CanSat 2021
Critical Design Review (CDR)
Version 1.0

#1567
DJS Arya

Presentation Outline

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Team Organization

Satvik Deshmukh
(Captain)
3rd Year EXTC

Dr. Amit Deshmukh
Faculty Advisor

Harshil Suvarna
3rd Year Mechanical

Greeshma Gala
3rd Year Mechanical

Krittika Roy
2nd Year EXTC

Vatsal Tapiawala
(Vice Captain)
3rd Year Mechanical

Harshil Shah
3rd Year Mechanical

Khyati Morparia
2nd Year EXTC

Nisarg Shah
3rd Year EXTC

Shweta Chavan
2nd Year EXTC

Anushka Kanabar
2nd Year EXTC

Acronyms (1/4)

Acronyms	Definitions
FSW	Flight Software
CDH	Communication and Data Handling
EPS	Electrical Power Subsystem
GCS	Ground Control Station
MOSFET	Metal Oxide Semi-conductor Field Effect Transistor
GPS	Global Positioning System
EEPROM	Electrically Erasable Programmable Read Only Memory
3D	3 Dimensional
BNS	Bonus Number
IDE	Integrated Development Environment

Acronyms	Definitions
BMP	Barometric Pressure
.csv	Comma Separated Value
A	Analysis
I	Inspection
T	Testing
D	Demonstration
GUI	Graphical User Interface
I2C	Inter Integrated Circuit
PCB	Printed Circuit Board
RAM	Random Access Memory
KB/MB/GB	kilobyte/ megabyte/ gigabyte
GS	Ground Station

Acronyms (2/4)

Acronyms	Definitions
LED	Light Emitting Diode
Ni-Cad/ Ni-MH/Li-ion	Nickel-Cadmium/ Nickel Metal Hydride/ Lithium ion
NMEA	National Marine Electronics Association
GGA	Generalized Gradient Approximation
PETG	Polyethylene Terephthalate Glycol
LoS	Line of Sight
MCU	Micro Controlling Unit
USB	Universal Serial Bus
MQTT	Message Queuing Telemetry Transport

Acronyms	Definitions
PAN ID	Personal Area Network Identification
NET ID	Network Identification
gm/kg	gram/ kilogram
SD	Secure Digital
SO	System Overview
SPI	Serial Peripheral Interface
mA/µA	milli Ampere/ micro-Ampere
RF	Radio Frequency
IC	Integrated Circuit
CP	Centre of Pressure
Pa/hPa	Pascal/ hecto Pascal
RTC	Real Time Clock

Acronyms (3/4)

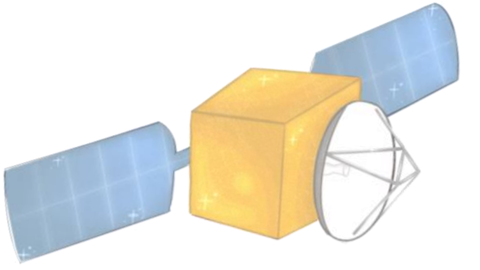
Acronyms	Definitions
CDR	Critical Design Review
CONOP	Concept of Operations
Sr.	Serial
No.	Number
HW	Hardware
CAD	Computer Aided Design
LCO	Launch Control Officer
PDR	Preliminary Design Review
EXTC	Electronics and Telecommunication
Rpm	rotation per minute
CG	Centre of Gravity
RP-SMA	Reverse Polarity Sub-Miniature Version A

Acronyms	Definitions
SOE	Sequence of Events
TBD	To Be Determined
TBR	To Be Resolved
VM	Verification Method
PFR	Post Flight Review
UART	Universal Asynchronous Receiver Transmitter
CR	Competition Requirement
mm/cm/m/km	millimeter/ centimeter/ meter/ kilometer
DoF	Degree of Freedom
dB	decibel
dBi	decibel relative to isotrope

Acronyms (4/4)

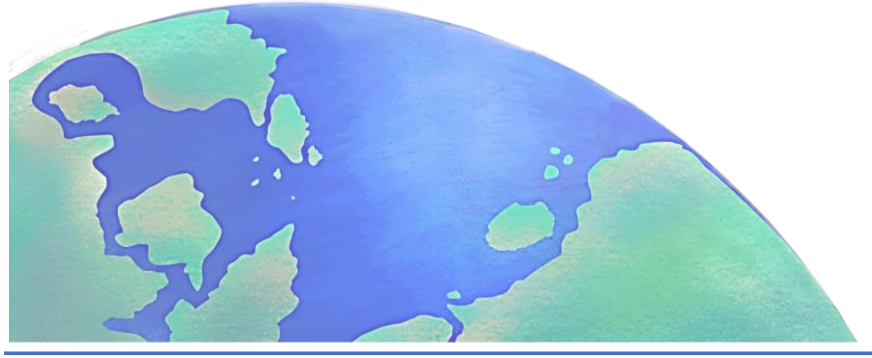
Acronyms	Definitions
KBps/MBps	Kilobytes Per Second/ Megabytes Per Second
SDHC	Secure Digital High Capacity
IMU	Inertial Measurement Unit
ppm	parts per million
CF	Carbon fiber
mW/W	milli Watt/ Watt
UTC	Universal Time Coordinated
mWh/Wh	milli Watt hour/ Watt hour
RSO	Range Safety Officer
ms/s/h	millisecond/second/ hour
IMU	Inertial Measurement Unit
VSWR	Voltage Standing Wave Radio

Acronyms	Definitions
DCS	Descent Control System
FRR	Flight Readiness Review
HWR	Hardware Review
PFB	Post Flight Briefing
dBm	Decibel milliwatts
FPS	Frames per Second
AC	Alternating Current
FPV	First Person View
ABS	Acrylonitrile-Butadlene-Styrene
GPIO	General Purpose Input/Output
PWM	Pulse Width Modulation
ASCII	American Standard Code for Information Interchange
mAh	milliampere hour



System Overview

Presenter’s Name: Anushka Kanabar



Mission Summary (1/3)

1. The CanSat shall consist of a container and two autorotating maple seed science payloads.
2. The container will include electronics that initiate the release of the payloads, and relay telemetry data to the ground station.
3. The rocket will launch the CanSat to a height of 670 to 725 m above the launch site and deploy it near apogee.
4. The container will protect the contents from damage during the uncontrolled, violent deployment.
5. On deployment from the rocket, the CanSat shall descend using a parachute at a rate of 15m/s.
6. At heights of 500m and 400m above the launch site, the container shall release the first and second autorotating payloads, respectively.

Mission Summary (2/3)

7. The maple seed payloads shall spin rapidly enough such that their descent rate does not exceed 20m/s.
8. The container shall incorporate its own telemetry along with the payload telemetry, using the team number as its NET ID.
9. Each payload shall transmit telemetry once a second which includes air pressure and air temperature, using the team number plus 5 as its NET ID.
10. The payloads shall transmit telemetry to the container for five minutes after release.
11. The container shall transmit all the telemetry to the ground station until it lands.
12. The recovery crew shall identify and collect the payloads and the container from the surrounding undergrowth.

Mission Summary (3/3)

Bonus Objective

13 A video camera shall be integrated into the container pointing downwards that captures the release and descent of both the science payloads.

14 The video should be in color with a minimum resolution of 640x480 pixels and a frame rate of 30 FPS.

15 The video shall be spin stabilized with the view not rotating more than +/- 30 degrees.

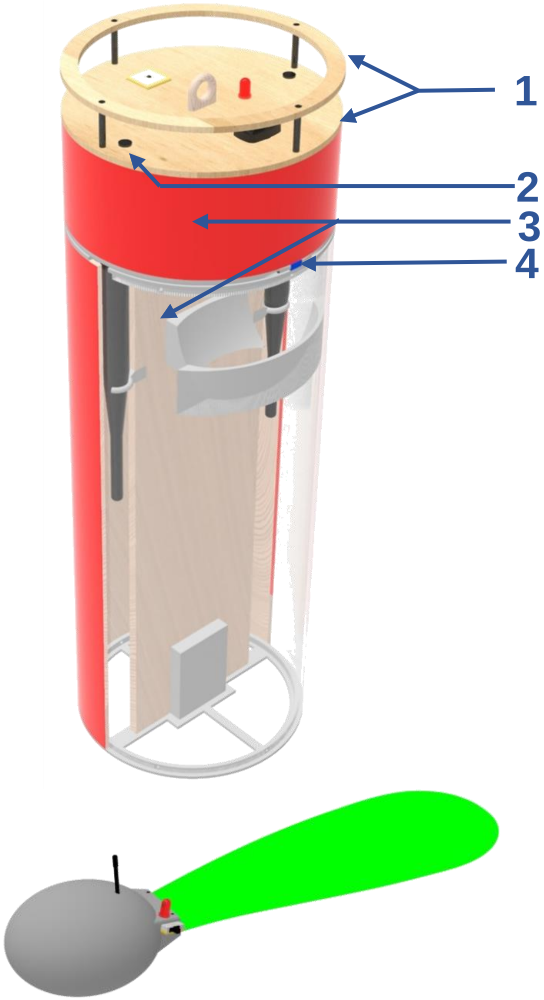
External Objectives

16 To gain an international standing, repute and experience from the competition and gather funding for making the project

17 To build an environment of friendliness and understanding and instill motivation among team members during this pandemic

18 To apply knowledge learnt from the course curriculum and understanding the functioning of a satellite

Summary of Changes Since PDR



CONTAINER

1	The material of the parachute ring and top plate was changed to Birch Plywood
2	The pin-locking mechanism of the electronics compartment door has been modified
3	The halves of the electronics compartment and the partition were manufactured from Balsa Wood
4	Hinges of the container doors have been modified

PAYLOAD

No modifications were made to the payload since PDR

No changes were made in the CanSat electronics

System Requirement Summary (1/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR1	Total mass of the CanSat (science payloads and container) shall be 600 grams +/- 10 grams.	Req	Very High	✓	✓	✓	
#CR2	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.	Req	Very High	✓	✓	✓	
#CR3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	Req	Very High	✓	✓	✓	✓
#CR4	The container shall be a fluorescent color; pink, red or orange.	Req	Very High	✓	✓		

System Requirement Summary (2/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR5	The container shall be solid and fully enclose the science payloads. Small holes to allow access to turn on the science payloads is allowed. The end of the container where the payload deploys may be open.	Req	Very High	✓		✓	
#CR6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Req	Very High	✓			✓
#CR7	The rocket airframe shall not be used as part of the CanSat operations.	Req	Very High	✓			✓
#CR8	The container 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.	Req	Very High	✓			✓

System Requirement Summary (3/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR9	The Parachutes shall be fluorescent Pink or Orange.	Req	Very High	√	√		
#CR10	The descent rate of the CanSat (container and science payload) shall be 15 meters/second +/- 5m/s.	Req	Very High	√		√	
#CR11	All structures shall be built to survive 15 Gs of launch acceleration.	Req	Very High			√	
#CR12	All structures shall be built to survive 30 Gs of shock.	Req	Very High			√	
#CR13	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Req	Very High		√	√	

System Requirement Summary (4/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR14	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Req	Very High	✓	✓		✓
#CR15	Mechanisms shall not use pyrotechnics or chemicals.	Req	Very High		✓		
#CR16	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.	Req	Very High		✓	✓	✓
#CR17	Both the container and payloads shall be labeled with team contact information including email address.	Req	Very High		✓		
#CR18	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Req	High		✓		

System Requirement Summary (5/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR19	XBee radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBee radios are also allowed.	Req	Very High		✓		
#CR20	XBee radios shall have their NETID/PANID set to their team number.	Req	Very High		✓		
#CR21	XBee radios shall not use broadcast mode.	Req	Very High		✓		
#CR22	The science payload shall descend spinning passively like a maple seed with no propulsion.	Req	Very High	✓	✓	✓	
#CR23	The science payload shall have a maximum descent rate of 20 m/s.	Req	Very High	✓		✓	
#CR24	The wing of the science payload shall be colored fluorescent orange, pink or green.	Req	Very High	✓	✓		

