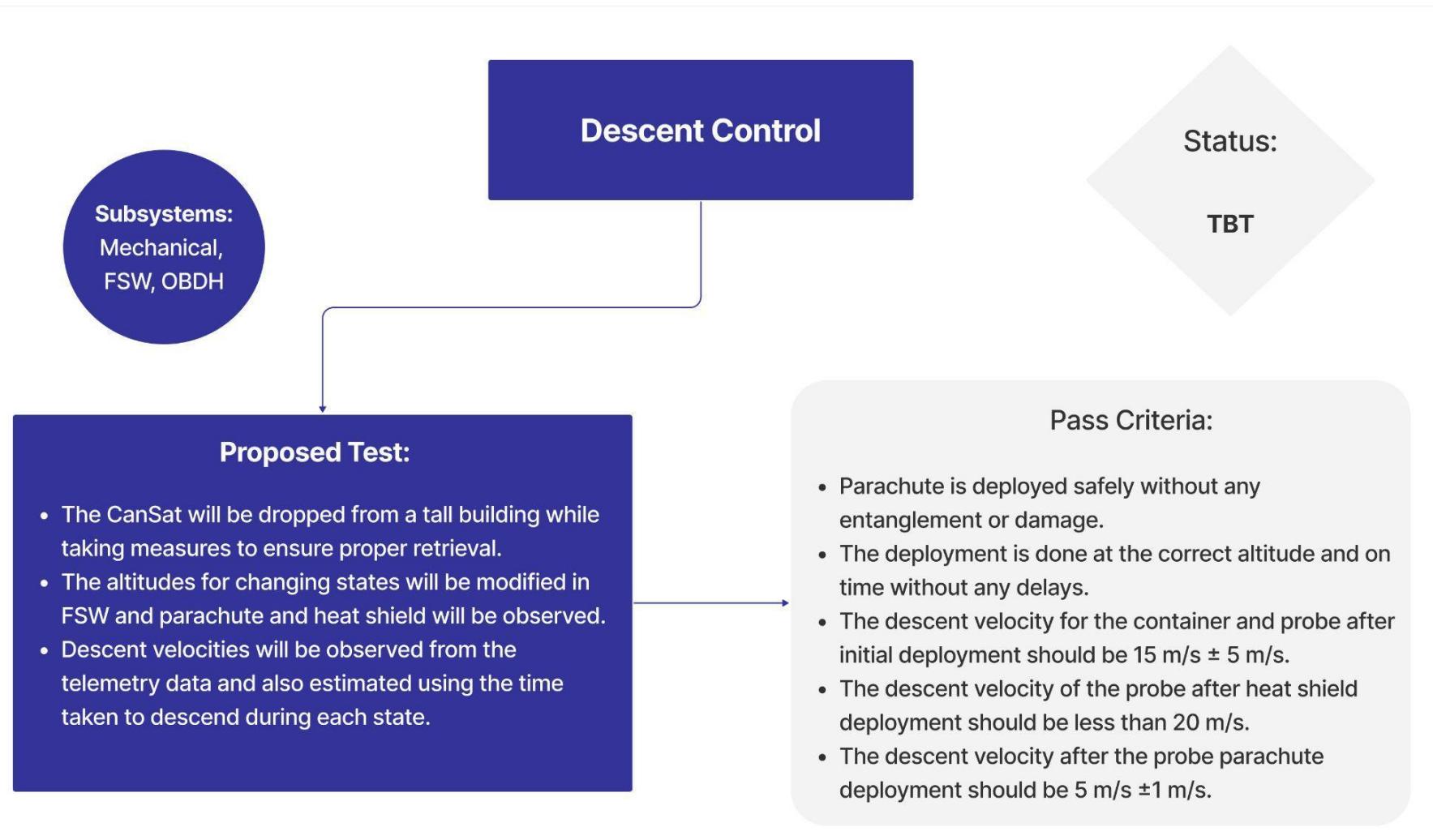
# Subsystem Level Testing Plan(7/7)



Subsystem	Test protocol	Pass Criteria	Test status
Descent Control	Aerobraking Heat Shield Deployment	The heat shield is deployed without getting stuck and is intact.	TBT
	Parachute Deployment	The container and probe parachutes deploy without entanglement.	TBT
	Descent Velocity	The descent velocity after parachute and heat shield deployment should be appropriate.	TBT
	Stability	The CanSat should be stable after parachute and heat shield deployment.	TBT