System Requirement Summary (6/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR25	The science payload shall measure altitude using an air pressure sensor.	Req	Very High	√		√	√
#CR26	The science payload shall measure air temperature.	Req	Very High	√		√	√
#CR27	The science payload shall measure rotation rate as it descends.	Req	Very High	√		√	√
#CR28	The science payload shall transmit all sensor data once per second.	Req	Very High	√		√	√
#CR29	The science payload telemetry shall be transmitted to the container only.	Req	Very High		√	√	√
#CR30	The science payload shall have their NETID/PANID set to their team number plus five. If team number is 1000, sensor payload NETID is 1005.	Req	Very High		√		

System Requirement Summary (7/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR31	The container shall include electronics to receive sensor payload telemetry.	Req	Very High	√		√	√
#CR32	The container shall include electronics and mechanisms to release the science payloads.	Req	Very High	√		√	√
#CR33	The container shall include a GPS sensor to track its position.	Req	Very High	√		√	√
#CR34	The container shall include a pressure sensor to measure altitude.	Req	Very High	√		√	√
#CR35	The container shall measure its battery voltage.	Req	Very High	√		√	√
#CR36	The container shall transmit its telemetry and the payload telemetry received once per second in the format described in the Telemetry Requirements section.	Req	Very High	√	√	√	

System Requirement Summary (8/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR37	The container shall stop transmitting telemetry when it lands.	Req	Very High		√	√	
#CR38	The container and science payloads must include an easily accessible power switch that can be accessed without disassembling the cansat and science payloads and in the stowed configuration.	Req	High		√		√
#CR39	The container must 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.	Req	High		√		√
#CR40	An audio beacon is required for the container. It may be powered after landing or operate continuously.	Req	Very High	√	√		
#CR41	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Req	Very High	√		√	

System Requirement Summary (9/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR42	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.	Req	Very High	✓	✓	✓	
#CR44	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Req	High		✓		
#CR45	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Req	Very High		✓		
#CR46	The Cansat must operate during the environmental tests laid out in Section 3.5.	Req	Very High		✓	✓	

System Requirement Summary (10/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR47	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Req	High		✓		
#CR48	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.	Req	Very High	✓		✓	
#CR49	The container must maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Req	Very High	✓		✓	✓
#CR50	The container shall have its time set to UTC time to within one second before launch.	Req	Very High		✓		

System Requirement Summary (11/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR51	The container 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.	Req	Very High	√		√	√
#CR52	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the container altitude.	Req	Very High	√		√	√
#CR53	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Req	Very High			√	√
#CR54	The ground station shall command the Cansat to start transmitting telemetry prior to launch.	Req	Very High		√		√

System Requirement Summary (12/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR55	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Req	Very High			√	√
#CR56	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	Req	Very High	√		√	√
#CR57	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	Req	Very High	√		√	√
#CR58	Each team shall develop their own ground station.	Req	Very High		√		

System Requirement Summary (13/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR59	All telemetry shall be displayed in real time during descent on the ground station.	Req	Very High	✓		✓	✓
#CR60	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Req	Very High		✓		
#CR61	Teams shall plot each telemetry data field in real time during flight.	Req	Very High	✓		✓	
#CR62	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBee radio and a hand-held antenna.	Req	Very High		✓		
#CR63	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.	Req	High		✓		

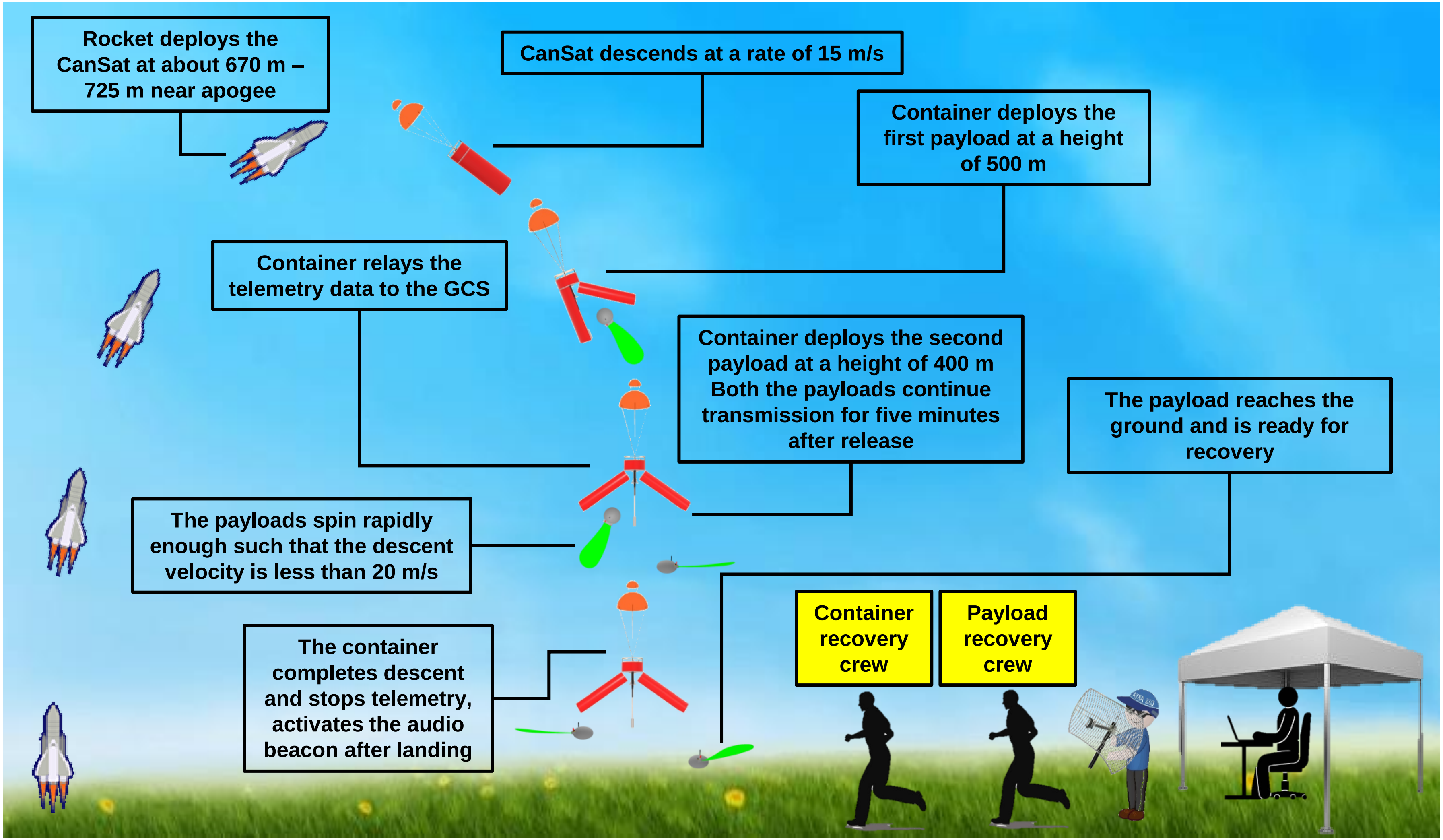
System Requirement Summary (14/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR64	The ground station software shall be able to command the container to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	Req	Very High			✓	✓
#CR65	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 container.	Req	Very High	✓		✓	✓
#CR66	The science payloads shall not transmit telemetry during the launch, and the container shall command the science payloads to begin telemetry transmission upon release from the container.	Req	Very High		✓		✓

System Requirement Summary (15/15)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#BNS1	A video camera shall be integrated into the container and point toward the ground. The camera shall capture the release of both science payloads and capture the descent of the science payloads. The video shall be spin stabilized with the view not rotating more than +/- 30 degrees. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the container is retrieved.	Bonus Requirement	Medium	✓		✓	✓

System Concept of Operations (CONOPS) (1/4)



System Concept of Operations (CONOPS) (2/4)

Pre-launch

- Arrival and team briefing
- Establishment of the Ground Control Station
- Review compatibility of CanSat with rocket
- Performing final check of CanSat and its components
- Submission of CanSat for launch

Launch

- Rocket launch and deployment of CanSat
- Descent of container and deployment of payloads
- Obtaining air pressure, temperature and rpm from the payloads and relaying it to the ground station via the container.
- Generation of the .csv file using GCS software

Post-launch

- Recovery of the CanSat
- Inspection of the payload for any damage
- Submission of received data to the judges
- Analyzing the data received
- Preparation for PFR
- Presentation of PFR to the judges

System Concept of Operations (CONOPS) (3/4)

Launch Day Activities

1 ARRIVAL
- Assembly of CanSat
- Setting up antenna and GCS
- Checking whether CanSat has any damage

2 PLACEMENT
- Power up the CanSat
- Check the communication between the CanSat and the GCS
- Place the CanSat in Rocket Payload section

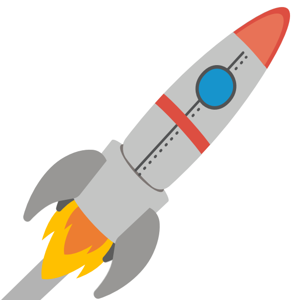
3 LAUNCH
- Rocket takes off
- CanSat is deployed at apogee.
- It starts to descend with a velocity of 15m/s with the help of parachute

4 SEPARATION
- The first and the second payloads are released at 500m and 400m respectively. Both the payloads then descend in autorotating motion with speed not more than 20m/s.

5 OBTAIN TELEMETRY
- During descent the payloads collect and transmit the altitude, temperature, rotation rate to the container for five minutes after their release and the container transmits all the telemetry to the ground station until it lands.

6 RECOVERY
- The payloads finish descent and stop telemetry.
- The Container lands with parachute, stops the telemetry and initiates audio beacon.
- All systems recovered by Recovery Crew.

7 DATA ANALYSIS
- Analyze the data retrieved from descent control devices.
- Submit requested data to jury.
- Getting ready for PFR.



System Concept of Operations (CONOPS) (4/4)