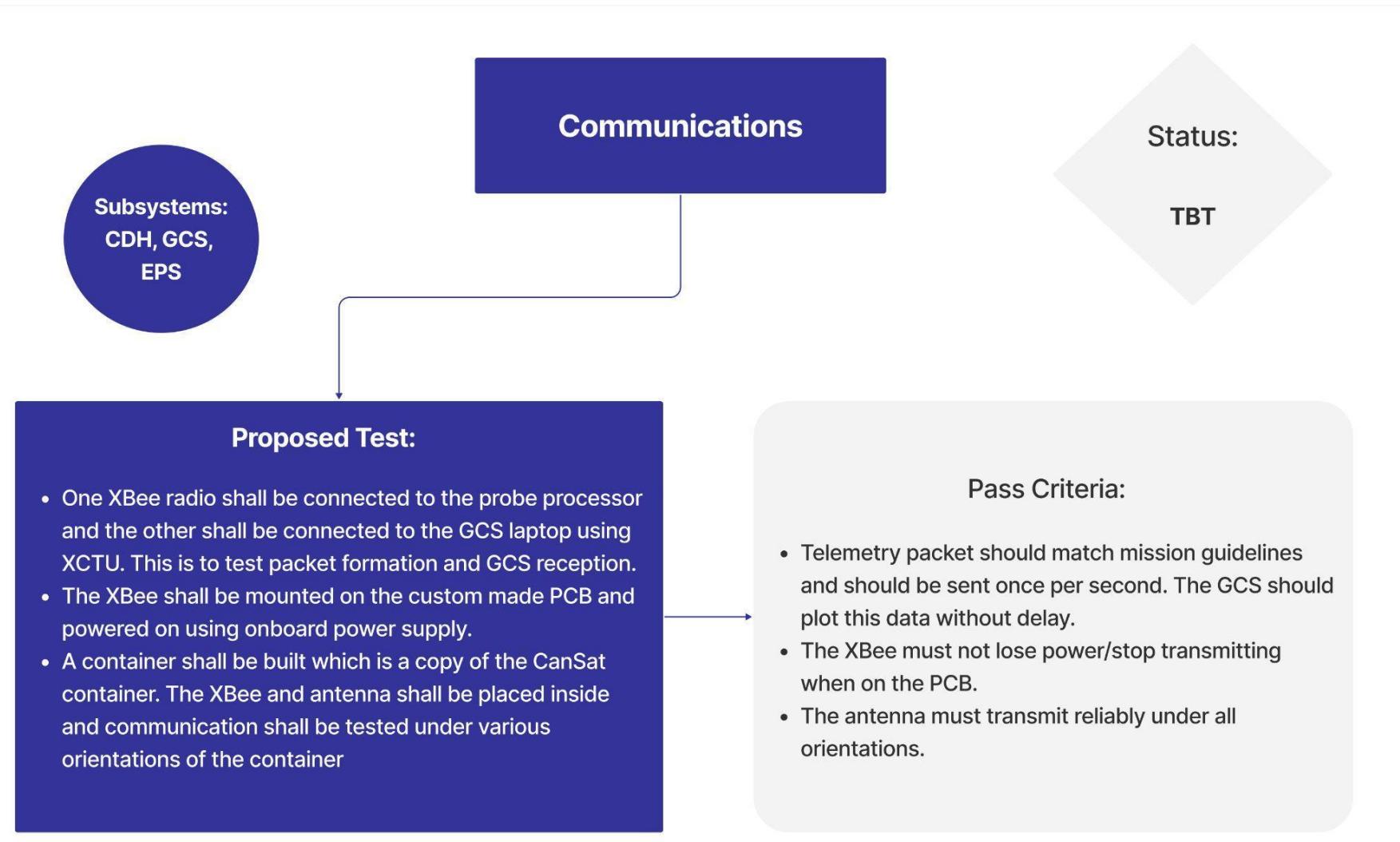


# Integrated Level Functional Test Plan (1/4)



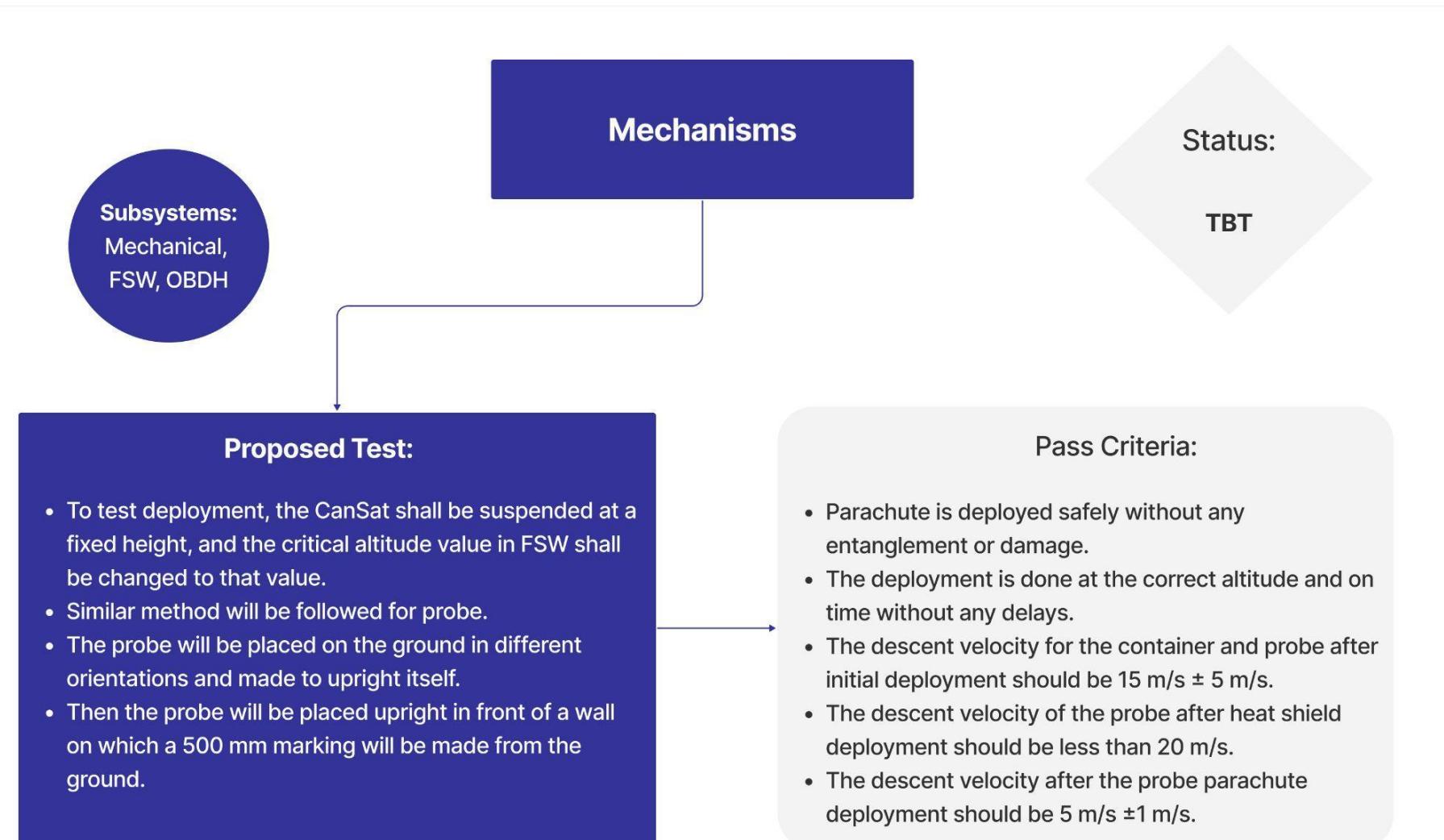


# Integrated Level Functional Test Plan (2/4)





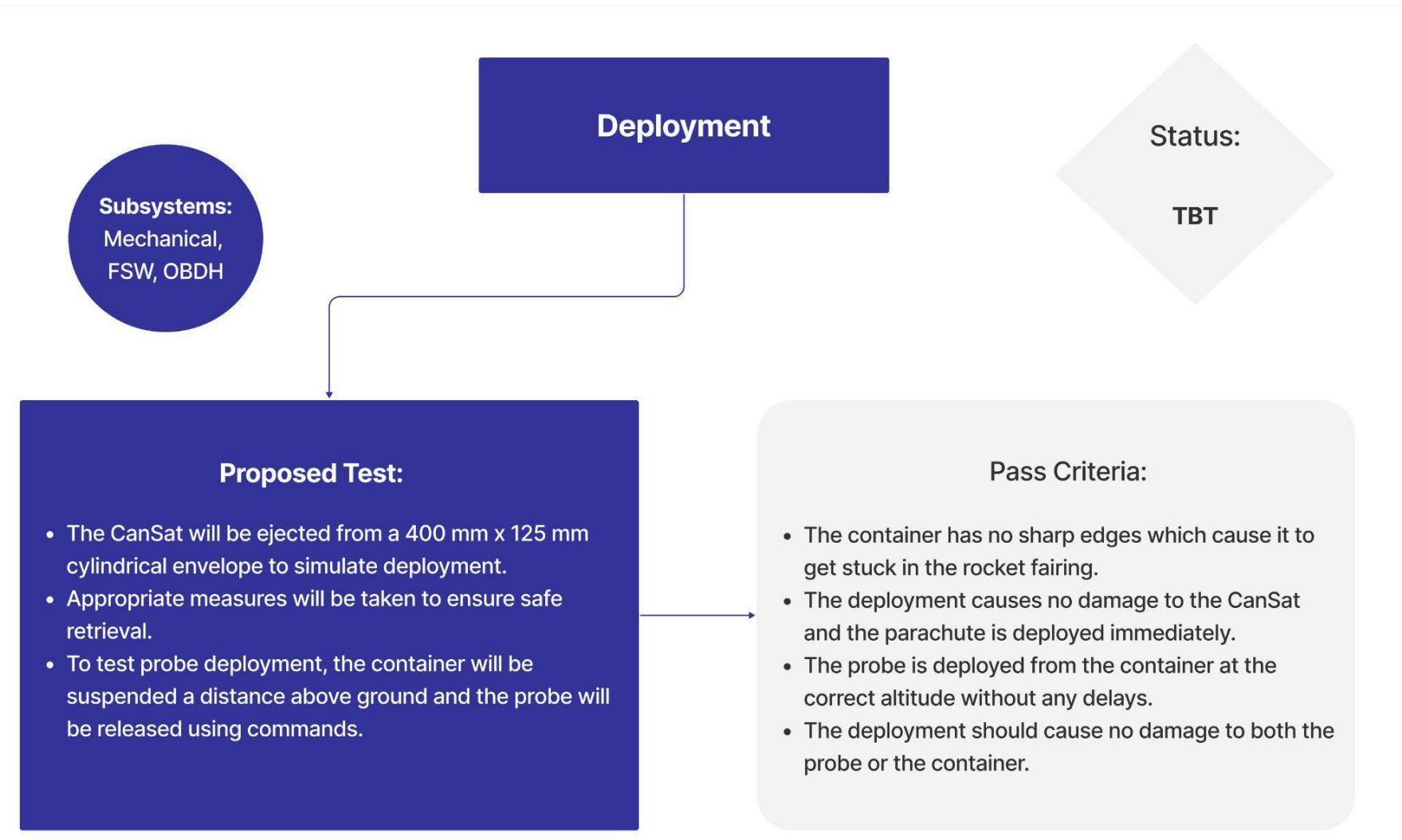
# Integrated Level Functional Test Plan (3/4)





# Integrated Level Functional Test Plan

## (4/4)





# Simulation Test Plan



- Simulation mode is a means to safely verify whether the flight software is accurately sending commands for key mechanisms at the correct instant.
- Only the payload pressure and altitude values are affected when in simulation, the rest remain unchanged.
- There are two major sections to be tested, one is the **GCS data sending ability**, and the other is the **FSW reception and substitution ability**.
- For testing, the CanSat shall be suspended from a height. Safety guards will be placed on the ground below to avoid unnecessary damage.

- Once the probe FSW receives the two commands from GCS, it enters simulation mode.
- The **boundary values** for mechanisms are varied to fit within the altitude range of the simulated csv data.
- The probe FSW **checks RF link** for pressure values received from the SIMP command and uses those values in place of sensor values to perform necessary operations.

- To simulate launch day csv data , the telemetry data received when we perform **descent testing** will be stored.
- The **pressure** values from this csv file will be read using the GCS laptop.
- The GCS will send two commands, **SIM ENABLE** to enable simulation mode, and **SIM ACTIVATE** to commence simulation.
- Using the packet format of **SIMP** command, these pressure values will be sent row by row to the probe, **once per second**.