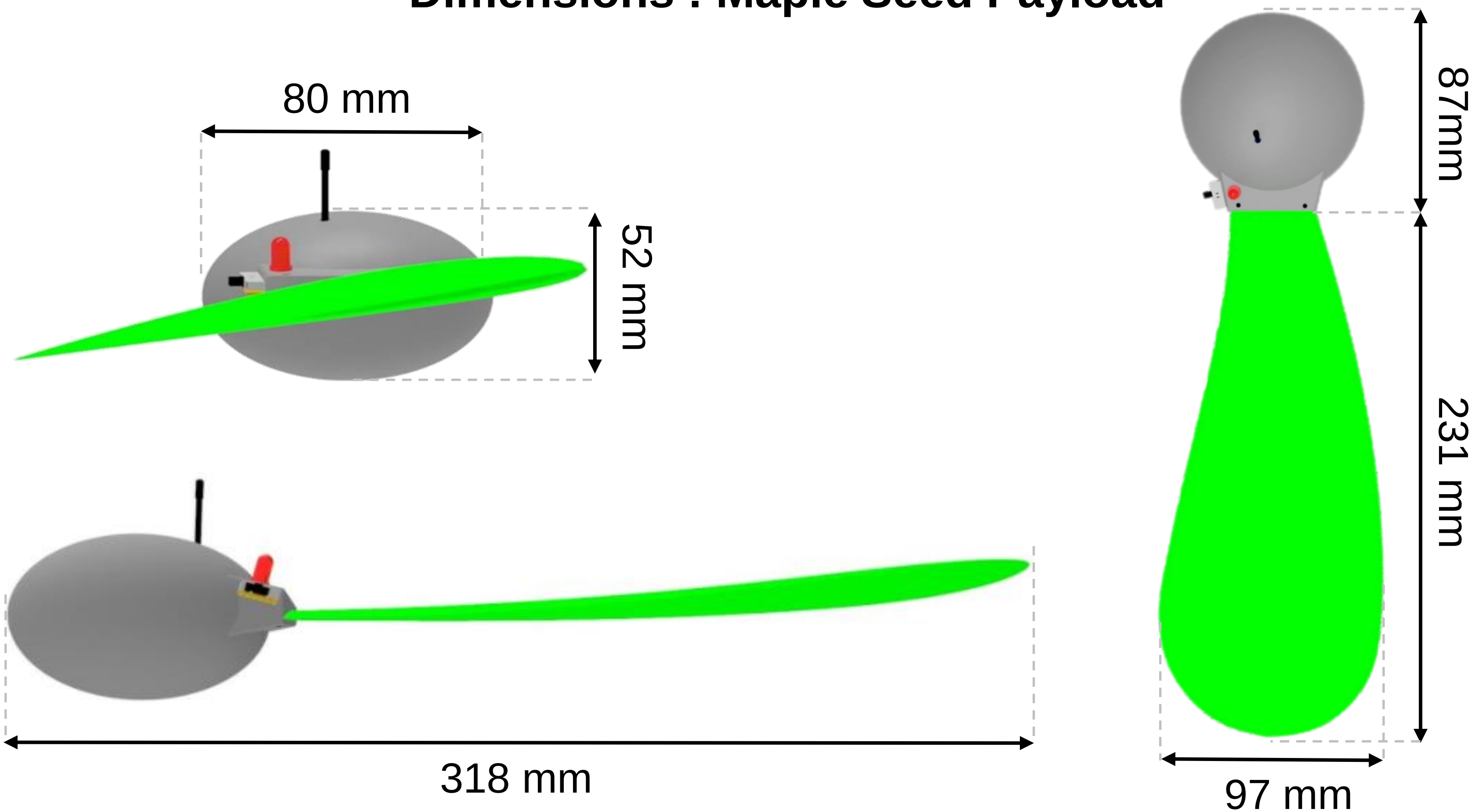
Satvik Deshmukh
Mission Control Officer

CanSat Crew
- Vatsal Tapiawala
- Greeshma Gala
- Krittika Roy

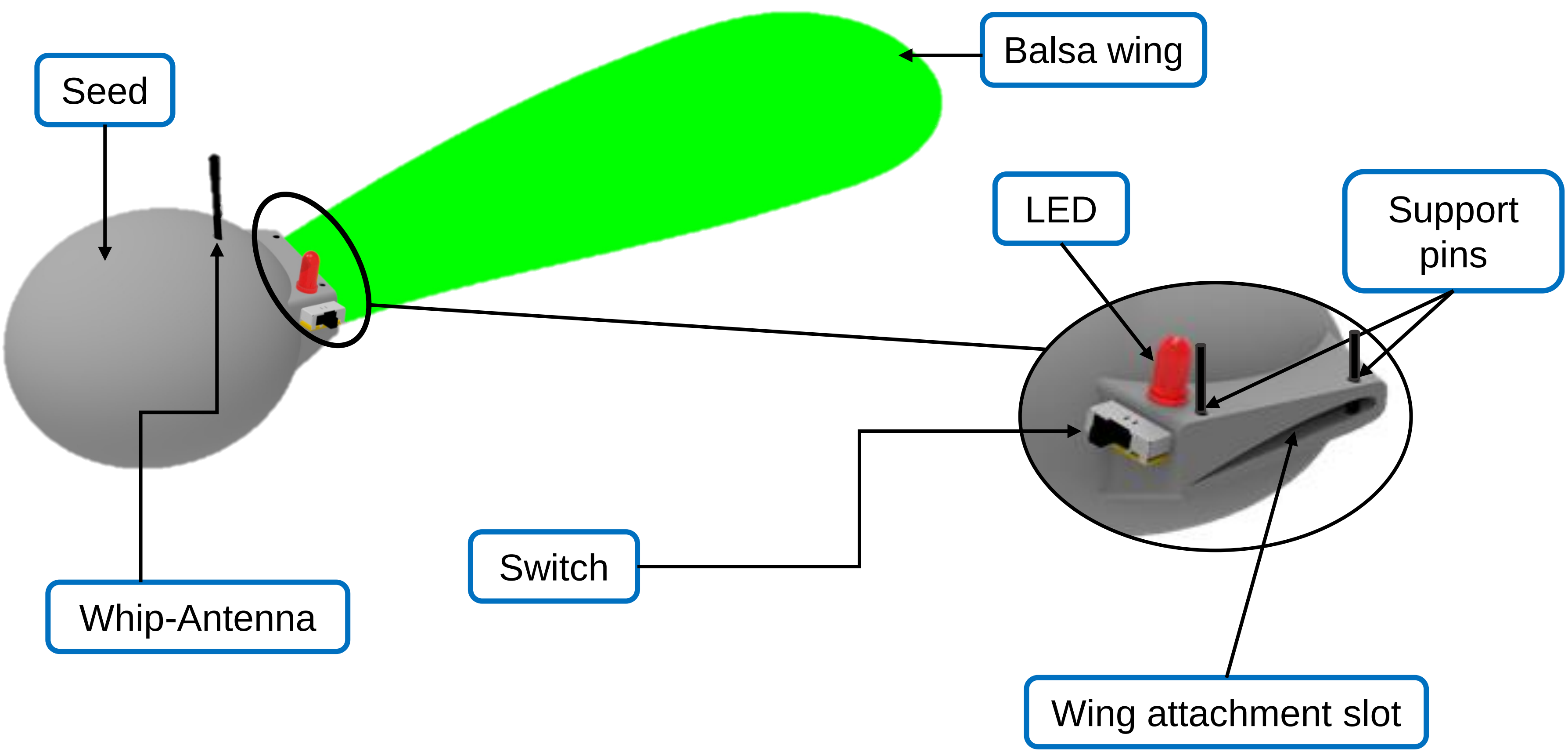
Ground Station Crew
- Nisarg Shah
- Harshil Shah
- Khyati Morparia

CanSat Recovery
- Harshil Suvarna
- Shweta Chavan
- Anushka Kanabar

Dimensions : Maple Seed Payload

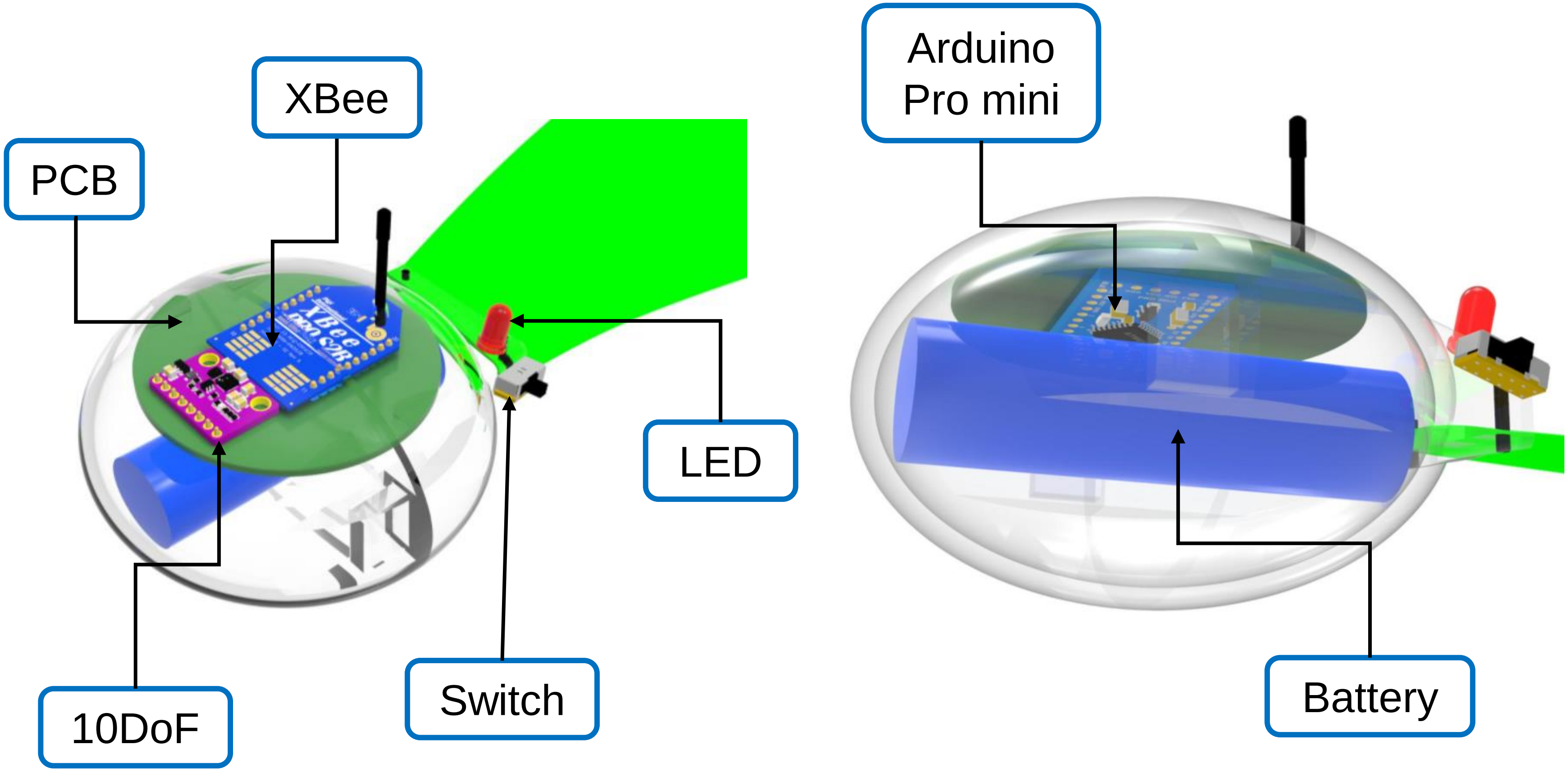


Placement of Major Components : Payload



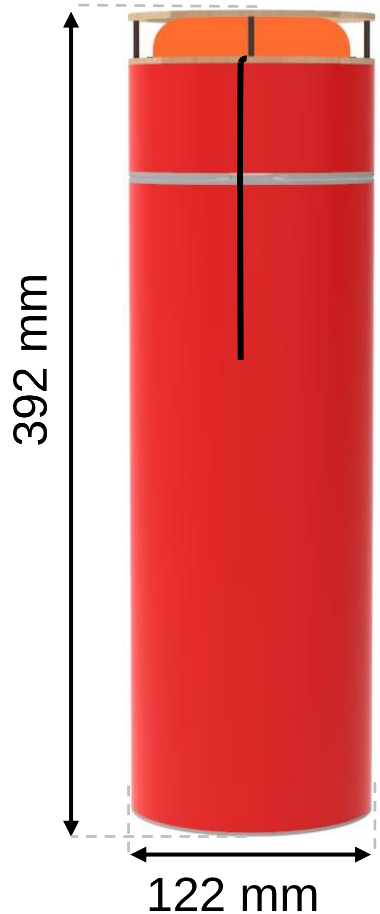
Payload Physical Layout (3/9)

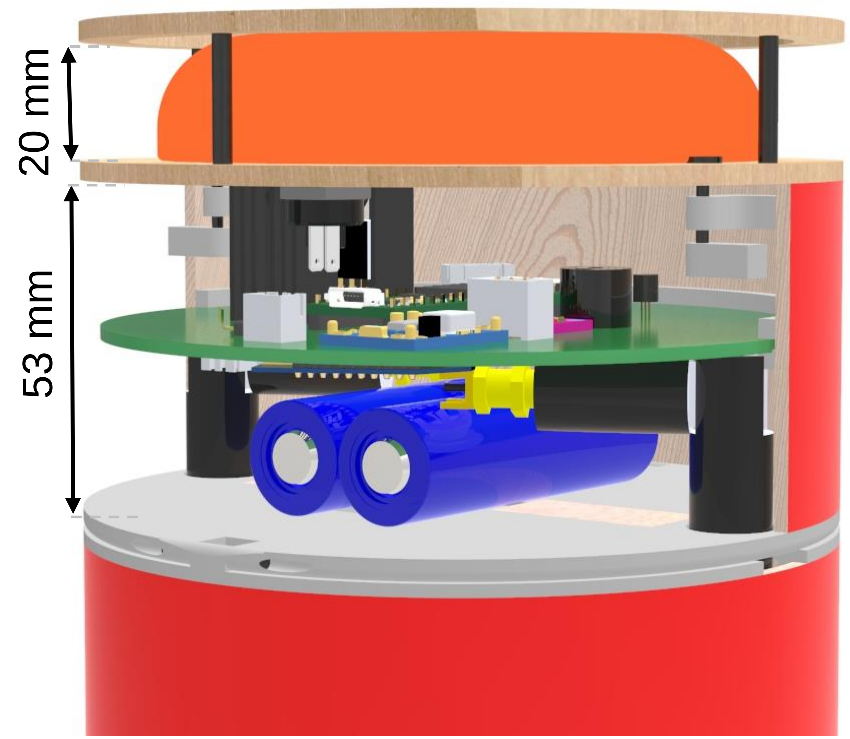
Placement of Major Components (Electronics): Payload