# Environmental Test Plan(1/2)



Test	Test Overview
<b>Drop test</b>	<p>A non-stretching kevlar cord is attached to the parachute and the other end is attached to the ceiling using an eyebolt. The CanSat is powered on and held at the ceiling. It is released to check the parachute attachment point. It is made sure that the CanSat does not hit the ground and works perfectly fine after the test is conducted. This test also verifies the component and battery mounts.</p>
<b>Thermal test</b>	<p>The CanSat is powered on and placed inside a sealed thermal chamber which will be heated to around <math>60^{\circ}\text{C}</math>, and this temperature will be maintained for two hours. A thermistor or thermocouple is used to monitor the temperature and the behavior of the CanSat is observed under such conditions. This test is conducted to verify whether the CanSat can perform properly under high-temperature conditions without losing any of its structural integrity or functionality.</p>
<b>Vibration test</b>	<p>In this test the CanSat is subjected to vibrations using a vibration table. The vibration table is made by securing a random orbital sander to a table upside down. The CanSat is secured to the sander and powered on. The test should generate vibrations of around 0 to 233 Hz which generates a shaking of around 20 to 29 Gs. The CanSat will be inspected for any damages or deformations in the structure.</p>



# Environmental Test Plan(2/2)



Test	Test Overview
<b>Fit Check</b>	Precise measurements are to be taken to ensure that the CanSat fits into the rocket fairing and is deployed without getting stuck. A vernier caliper will be used to make the measurements and a cylindrical envelope of 400 mm x 125 mm will be built to ensure maximum failsafe.
<b>Vacuum test</b>	A vacuum chamber is fabricated in-house using a large container that can be sealed and vacuum cleaners. The CanSat is suspended inside the vacuum chamber and powered on. A vacuum is created and the behavior of the CanSat is observed. Further observations are made by letting in the air slowly. This test is conducted to observe the response of the CanSat to vacuum conditions that can be created during deployment.