Payload Physical Layout (4/9)

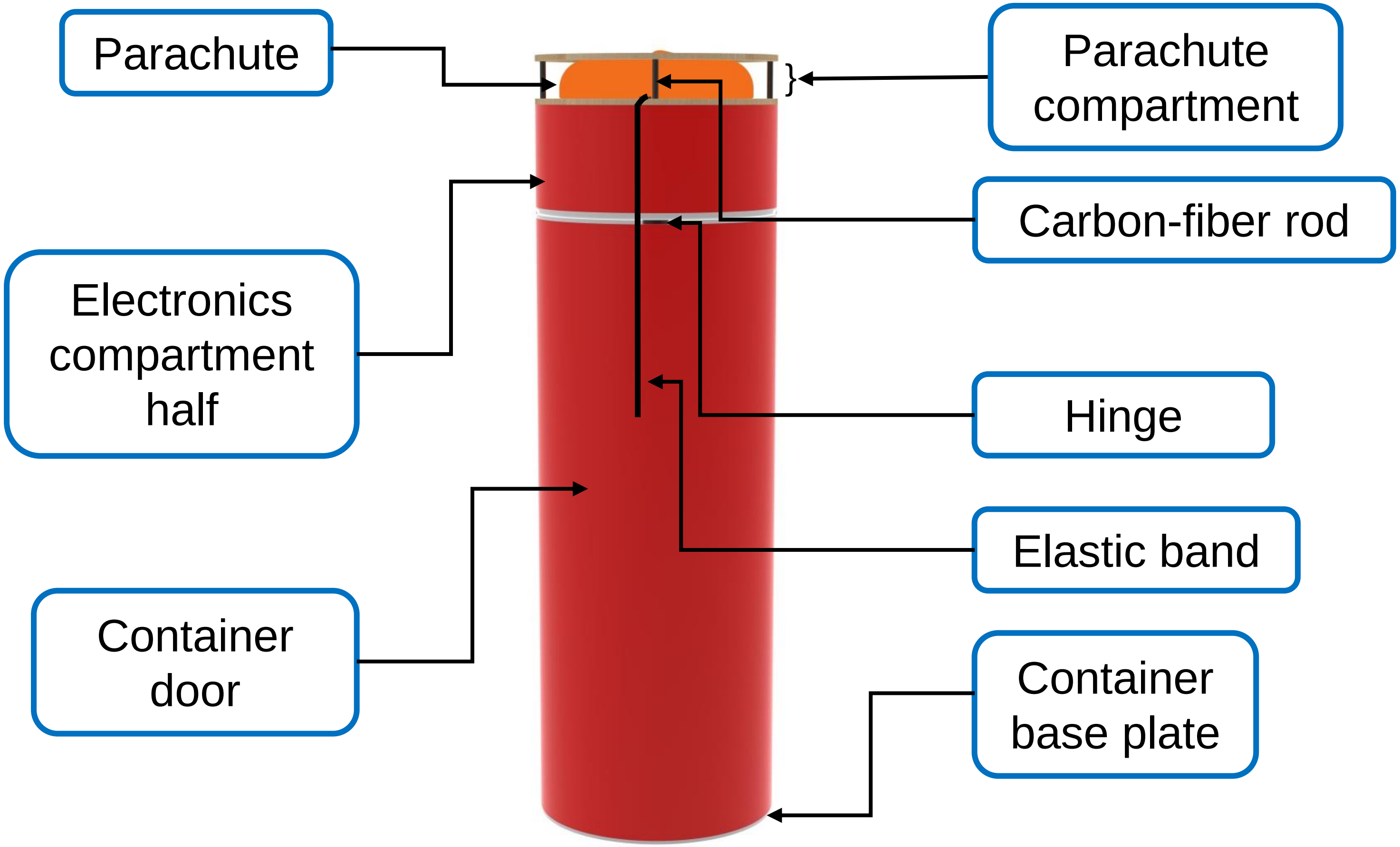
Dimensions : Container



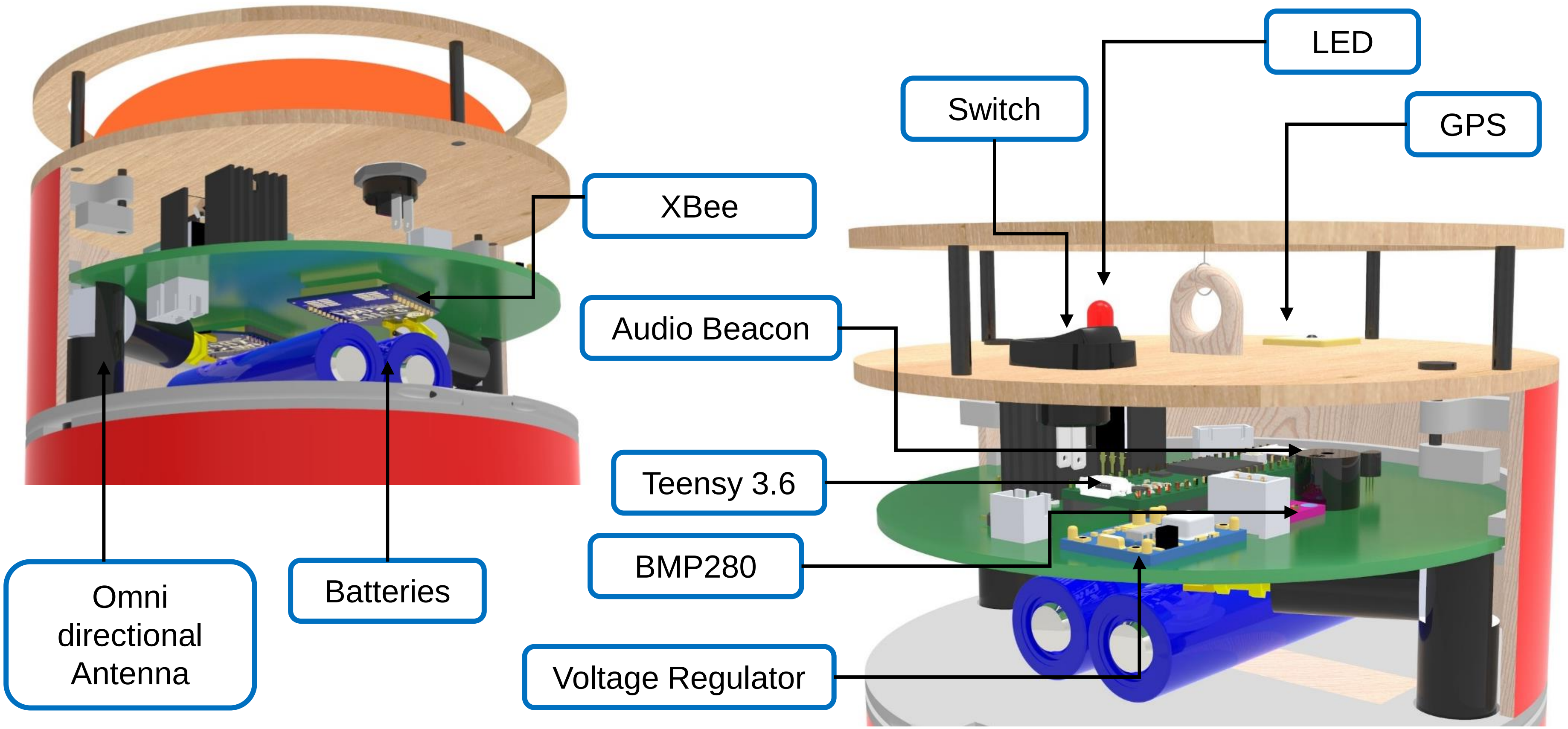


Payload Physical Layout (5/9)

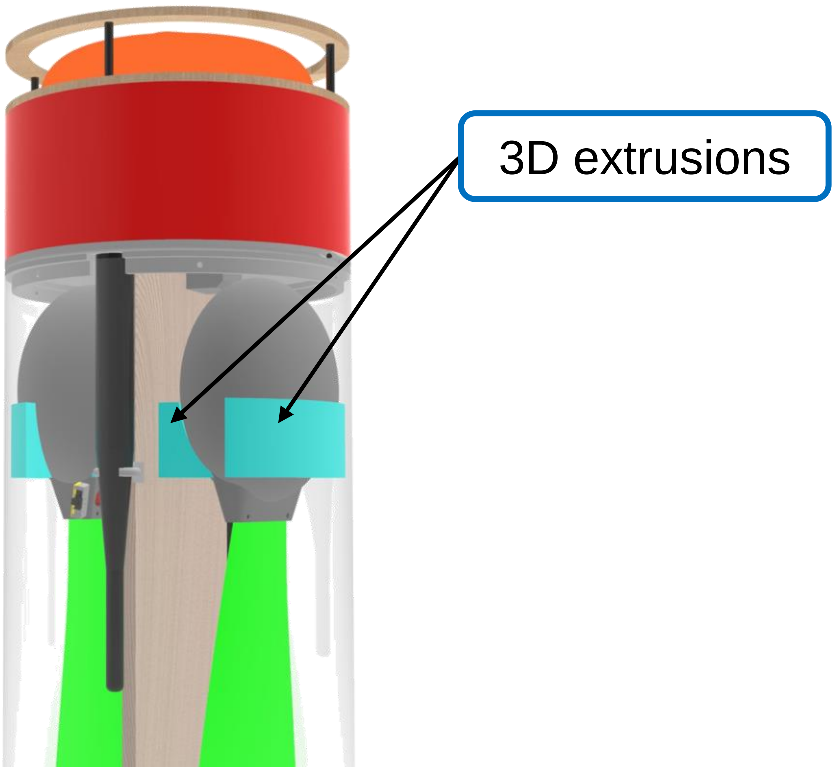
Placement of Major Components : Container



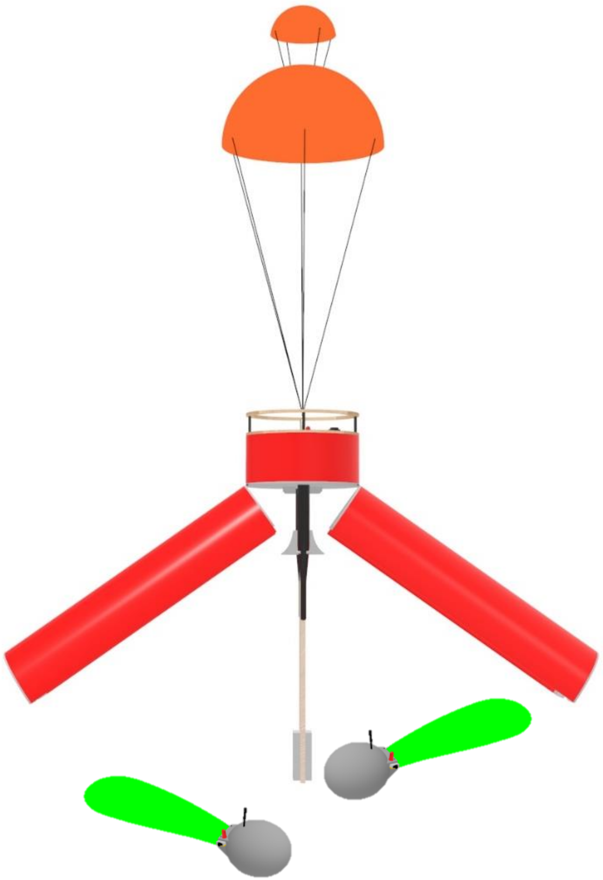
Placement of Major Components (Electronics): Container



CanSat Configuration



Launch(Stowed) configuration



Deployed Configuration

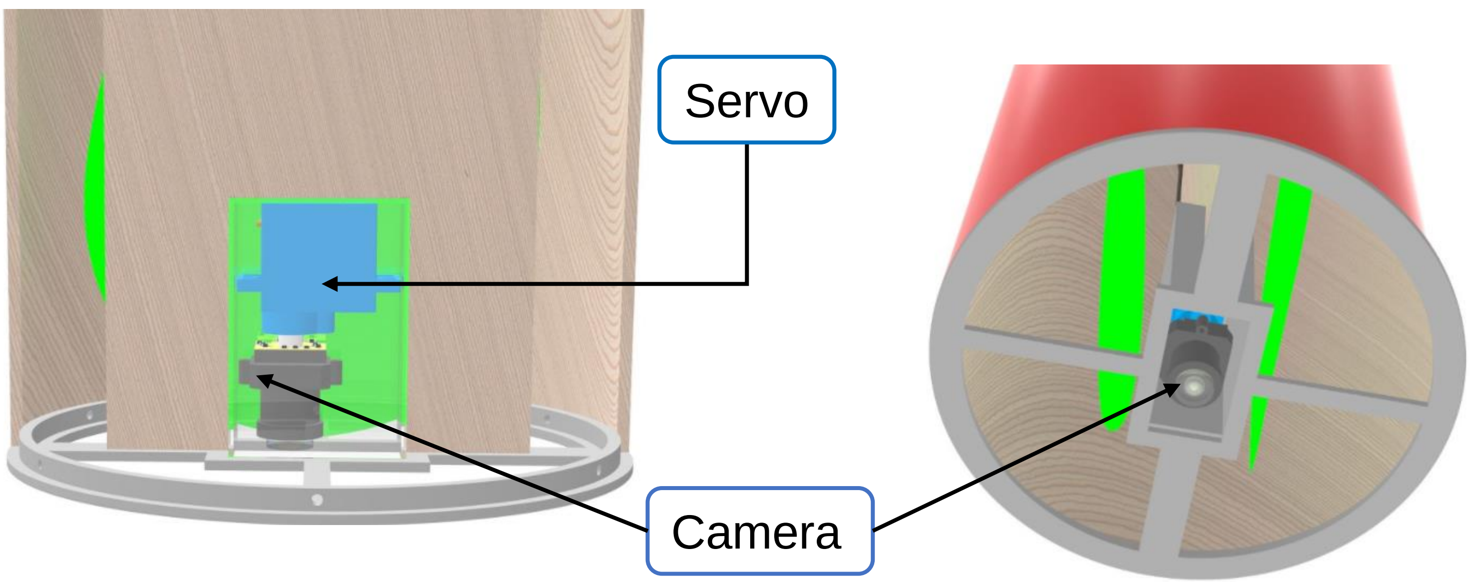
Payload Physical Layout (8/9)

Actual Images of Payload and Container

Payload

Container

Camera Setup



The camera is spin stabilized by a servo, with the view of ±30º. A wide-angle camera is used to capture the release and descent of the science payloads.

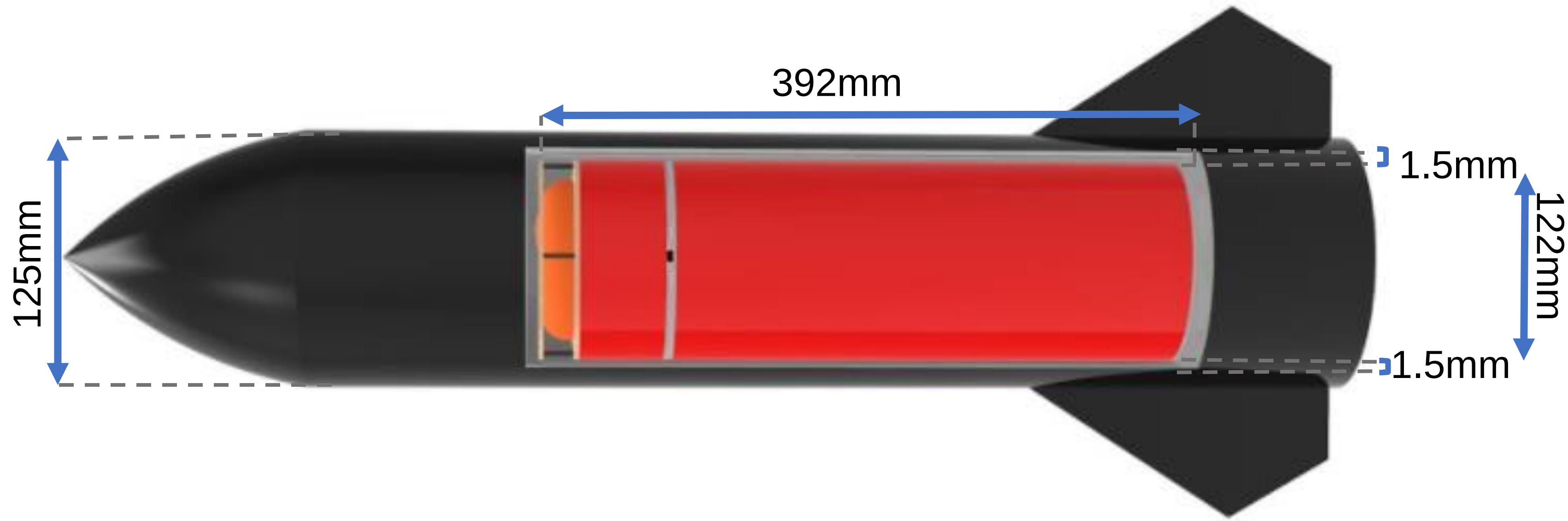
Launch Vehicle Compatibility (1/2)

Launch Configuration

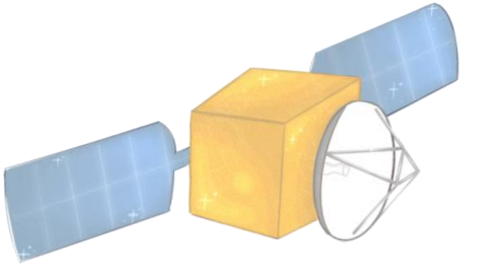
Title	Parameter	Dimensions in Mission Guide (mm)	Actual CanSat Dimension (mm)	Clearance (mm)
Rocket payload section	Height	400	392	8
	Diameter	125	122	3
Payload (x2)	Length of seed	-	87	-
	Wing span	-	231	-
Parachute dimension after separation	Diameter	-	170	-

Launch Vehicle Compatibility (2/2)

- The CanSat has been designed to release through the rocket nose smoothly to reduce possibility of deployment failure.
- There are **no sharp protrusions** on the CanSat.
- No lasers are used.

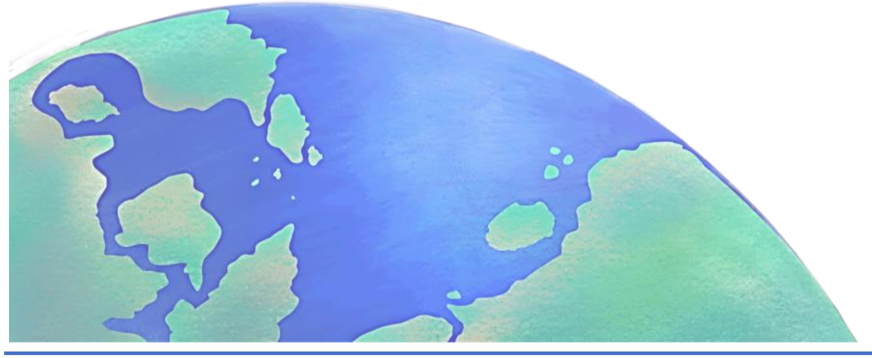


These dimensions enable smooth separation of the container from the rocket.



Sensor Subsystem Design

Presenter’s Name: Shweta Chavan



Sensor Subsystem Overview (1/2)

Payload Sensors

Component Name	Model	Function of Sensor
Air Pressure Sensor	**BMP280**	**Measurement of air pressure**
Air Temperature Sensor	**BMP280**	**Measurement of air temperature**
Rotation Sensor	**MPU9250**	**Measurement of number of rotations per minute**

Sensor Subsystem Overview (2/2)

Container Sensors		
Component Name	**Model**	**Function of Sensor**
Air Pressure Sensor	BMP280	Measurement of air pressure
GPS Sensor	Adafruit Ultimate GPS	Determination of location (latitude, longitude, altitude), no. of satellites and time
Battery Voltage Sensor	Teensy 3.6’s Analog Input Pin + Voltage Divider	Measurement of container battery voltage
Bonus Camera	Adafruit Mini Spy Camera	Recording video of payloads during their release and descent

Sensor Changes Since PDR

No sensor changes have been made to the Sensor Subsystem Design since the PDR.

Sensor Subsystem Requirements (1/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR13	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Req	Very High		√	√	
#CR19	XBee radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBee radios are also allowed.	Req	Very High		√		
#CR20	XBee radios shall have their NETID/PANID set to their team number.	Req	Very High		√		
#CR21	XBee radios shall not use broadcast mode.	Req	Very High		√		
#CR25	The science payload shall measure altitude using an air pressure sensor.	Req	Very High	√		√	√
#CR26	The science payload shall measure air temperature.	Req	Very High	√		√	√

Sensor Subsystem Requirements (2/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR27	The science payload shall measure rotation rate as it descends.	Req	Very High	√		√	√
#CR28	The science payload shall transmit all sensor data once per second.	Req	Very High	√		√	√
#CR29	The science payload telemetry shall be transmitted to the container only.	Req	Very High		√	√	√
#CR31	The container shall include electronics to receive sensor payload telemetry.	Req	Very High	√		√	√
#CR32	The container shall include electronics and mechanisms to release the science payloads.	Req	Very High	√		√	√

Sensor Subsystem Requirements (3/4)

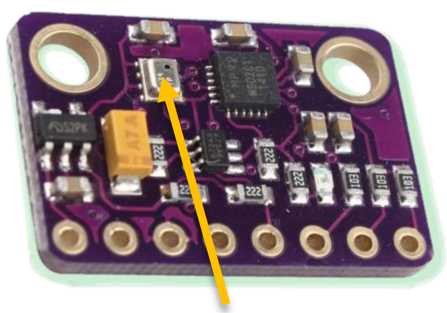
Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR40	An audio beacon is required for the container. It may be powered after landing or operate continuously.	Req	Very High	√	√		
#CR41	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Req	Very High	√		√	
#CR50	The container shall have its time set to UTC time to within one second before launch.	Req	Very High		√		

Sensor Subsystem Requirements (4/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#BNS1	A video camera shall be integrated into the container and point toward the ground. The camera shall capture the release of both science payloads and capture the descent of the science payloads. The video shall be spin stabilized with the view not rotating more than +/- 30 degrees. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the container is retrieved.	Bonus Requirement	Medium	✓		✓	✓

Payload Air Pressure Sensor Summary (1/2)

Component Name	Interfaces	Supply Voltage (V)	Current Consumption (µA)	Pressure Range (hPa)	Sensitivity/ Accuracy (hPa)	Dimension (mm)	Mass (gm)	Cost (₹)
BMP280	SPI, I2C	3.3	2.7	300 – 1100	±1.0	2.0 x 2.5 x 0.95	0.048	225.00



BMP280

FORMULA:

$$P(Pa) = P_0 e^{\frac{-mgh}{kT}}$$

Selected Sensor : BMP280

- Low current consumption
- High accuracy
- Compact in size
- Shared I2C Bus - lesser wiring
- Included on the 10-DoF IMU Board (GY-91)
- Measured pressure is relative to the mean sea level pressure
- The altitude is measured using pressure with the help of the formula alongside

Payload Air Pressure Sensor Summary (2/2)

DATA PROCESSING :

```
#include <Wire.h>
#include <Adafruit_BMP280.h>
Adafruit_BMP280 bmp; // I2C
void setup() {
  Serial.begin(9600);
  bmp.setSampling(Adafruit_BMP280::MODE_NORMAL,
                  Adafruit_BMP280::SAMPLING_X2,
                  Adafruit_BMP280::SAMPLING_X16,
                  Adafruit_BMP280::FILTER_X16,
                  Adafruit_BMP280::STANDBY_MS_500);
}
void loop() {
    Serial.print(F("Temperature = "));
    Serial.print(bmp.readTemperature());
    Serial.println(" *C");

    Serial.print(F("Pressure = "));
    Serial.print(bmp.readPressure());
    Serial.println(" Pa");

    Serial.print(F("Approx altitude = "));
    /* Adjusted to local forecast! */
    Serial.print(bmp.readAltitude(1013.25));
    Serial.println(" m");
}
```