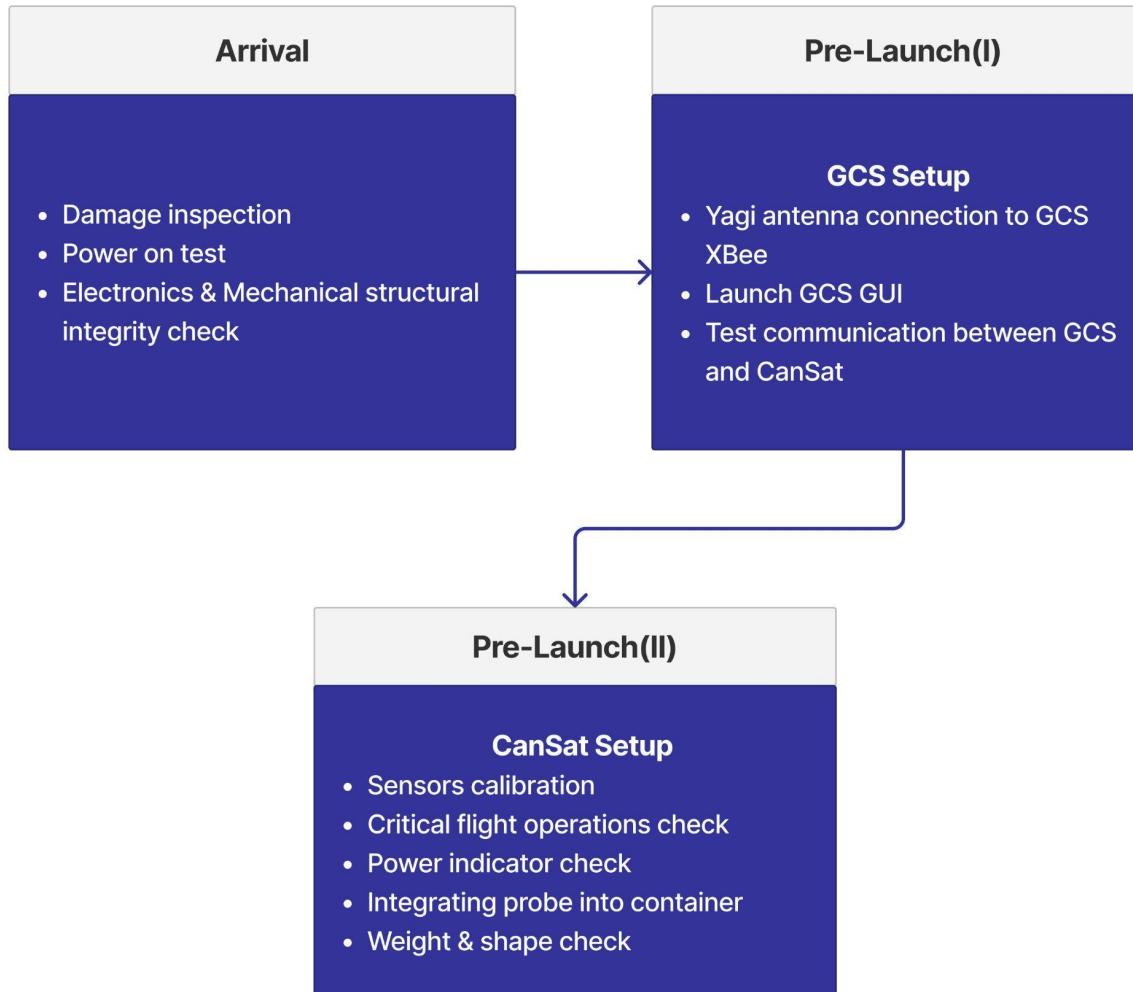
---

# Mission Operations & Analysis

**Shubham Salunkhe**

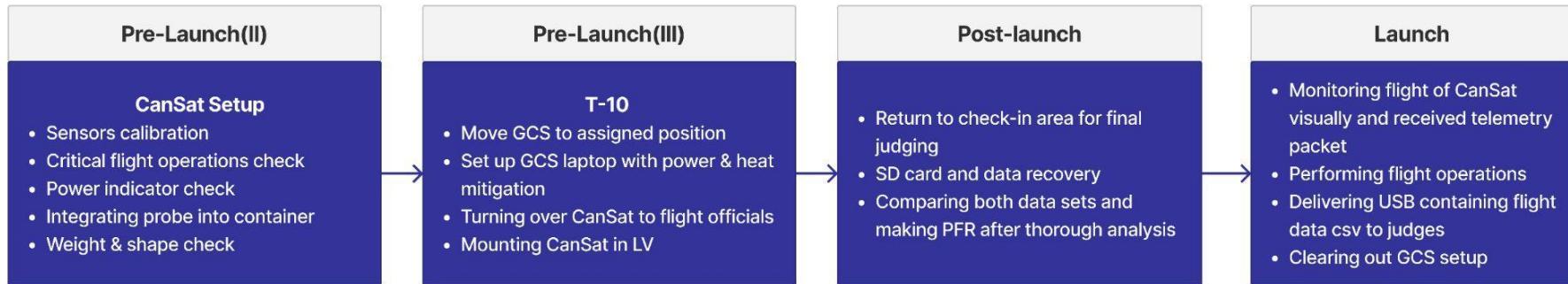


# Overview of Mission Sequence of Events(1/3)





# Overview of Mission Sequence of Events(2/3)



## CanSat Assembly & Testing

- Calibrate sensors to appropriate start values.
- Check whether battery power levels are sufficient.
- Communication test between probe and GCS XBee.
- Mechanism testing.
- Final weight & dimensions check
- Interconnecting elements integrity.

## Antenna Construction & Ground System Setup

- Connecting XBee to GCS laptop using serial connection.
- Launching GUI on laptop and ensuring working.
- Mounting Yagi antenna on custom made handheld mount.
- Connecting Yagi to XBee using SMA cable.
- Verify connection with CanSat.



# Overview of Mission Sequence of Events(3/3)



Role	Responsibilities	Personnel
Mission Control Officer	Inform the flight officer when the team and CanSat is ready to launch, coordinate the operations of the entire team with the flight officials, be in possession of mission operations manual during launch and announce team names and countdown just before launch.	Shubham Salunkhe
Ground Station Crew	Monitor ground station telemetry and send commands to CanSat. Visually track probe descent and maintain GCS antenna orientation.	Yash Kuwalekar, Ojas Taskar, Mihir Sahasrabudhe
Recovery Crew	Track CanSat and go out into the field for recovery after interacting with field judges. Ensure all field scores are filled in.	Ojas Taskar, Kimaya Mutha
CanSat Crew	Prepare CanSat, integrate into rocket and verify its status. Conduct final checks to ensure working integrity of the entire CanSat.	Aarya Kulkarni, Kimaya Mutha, Shaunak Natu, Shreya Puri



# Mission Operations Manual

## Development Plan(1/2)



Development	Content
The mission development manual will be developed while performing subsystem level and integration level testing.	
Preliminary tests are indicated below.	
Manual will be assembled after critical test procedure are verified.	Based on the subsystem level understanding, tests will be designed for each checklisted item provided in the template. We will try to ensure that a thorough manual is created to mitigate any chances of failure.
It shall be a 3 page binder. Each section shall begin on a new page and pages will be numbered.	
Table of contents will be made according to the template.	



# Mission Operations Manual

## Development Plan(2/2)



Operations	Setup	Testing
<b>Ground Station Configuration</b>	<ul style="list-style-type: none"><li>• Handheld antenna</li><li>• Antenna Mounting</li><li>• GCS laptop with overheating mitigation and backup power</li><li>• Data logging GUI</li></ul>	<ol style="list-style-type: none"><li>1. Communication with CanSat.</li><li>2. Telemetry packet reception and csv file formation.</li><li>3. Real time packet parameter plotting.</li><li>4. Command reception at CanSat.</li></ol>
<b>CanSat Preparation</b>	<ul style="list-style-type: none"><li>• Sensor calibration</li><li>• Battery charging</li><li>• Electronics and mechanical structure integrity</li></ul>	<ol style="list-style-type: none"><li>1. Mass and Dimension check</li><li>2. Mechanism inspection</li><li>3. Ensuring no protruding edges.</li></ol>
<b>CanSat Integration</b>	None	<ol style="list-style-type: none"><li>1. Clearance &amp; Visual inspection</li></ol>
<b>Launch Preparation</b>	<ul style="list-style-type: none"><li>• Altitude sensor calibration</li><li>• Mission time setting</li></ul>	<ol style="list-style-type: none"><li>1. Communication with fully integrated CanSat using handheld GCS antenna mount</li></ol>
<b>Launch Procedure</b>	Additional steps will be added, when developed.	None.

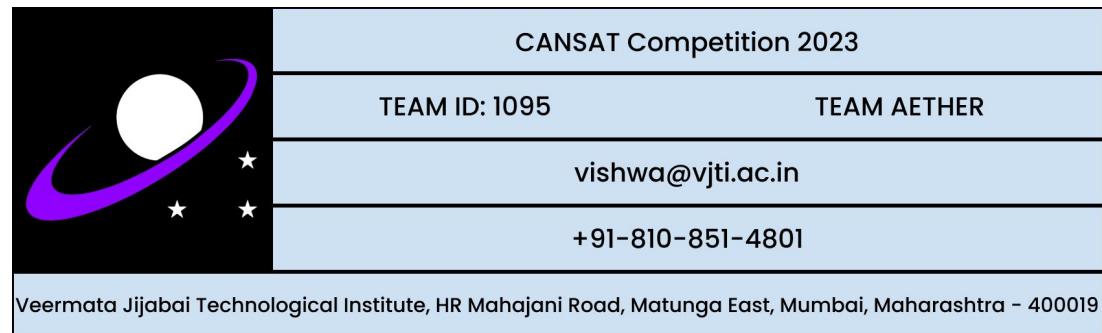


# CanSat Location and Recovery



Parameter used for recovery	Container	Probe
<b>GPS Sensor</b>	The container does not have a GPS sensor.	The last reading of the GPS sensor will be used to track the probe landing location.
<b>Buzzer</b>	A 92dB buzzer is present which is used for audio location.	Buzzer is used to locate probe by sound.
<b>Coloured Body</b>	Container has pink coloured body which makes it easily visible.	Probe has orange coloured body which can be used.
<b>Coloured Parachute</b>	Fluorescent yellow coloured parachute is used for recovery.	Probe parachute is yellow in colour, which facilitates easy spotting.
<b>Visual Tracking</b>	The members of the recovery crew will be visually tracking both the container and the probe to see where they land.	