DATA FORMAT :

Pressure: **XXXXXX.XX Pa (float)**
Altitude: **XXX.XX m (float)**

OUTPUT :

```
Temperature = 30.81 *C
Pressure = 100720.71 Pa
Approx altitude = 50.44 m

Temperature = 30.81 *C
Pressure = 100720.71 Pa
Approx altitude = 50.44 m

Temperature = 30.81 *C
Pressure = 100720.35 Pa
Approx altitude = 50.46 m

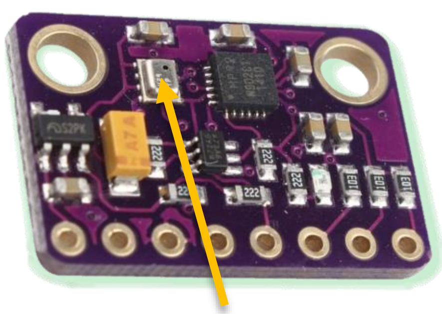
Temperature = 30.82 *C
Pressure = 100720.55 Pa
Approx altitude = 50.45 m

Temperature = 30.82 *C
Pressure = 100720.53 Pa
Approx altitude = 50.45 m
```

DATA PROCESSING LIBRARY : `#include <Adafruit_BMP280.h>`

Payload Air Temperature Sensor Summary (1/2)

Component Name	Interfaces	Supply Voltage (V)	Current Consumption (µA)	Temperature Range (°C)	Sensitivity/ Accuracy (hPa)	Dimension (mm)	Mass (gm)	Cost (₹)
BMP280	SPI, I2C	3.3	2.7	-40 to +85	±1.0	2.0 x 2.5 x 0.95	0.048	225.00



BMP280

FORMULA:

$$T(°C) = -\frac{mgh}{k\ ln\left(\frac{P}{P_0}\right)}$$

Selected Sensor : BMP280

- Low current consumption
- High accuracy
- Compact in size
- Shared I2C Bus - lesser wiring
- Included on the 10-DoF IMU Board (GY-91)
- Measured pressure is relative to the mean sea level pressure
- The temperature is measured using pressure with the help of the formula alongside

Payload Air Temperature Sensor Summary (2/2)

DATA PROCESSING :

```
#include <Wire.h>
#include <Adafruit_BMP280.h>
Adafruit_BMP280 bmp; // I2C
void setup() {
  Serial.begin(9600);
  bmp.setSampling(Adafruit_BMP280::MODE_NORMAL,
                  Adafruit_BMP280::SAMPLING_X2,
                  Adafruit_BMP280::SAMPLING_X16,
                  Adafruit_BMP280::FILTER_X16,
                  Adafruit_BMP280::STANDBY_MS_500);
}
void loop() {
    Serial.print(F("Temperature = "));
    Serial.print(bmp.readTemperature());
    Serial.println(" *C");

    Serial.print(F("Pressure = "));
    Serial.print(bmp.readPressure());
    Serial.println(" Pa");

    Serial.print(F("Approx altitude = "));
    /* Adjusted to local forecast! */
    Serial.print(bmp.readAltitude(1013.25));
    Serial.println(" m");
}
```

DATA FORMAT :

Temperature: **XX.XX °C (float)**

OUTPUT :

```
Temperature = 30.81 *C
Pressure = 100720.71 Pa
Approx altitude = 50.44 m

Temperature = 30.81 *C
Pressure = 100720.71 Pa
Approx altitude = 50.44 m

Temperature = 30.81 *C
Pressure = 100720.35 Pa
Approx altitude = 50.46 m

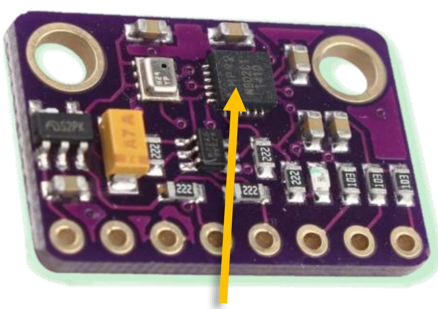
Temperature = 30.82 *C
Pressure = 100720.55 Pa
Approx altitude = 50.45 m

Temperature = 30.82 *C
Pressure = 100720.53 Pa
Approx altitude = 50.45 m
```

DATA PROCESSING LIBRARY : `#include <Adafruit_BMP280.h>`

Payload Rotation Sensor Summary (1/2)

Component Name	Interfaces	Operating Voltage (V)	Current consumption (mA)	Range (RPM)	Dimension (mm)	Mass (gm)	Price (Rs)
MPU9250	SPI, I2C	3.3	3.5	-300 to 300	3x3x1	0.11	439.00



MPU9250

FORMULA:

$$\text{RPM} = \frac{rad/sec}{2\pi} \cdot 60$$

Selected Sensor : MPU9250

- Best suited for RPM calculations
- Provides a high 16 bit resolution and has 9-DoF
- Permissible current consumption
- Shared I2C Bus - lesser wiring
- Compact in size
- Has a **sensitivity/accuracy** of **0.01 RPM**
- Included on the 10-DoF IMU Board (GY-91)
- The sensor calculates RPM with respect to the Z-plane and a relative zero position

Payload Rotation Sensor Summary (2/2)

DATA PROCESSING :

```
#include "MPU9250.h"
MPU9250 IMU(Wire,0x68);
int status;
float RPM,z;

void setup() {
 Serial.begin(115200);
}

void loop()
{
  IMU.readSensor();
  z = IMU.getGyroZ_rads();
  RPM = z*9.5493;
  // 1 rad per sec = 9.5493 RPM
  Serial.print("RPM = ");
  Serial.println(abs(RPM));
}
```

DATA FORMAT :

Rotations per minute (RPM):
XX.XX (float)

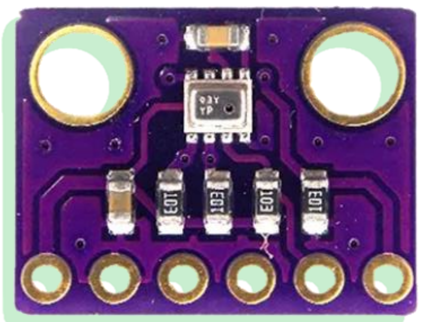
OUTPUT :

```
RPM = 3.78
RPM = 6.04
RPM = 7.79
RPM = 37.44
RPM = 41.63
RPM = 42.57
RPM = 47.28
RPM = 31.34
RPM = 32.25
RPM = 24.98
```

DATA PROCESSING LIBRARY : `#include "MPU9250.h"`

Container Air Pressure Sensor Summary (1/2)

Component Name	Interfaces	Supply Voltage (V)	Current Consumption (µA)	Pressure Range (hPa)	Sensitivity/ Accuracy (hPa)	Dimension (mm)	Mass (gm)	Cost (₹)
BMP280	SPI, I2C	3.3	2.7	300 – 1100	±1.0	2.0 x 2.5 x 0.95	0.048	225.00



BMP280

FORMULA:

$$P(Pa) = P_0 e^{\frac{-mgh}{kT}}$$

Selected Sensor : BMP280

- Low current consumption
- High accuracy
- Compact in size
- Shared I2C Bus - lesser wiring
- Easily available
- Measured pressure is relative to the mean sea level pressure
- The altitude is measured using the pressure with the help of the formula alongside

Container Air Pressure Sensor Summary (2/2)

DATA PROCESSING :

```
#include <Wire.h>
#include <Adafruit_BMP280.h>
Adafruit_BMP280 bmp; // I2C
void setup() {
  Serial.begin(9600);
  bmp.setSampling(Adafruit_BMP280::MODE_NORMAL,
                  Adafruit_BMP280::SAMPLING_X2,
                  Adafruit_BMP280::SAMPLING_X16,
                  Adafruit_BMP280::FILTER_X16,
                  Adafruit_BMP280::STANDBY_MS_500);
}
void loop() {
    Serial.print(F("Temperature = "));
    Serial.print(bmp.readTemperature());
    Serial.println(" *C");

    Serial.print(F("Pressure = "));
    Serial.print(bmp.readPressure());
    Serial.println(" Pa");

    Serial.print(F("Approx altitude = "));
    /* Adjusted to local forecast! */
    Serial.print(bmp.readAltitude(1013.25));
    Serial.println(" m");
}
```

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Temperature = 30.82 *C
Pressure = 100720.55 Pa
Approx altitude = 50.45 m

Temperature = 30.82 *C
Pressure = 100720.53 Pa
Approx altitude = 50.45 m
```

DATA PROCESSING LIBRARY : `#include <Adafruit_BMP280.h>`

Container GPS Sensor Summary (1/2)

Component Name	Interfaces	Operating Voltage (V)	Current (mA)	Sensitivity (dBm)	Position Accuracy Range (m)	Dimension (mm)	Mass (gm)	Cost (₹)
Adafruit Ultimate GPS	UART	5	25	-165	1.5 to 1.8	25.5 x 35 x 6.5	8.5	2900.00

Adafruit Ultimate GPS

Selected Sensor : Adafruit Ultimate GPS

- High positional accuracy range
- Uses NMEA0183 GGA protocol to satisfy mission requirements
- Low current consumption
- Accurate time and location coordinates
- Patch antenna aids quick fixing with satellites
- Range of Latitude 0° to 90°
- Range of Longitude 0° to 180°

NMEA 0183 GGA FORMAT

$GPGGA,172814.0,3723.46587704,N,12202.26957864,W,2,6,1.2,18.893,M,-25.669,M,2.0,0031*4F

Container GPS Sensor Summary (2/2)

DATA PROCESSING :

```
#include <Adafruit_GPS.h>
#define GPSSerial Serial1
Adafruit_GPS GPS(&GPSSerial);
#define GPSECHO false
uint32_t timer = millis();

void setup()
{
  Serial.begin(9600);
}

void loop()
{
  char c = GPS.read();
  if (millis() - timer > 1000)
  {
    timer = millis(); // reset the timer
    Serial.print("\nTime: ");
    if (GPS.hour < 10) { Serial.print('0'); }
    Serial.print(GPS.hour, DEC);
    Serial.print(':');
    if (GPS.minute < 10) { Serial.print('0'); }
    Serial.print(GPS.minute, DEC);
    Serial.print(':');
    if (GPS.seconds < 10) { Serial.print('0'); }
    Serial.print(GPS.seconds, DEC);
    Serial.print('.');
    if (GPS.milliseconds < 10) { Serial.print("00"); }
    else if (GPS.milliseconds > 9 && GPS.milliseconds < 100) {Serial.print("0");}
    Serial.println(GPS.milliseconds);

    if (GPS.fix)
    {
      Serial.print("Location: ");
      Serial.print(GPS.latitude, 4); Serial.print(GPS.lat); Serial.print(", ");
      Serial.print(GPS.longitude, 4); Serial.println(GPS.lon);
      Serial.print("Altitude: "); Serial.println(GPS.altitude);
      Serial.print("Satellites: "); Serial.println((int)GPS.satellites);
}}}
```

DATA FORMAT :

Location: **XXXX.XXXX (float)**
No. of Satellites: **X (integer)**

OUTPUT :

```
Time: 08:52:36.39200
Location: 1912.0175N, 7251.4263E
Altitude: 79.10
Satellites: 5
$GPGGA,085237.000,1912.0174,N,07251.4264,E,2,05,1.11,79.1,M,-62.7,M,0000,0000*7D

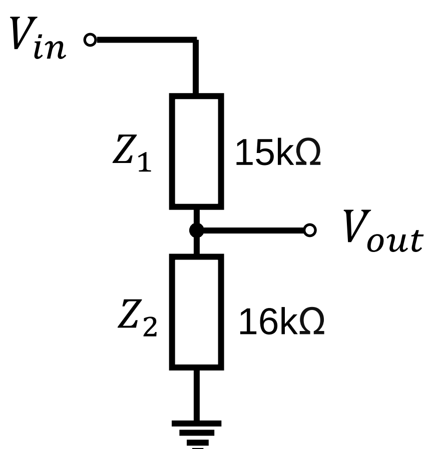
$GPRMC,085237.000,A,1912.0174,N,07251.4264,E,0.29,207.38,251020,,,D*6D
```

The coordinates obtained from our GPS which are in DMM format comply with the coordinates obtained from Google Earth which are in DMS format.

DATA PROCESSING LIBRARY : `#include <Adafruit_GPS.h>`

Container Voltage Sensor Summary (1/2)

Component Name	Interfaces	Operating Voltage Range (V)	Operating Current (μA)	Rate of Error (%)	Mass (gm)	Cost (₹)
Teensy 3.6's Analog Input Pin + Voltage Divider	**Analog**	**0 to 7.4**	**Negligible**	**0.001**	**<0.5**	**<10.00**



FORMULA : $V_{out} = V_{in}\left(\frac{z_2}{z_1 + z_2}\right)$

Selected Sensor: Teensy 3.6's Analog Input Pin + Voltage Divider

- Simple construction (only 2 resistors) and efficient use of on-board components based on Ohm's Law
- Has a **sensitivity** of **0.1V**
- Large and adjustable operating range
- Low error rate thus assuring greater accuracy
- The use of common resistors as a voltage divider promotes cost and space efficiency

Container Voltage Sensor Summary (2/2)

DATA PROCESSING :

```
int sum = 0;                    // sum of samples taken
unsigned char sample_count = 0; // current sample number
float voltage = 0.0;            // calculated voltage

void setup()
{
    Serial.begin(9600);
}

void loop()
{
    while (sample_count < 10) {
        sum += analogRead(16);
        sample_count++;
    }
    voltage = ((float)sum/(float)NUM_SAMPLES * 3.3)/1024.0;
    Serial.print("Volatge = ");
    Serial.print(voltage * 12.7);
    Serial.println (" V");
    sample_count = 0;
    sum = 0;
}
```

DATA FORMAT :

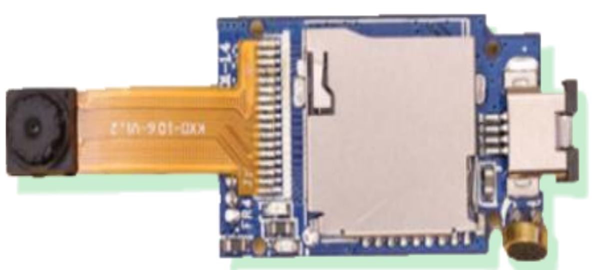
Voltage: **X.X V (float)**

OUTPUT :

```
Voltage= 7.3 V
Voltage= 7.3 V
Voltage= 7.3 V
Voltage= 7.3 V
Voltage= 7.3 V
Voltage= 7.3 V
Voltage= 7.3 V
Voltage= 7.3 V
Voltage= 7.3 V
Voltage= 7.3 V
```

Bonus Objective Camera Summary (1/2)

Component Name	Interfaces	Operating Voltage (V)	Operating Current (mA)	Video Resolution (pixels)	Frames Per Second (fps)	Dimension (mm)	Mass (gm)	Cost (₹)
Adafruit Mini Spy Camera	**Digital**	**5**	**110**	**640x480**	**30**	**28.5 x 17 x 4.2**	**2.8**	**920.00**



Adafruit Mini Spy Camera

Selected Camera : Adafruit Mini Spy Camera

- This camera includes capture rate of **30 FPS** and a **color video** with a minimum resolution of **640x480 pixels**.
- External switch is not required to activate the camera, it is digitally triggered
- The camera houses an internal SD card slot which stores the descent of both the payloads.
- The camera is spin stabilized with the help of a servo so that the view does not exceed +/- 30 degrees

Bonus Objective Camera Summary (2/2)

DATA PROCESSING :

```
int trig = 0;
int led = 1;

void setup()
{
  // initialize the digital pins as output.
  pinMode(led, OUTPUT);
  pinMode(trig, OUTPUT);

  digitalWrite(led, HIGH);
  digitalWrite(trig, HIGH);
}

void loop()
{
  digitalWrite(trig, LOW);
  digitalWrite(led, LOW);

  delay(1500);