We will label the probe and the container using this sticker.





# Requirements Compliance

**Yash Kuwalekar**



# Requirements Compliance Overview



- Our current design of the CANSAT complies with 61 requirements given in the Mission Guide document.
- All the designing has been done keeping in mind the guidelines mentioned in the *Guidance for Success* document.
- All the environmental tests have been planned following the *Environmental Tests guide*.
- All the estimated values in the budget have been selected keeping in mind all the fail safe margins.

- The colour  indicates that the requirement is fully met.
- The colour  indicates that the requirement is partial/not completely verified yet(theoretical verification).
- The colour  indicates that the requirement is not met.

We have compiled all 61 requirements, out of which 55 are green, 6 are yellow and 0 are red.



# Requirements Compliance(1/8)



ID	Requirement	Comply / No Comply / Partial	Notes
1	Total mass of the CanSat (science probe and container) shall be 700 grams +/- 10 grams.	Comply	
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	Comply	
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	Comply	
4	The container shall be a fluorescent color; pink, red or orange.	Comply	
5	The container shall be solid and fully enclose the science probes. Small holes to allow access to turn on the science probes are allowed. The end of the container where the probe deploys may be open.	Partial	
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	
7	The rocket airframe shall not be used as part of the CanSat operations.	Comply	
8	The container's parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	Comply	



# Requirements Compliance(2/8)



ID	Requirement	Comply / No Comply / Partial	Notes
9	The Parachute shall be fluorescent Pink or Orange	Comply	
10	.The descent rate of the CanSat (container and science probe) shall be 15 meters/second +/- 5 m/s.	Comply	
11	0 altitude reference shall be at the launch pad.	Comply	
12	All structures shall be built to survive 15 Gs of launch acceleration.	Partial	
13	All structures shall be built to survive 30 Gs of shock.	Partial	
14	All electronics and mechanical components shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	
15	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Partial	
16	Mechanisms shall not use pyrotechnics or chemicals.	Comply	
17	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	Comply	



# Requirements Compliance(3/8)



ID	Requirement	Comply / No Comply / Partial	Notes
18	Both the container and probe shall be labeled with team contact information including email address.	Comply	
19	Cost of the CanSat shall be under \$1000. Ground support and analysis tools are not included in the cost. Equipment from previous years shall be included in this cost, based on current market value.	Comply	
20	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	Comply	
21	XBEE radios shall have their NETID/PANID set to their team number.	Comply	
22	XBEE radios shall not use broadcast mode.	Comply	
23	The container(if needed) and probe shall include an easily accessible power switch that can be accessed without disassembling the cansat and science probes and in the stowed configuration.	Comply	
24	The probe shall include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the cansat and in the stowed state.	Comply	
25	An audio beacon is required for the probe. It shall be powered after landing.	Comply	



# Requirements Compliance(4/8)



ID	Requirement	Comply / No Comply / Partial	Notes
26	The audio beacon shall have a minimum sound pressure level of 92 dB, unobstructed.	Comply	
27	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells. Coin cells are allowed.	Comply	
28	An easily accessible battery compartment shall be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Partial	Theoretical
29	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	
30	The Cansat shall operate during the environmental tests laid out in Section 3.5.	Partial	Theoretical
31	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Comply	
32	The probe shall be released from the container when the CanSat reaches 500 meters.	Comply	



# Requirements Compliance(5/8)



ID	Requirement	Comply / No Comply / Partial	Notes
33	The probe shall deploy a heat shield after leaving the container.	Comply	
34	The heat shield shall be used as an aerobrake and limit the descent rate to 20 m/s or less.	Comply	
35	At 200 meters, the probe shall release a parachute to reduce the descent rate to 5 m/s +/- 1 m/sec.	Comply	Theoretical
36	Once landed, the probe shall upright itself.	Comply	Theoretical
37	After uprighting, the probe shall deploy a flag 500 mm above the base of the probe when the probe is in the upright position.	Comply	
38	The probe shall transmit telemetry once per second.	Comply	
39	The probe telemetry shall include altitude, air pressure, temperature, battery voltage, probe tilt angles, command echo, and GPS coordinates that include latitude, longitude, altitude and number of satellites tracked.	Comply	
40	The probe shall include a video camera pointing down to the ground.	Comply	



# Requirements Compliance(6/8)



ID	Requirement	Comply / No Comply / Partial	Notes
41	The video camera shall record the flight of the probe from release to landing.	Comply	
42	The video camera shall record video in color and with a minimum resolution of 640x480.	Comply	
43	The flight software shall maintain a count of packets transmitted which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	Comply	
44	The probe shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	
45	The probe shall have its time set to within one second UTC time prior to launch.	Comply	
46	The probe flight software shall support simulated flight mode where the ground station sends air pressure values at a one second interval using a provided flight profile csv file.	Comply	
48	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the payload altitude.	Comply	



# Requirements Compliance(7/8)



ID	Requirement	Comply / No Comply / Partial	Notes
49	The payload flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	
50	The ground station shall command the Cansat to start calibrating the altitude to zero when the Cansat is on the launch pad prior to launch.	Comply	
51	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	
52	Telemetry shall include mission time with 1 second or better resolution.	Comply	
53	Configuration states such as zero altitude calibration shall be maintained in the event of a processor reset during launch and mission.	Comply	
54	Each team shall develop their own ground station.	Comply	
55	All telemetry shall be displayed in real time during descent on the ground station.	Comply	
56	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	



# Requirements Compliance(8/8)



ID	Requirement	Comply / No Comply / Partial	Notes
57	Teams shall plot each telemetry data field in real time during flight.	Comply	
58	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	
59	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	Comply	
60	The ground station software shall be able to command the payload to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	Comply	
61	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the CanSat.	Comply	



---

# Management

**Shreya Puri**



# CanSat Budget – Hardware(1/4)



Electronics				
Components	Units required	Cost/unit (\$)	Total Cost (\$)	Considerations
MS5611	2	8.15	16.3	Actual
Teensy 4.1	1	5.20	5.20	Actual
Adafruit LSM6DS3TR-C	2	9.95	19.90	Estimate
Neo 6M GPS	1	4.91	4.91	Reused
ESP32 CAM	1	8	8	Estimate
SanDisk Ultra	3	4.38	13.14	Actual
Duracell DL2032 Coin Cell	1	1.23	1.23	Actual
92dB Buzzer	2	5	10	Estimate



# CanSat Budget – Hardware(2/4)



Electronics				
Components	Units required	Cost/unit (\$)	Total Cost (\$)	Considerations
RGB LED	1	0.43	0.43	Actual
LED	2	0.2	0.2	Actual
SQ11 Mini Camera	1	12	12	Actual
XBee Pro S2C	1	28.90	28.90	Actual
Molex 214415-0011	1	19.34	19.34	Actual
SMA cable	1	3	3	Actual
Wiring for mechanisms	-	4	4	Estimate
Custom PCBs	5	14	70	Estimate
ON/OFF Switch	2	0.75	1.5	Actual
Battery Holder	2	1	2	Actual
Orange ICR18650-20C	2	4.5	9	Actual



# CanSat Budget – Hardware(3/4)



## Total Electronics Cost (\$)

Mechanical				
Components	Units required	Cost/unit (\$)	Total Cost (\$)	Considerations
SG90 Servo Motor	3	1.5	4.5	Actual
Flag mechanism deployable stick	1	4.5	4.5	Estimate
PLA	Sponsored			
Carbon Fiber	3	2.5	7.5	Estimate
<b>Total Mechanical Cost (\$)</b>			<b>16.5</b>	



# CanSat Budget – Hardware(4/4)





# CanSat Budget – Other Costs(1/3)



## Ground Control Station

Component	Units required	Units bought	Cost/unit (\$)	Total Cost (\$)	Considerations	Type
XBee Pro S2C	1	1	28.90	28.90	Actual	New
XBee Adapter	1	1	13.47	13.47	Actual	New
Laptop	1		N/A, owned by team member			
Yagi antenna	1	1	38.21	38.21	Actual	New
SMA cables	2	2	2	4	Estimate	New
Umbrella	1	1	7.35	7.35	Actual	New
Table fan	1	1	9.80	9.80	Actual	New
Powerbank	1	1	14	14	Estimate	New
<b>Total GCS Cost (\$)</b>				<b>115.73</b>		



# CanSat Budget – Other Costs(2/3)



Other Costs				
Particular	Quantity	Cost/unit	Total Cost (\$)	Considerations
Prototyping & Testing	1	175	175	Estimate
Registration Fee	1	200	200	Actual
Flights	10	1470	14700	Estimate
Transportation	10	90/person for 4 days	900	Estimate
Accommodation	10	250/night for each room	750	Estimate
Food	10	50/person	500	Estimate
Tourist Visa	10	114	1140	Estimate
Uniform	10	9/person	90	Actual
Total (\$)			18,455	

Team Logo  
Here  
(If You Want)



Team Logo  
Here  
(If You Want)



Team Logo  
Here  
(If You Want)





# CanSat Budget – Other Costs(3/3)



Income	
Source	Amount (\$)
University	1000
Sponsors	Not known
<b>We are currently in the process of searching for sponsors to provide the rest of the funds required.</b>	

Total Costs	
Name	Total (\$)
Hardware	245.55
Other Costs	18,570.73
Total Cost	18,816.28



# Program Schedule Overview



TC - Team Captain  
TL - Technical Lead

SPONS - Sponsorship Team  
ALL - All Members

Mech - Mechanical Subsystem  
EPS - Electrical Power Subsystem

Task	Assign	Start	End	Days	Status	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
PDR Preparation	ALL	1-Nov-22	31-Jan-23	92	Completed								
Registration	TC	3-Nov-22		1	Completed								
Securing Approval of Funds from College	SPONS	7-Nov-22	11-Nov-22	5	Completed								
End Semester Exams (5th sem)	ALL	28-Nov-22	15-Dec-22	18									
Registration Fee Payment	TC	14-Dec-22		1	Completed								
Ordering Primary Components	TL	16-Dec-22	20-Dec-22	5	Completed								
Sponsorship	SPONS	19-Dec-22	25-Feb-23	69	Ongoing								
PDR Submission	TC	1-Feb-23		1	Completed								
Team Break	ALL	2-Feb-23	5-Feb-23	4									
Ordering Secondary Components	TL	5-Feb-23	7-Feb-23	3	Upcoming								
Building Subsystems and Prototyping Design Concepts	ALL	6-Feb-23	25-Feb-23	20	Upcoming								
CDR Preparation	ALL	6-Feb-23	30-Mar-23	53	Upcoming								
PDR Presentation	ALL	14-Feb-23		1	Upcoming								
Verification of Designs and Changes in PDR (if needed)	ALL	26-Feb-23	12-Mar-23	15	Upcoming								
Mid Semester Test (6th Sem)	ALL	13-Mar-23	18-Mar-23	6									
CDR Submission	TC	31-Mar-23		1	Upcoming								
Manufacturing	MECH,EPS	19-Mar-23	30-Apr-23	43	Upcoming								
Environmental testing (+ repairs if required)	MECH	1-May-23	10-May-23	10	Upcoming								
End Semester Exams (6th sem)	ALL	15-May-23	31-May-23	17									
Environmental Test Submission	TC	26-May-23		1	Upcoming								
Final Testing and Transportation Preparation	ALL	2-Jun-23	5-Jun-23	4	Upcoming								
Competition	ALL	10-Jun-23		1	Upcoming								
PFR submission	ALL	11-Jun-23		1	Upcoming								



# Detailed Program Schedule (1/4)



## Flight Software Subsystem

Task	Start	End	Days	Status	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mission Guide Study	1-Nov-22	5-Nov-22	5	Completed								
Recognising FSW Tasks	6-Nov-22	12-Nov-22	7	Completed								
Exploring GCS approaches	8-Nov-22	14-Nov-22	7	Completed								
GCS Software Development	15-Nov-22	28-Jan-23	75	Completed								
Main Algorithm & FSW State Diagram	18-Nov-22	30-Dec-22	43	Completed								
Subsystem Holiday	16-Dec-22	22-Dec-22	7	Completed								
Sensor Library Study	23-Dec-22	7-Jan-23	16	Completed								
Individual Sensor Code	10-Jan-23	15-Feb-23	37	Ongoing								
GCS integration with CDH	14-Jan-23	14-Feb-23	32	Ongoing								
Team Break	2-Feb-23	5-Feb-23	4	Completed								
Simulation Mode Programming	9-Feb-23	26-Feb-23	18	Upcoming								
Code Integration	2-Mar-23	18-Apr-23	48	Upcoming								
Command Test	26-Mar-23	22-Apr-23	28	Upcoming								
Simulation Mode Test	18-Apr-23	30-Apr-23	13	Upcoming								
Refinement and Optimization	25-Apr-23	7-May-23	13	Upcoming								



# Detailed Program Schedule (2/4)



## Mechanical Subsystem

Task	Start	End	Days	Status	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
CAD software learning and basic modelling	1-Nov-22	25-Nov-22	25	Completed								
Basic courses on aeromodelling and dynamics	15-Nov-22	20-Dec-22	36	Completed								
Segregation of payload and container components and tasks	15-Dec-22	20-Dec-22	6	Completed								
Container and Payload body initial design	21-Dec-22	28-Dec-22	8	Completed								
CAD modelling of electronic components	25-Dec-22	31-Dec-22	7	Completed								
Developing and finalising flight mechanisms	1-Jan-23	9-Jan-23	9	Completed								
Parachute Design	1-Jan-23	4-Jan-23	4	Completed								
Heat shield designing and prototyping	1-Jan-23	7-Jan-23	7	Completed								
Subsystem Holiday	10-Jan-23	14-Jan-23	5	Upcoming								
Design finalisation, PCB placement and PDR preparation	15-Jan-23	25-Jan-23	11	Completed								
Team Break	2-Feb-23	5-Feb-23	4	Upcoming								
3D Printing Parts and prototyping	6-Feb-23	30-Mar-23	53	Upcoming								
Review and Part Redesign	1-Mar-23	21-Apr-23	52	Upcoming								
Prototype Assembly	1-Apr-23	15-Apr-23	15	Upcoming								
Integration Testing	16-Apr-23	20-Apr-23	5	Upcoming								
Environmental Testing	1-May-23	10-May-23	10	Upcoming								
Final integration and mechanisms check	12-May-23	24-May-23	13	Upcoming								



# Detailed Program Schedule (3/4)

## Sensor Subsystem



### EPS and Sensor Subsystem

Task	Start	End	Days	Status	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Electronics & Sensors Study	1-Nov-22	25-Nov-22	25	Completed								
Ordering electronic components	16-Dec-22	20-Dec-22	5	Completed								
Preliminary component testing for working	21-Dec-22	25-Dec-22	5	Completed								
Designing configuration of EPS	26-Dec-22	10-Jan-23	16	Completed								
Interfacing of sensors with processor	26-Dec-22	15-Jan-23	21	Completed								
Subsystem Holiday	28-Dec-22	6-Jan-23	10	Completed								
EPS Battery selection	11-Jan-23	13-Jan-23	3	Completed								
EPS Design Finalisation and PCB designing	14-Jan-23	17-Jan-23	4	Completed								
PDR preparation	17-Jan-23	25-Jan-23	9	Completed								
Team Break	2-Feb-23	5-Feb-23	4	Completed								
Subsystem Building	17-Feb-23	11-Mar-23	23	Upcoming								
Integration Level Testing	19-Mar-23	30-Mar-23	12	Upcoming								



# Detailed Program Schedule (4/4)



## Communication & Data Handling Subsystem

Task	Start	End	Days	Status	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Components Study and Past PDR Reading	1-Nov-22	20-Dec-22	50	Completed								
Antenna Criteria study and selection	15-Dec-22	19-Dec-22	5	Completed								
Subsystem Holiday	20-Dec-22	26-Dec-22	7	In Progress								
XBee Radio datasheet and modes study	21-Dec-22	27-Dec-22	7	Completed								
XBee Radios interfacing and test	28-Dec-22	4-Jan-23	8	Completed								
Communications related configuration	5-Jan-23	15-Jan-23	11	Completed								
PDR preparation	16-Jan-23	23-Jan-23	8	Completed								
Team Break	2-Feb-23	5-Feb-23	4	In Progress								
Prototyping entire subsystem and req changes	6-Feb-23	12-Mar-23	35	Upcoming								
Integration level testing	19-Mar-23	30-Mar-23	12	Upcoming								



# Conclusions



Major Accomplishments	Major Unfinished work
<ul style="list-style-type: none"><li>• PDR document is completed</li><li>• CanSat Designs are finalized</li><li>• EPS design and PCB design</li><li>• Most of the sensors have been received</li><li>• Individual Sensor Testing and Programming</li><li>• GCS Software testing with CDH</li><li>• Testing plans have been finalized</li><li>• Received Sponsorship for 3D Printing</li><li>• Received Funds from the Institute</li></ul>	<ul style="list-style-type: none"><li>• Mechanism Testing</li><li>• Improvements in designs based on Test results and analysis</li><li>• Antenna not tested</li><li>• CanSat PCBs yet to be put for manufacturing</li><li>• FSW code integration</li><li>• Integration Level Testing</li><li>• Sponsorship for other needs</li></ul>

## Readiness to proceed to next stage of development

- Preliminary Design Phase of all subsystems has been completed and we are ready to move into the Development Phase.
- Proper plan for Development and Testing and regular meetings are conducted to track the progress of our team.
- CanSat Designs are compliant with most of the requirements.
- Significant portion of required funds have been allotted to proceed with the competition.