  digitalWrite(trig, HIGH);
  digitalWrite(led, HIGH);
}
```

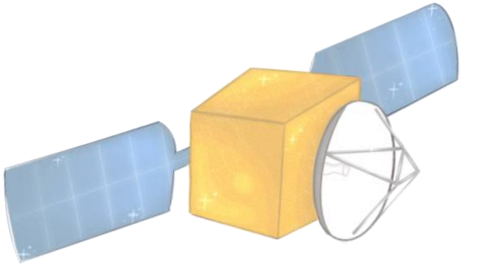
DATA FORMAT :

Digital

VIDEO FORMAT :

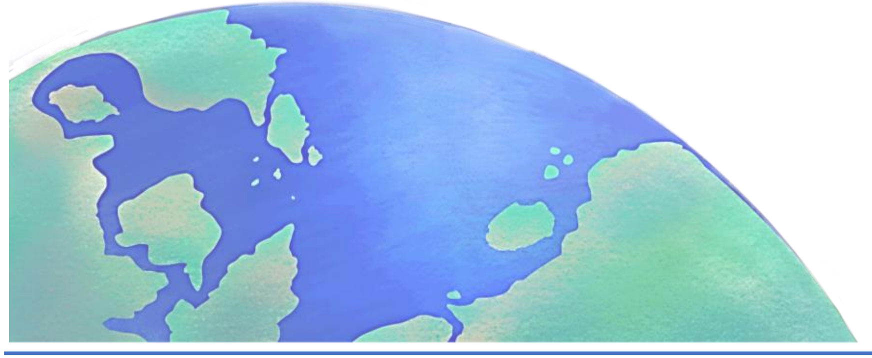
AVI (Audio Video Interleave)

This is a sample photo taken by our chosen Adafruit Mini Spy Camera



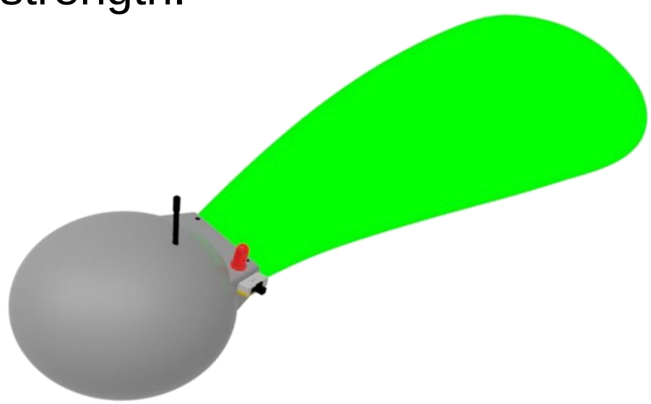
Descent Control Design

Presenter’s Name: Greeshma Gala

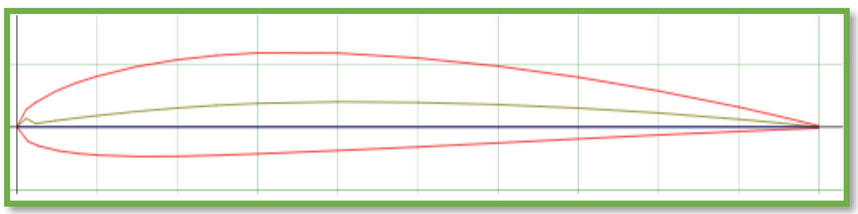


Payload Descent Control System

- The wing of the payload is made using the NACA 2408 airfoil, with root and tip having an angle of attack of 11° and 4° respectively resulting in a twist angle of 6º along with a dihedral angle of 8° to generate sufficient lift.
- The material used is **Balsa wood** which is coated with fluorescent green **Monokote**.
- The seed is **3D printed** using **PETG** to keep it lightweight while providing sufficient strength.



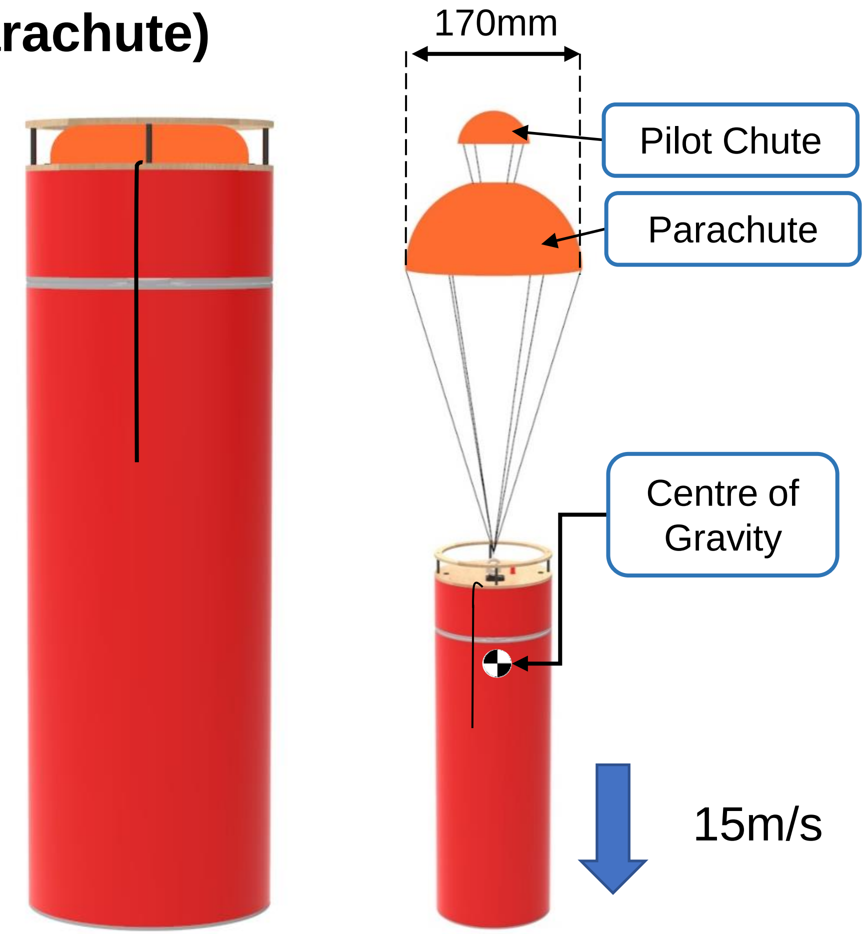
PAYLOAD



NACA 2408

Container Descent Control System (Parachute)

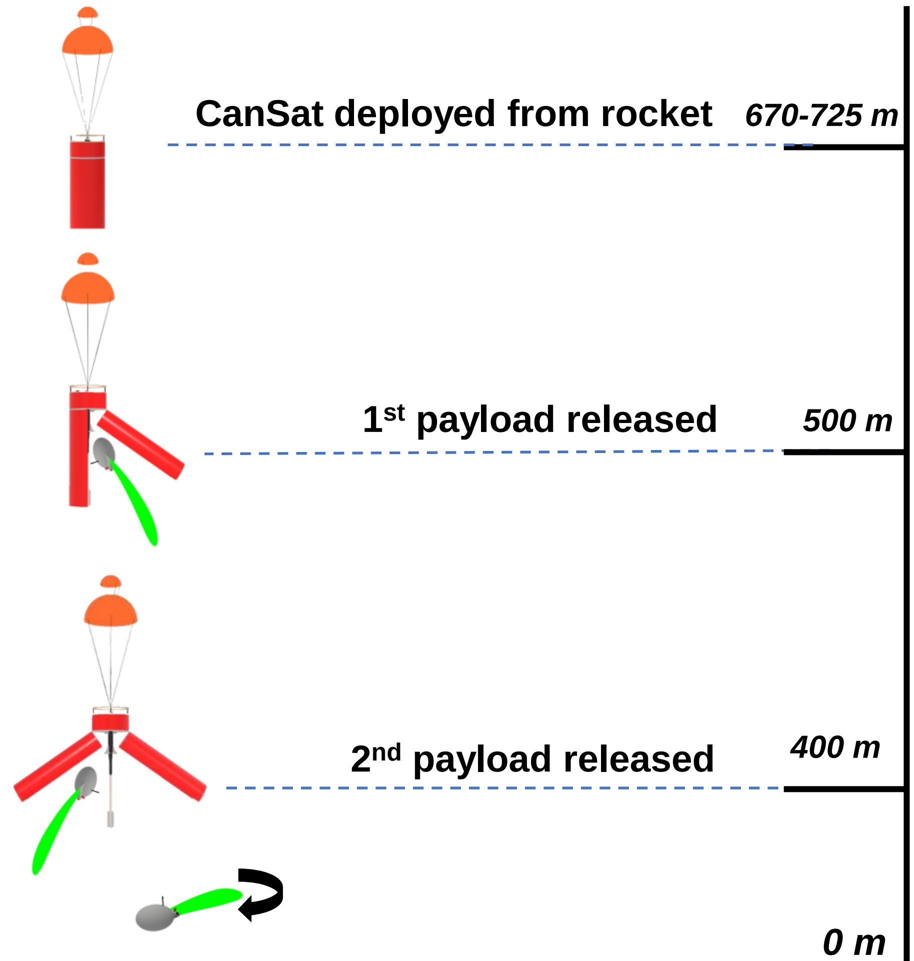
- The CanSat when released from the rocket descends with a velocity of 15 m/s with the help of a parachute.
- The parachute diameter is 170 mm as per the calculations.
- A spill hole of radius 26.5 mm has been introduced for stabilization.
- It is made from fluorescent orange ripstop nylon cloth.
- The parachute strings are kept long enough to ensure greater stability
- The parachute is attached to the container with the help of a swivel to make its rotation independent.
- A pilot chute is used to deploy the main parachute.



Undeployed Parachute *Deployed Parachute*

Descent Control Overview (3/4)

- Descent velocity for CanSat (payload + container) shall be 15m/s with the help of parachute
- The payloads descend with a constant velocity less than 20m/s after being released at a height of 500m and 400m respectively from ground level.
- The payloads auto rotate during their descent while maintaining communication with the container.



Flight Diagram

Descent Control Overview (4/4)

Components	Materials Selected
Parachute	Fluorescent orange Ripstop Nylon cloth
Parachute strings	Nylon
Parachute connection with Container (Fishing Swivel)	Stainless steel
Wing of the Maple seed	Balsa wood coated with fluorescent green monokote

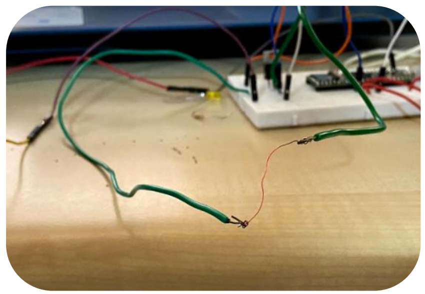
Descent Control Changes Since PDR

- **There have been no descent control changes since the PDR.**

PROTOTYPE TESTING

Descent test for payload

The payloads were dropped from a height of 60 m. Autorotation was observed after 15 m. The payloads were not damaged.

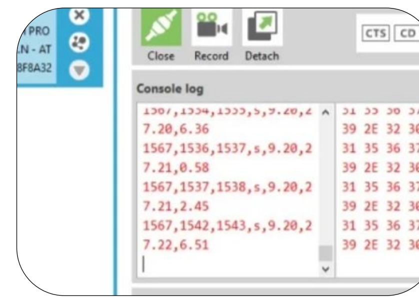


Payload release mechanism

The release mechanism was tested successfully by passing a high current through the nichrome wire, which breaks the fishing line, opening the container doors.

Container parachute descent test

The CanSat was dropped from a height of 100 m. The passive parachute release mechanism was tested.



Data transmission test

The antenna was tested and it transmitted the data across the required distances, without any losses.

Descent Control Requirements

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR4	The container shall be a fluorescent color; pink, red or orange.	Req	Very High	√	√		
#CR9	The Parachutes shall be fluorescent Pink or Orange.	Req	Very High	√	√		
#CR10	The descent rate of the CanSat (container and science payload) shall be 15 meters/second +/- 5m/s.	Req	Very High	√		√	
#CR22	The science payload shall descend spinning passively like a maple seed with no propulsion.	Req	Very High	√	√	√	
#CR23	The science payload shall have a maximum descent rate of 20 m/s.	Req	Very High	√		√	
#CR24	The wing of the science payload shall be colored fluorescent orange, pink or green.	Req	Very High	√	√		

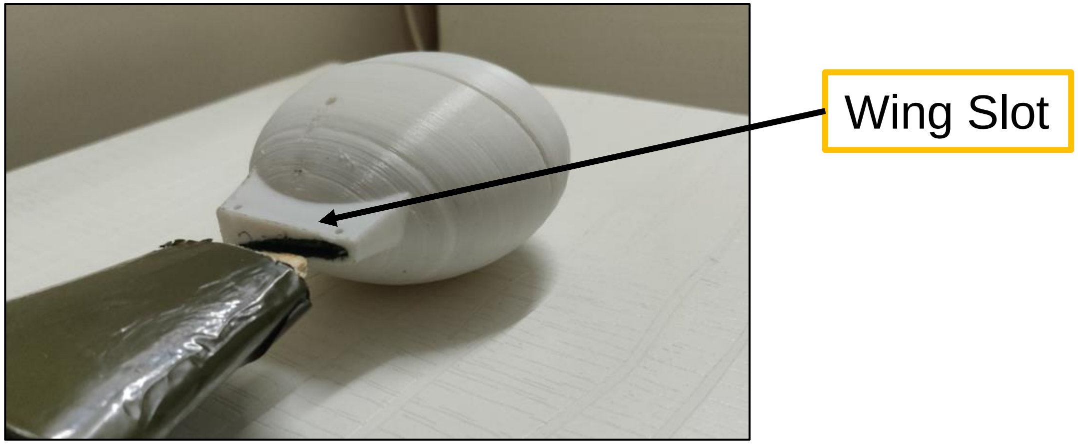
Payload Descent Control Hardware Summary (1/2)

Component sizing:

- Dimensions of the various mechanical components were mentioned in Payload Physical Layout with details
- The payloads' wingspan are 231 mm each with a wing area of 33886.28 mm^2.
- It has a dihedral angle of 8°, root AOA of 11° and tip AOA of 4°, resulting in a twist angle of 6°.

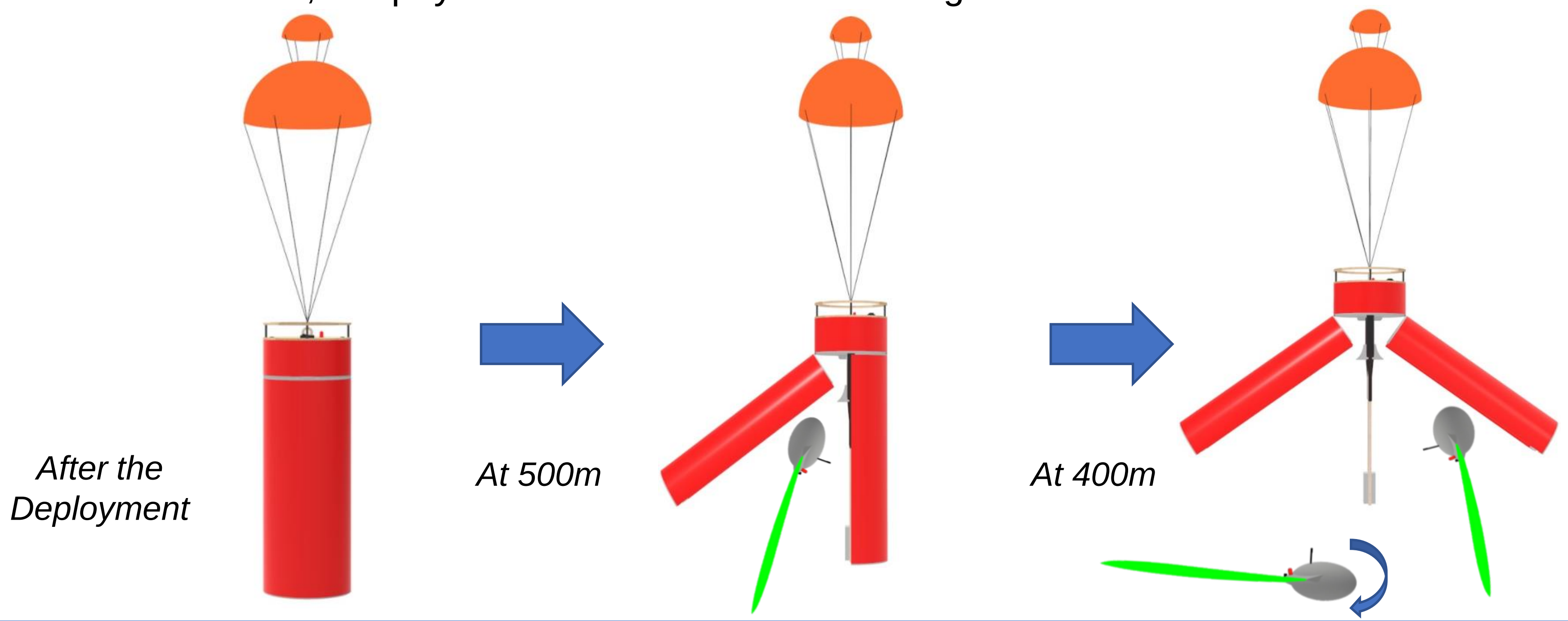
Key considerations & Colour Selection:

- The payload is designed to be lightweight and streamlined with no sharp edges or exposed parts.
- The airfoil used for the wing is the NACA 2408
- It is made of Balsa, and covered with fluorescent green Monokote, while the seed and the wing attachment slot is made up of grey 3D printed PETG.



Payload Descent Control Hardware Summary (2/2)

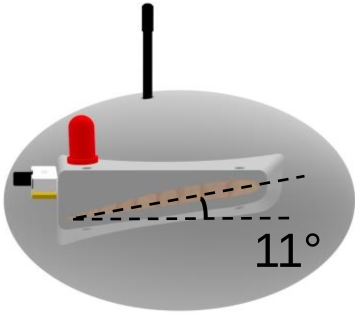
- The payloads are stowed in the container with the help of 3D printed extrusions before release.
- The wings are lodged into the wing attachment slot on the seed and locked by support pins
- The lift generated on the wing due to the downward velocity of the seed and the acting aerodynamic forces exerts a torque to spin the seed about the vertical axis passively, initiating the gyration.
- Once released, the payloads descend in auto rotating motion.



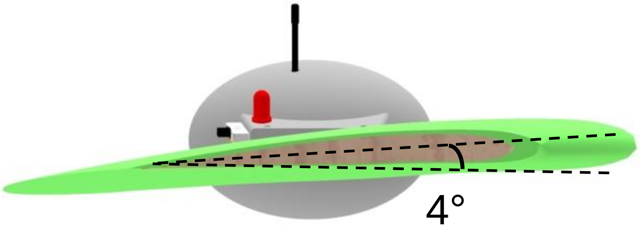
Design of method

- The payload makes use of a **passive mechanism** for descent.
- Since the seed is heavier than the wing, the CG of the payload is shifted towards the seed-wing attachment.
- The CG is maintained below the horizontal axis to increase the stability of the descent. This ensures uniform rotational motion about the CG.
- The airfoil at the root has an AOA of 11º while the tip has an AOA of 4º. This provides the wing with a twist angle of 6º. The dihedral angle is 8º. The angles provide us with the optimal lift for the required descent velocity.
- The speed of rotation and descent is calculated using the wingspan.

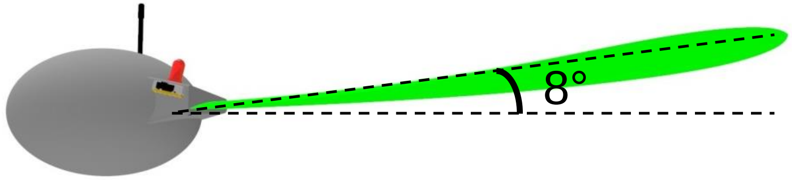
At the root of the wing



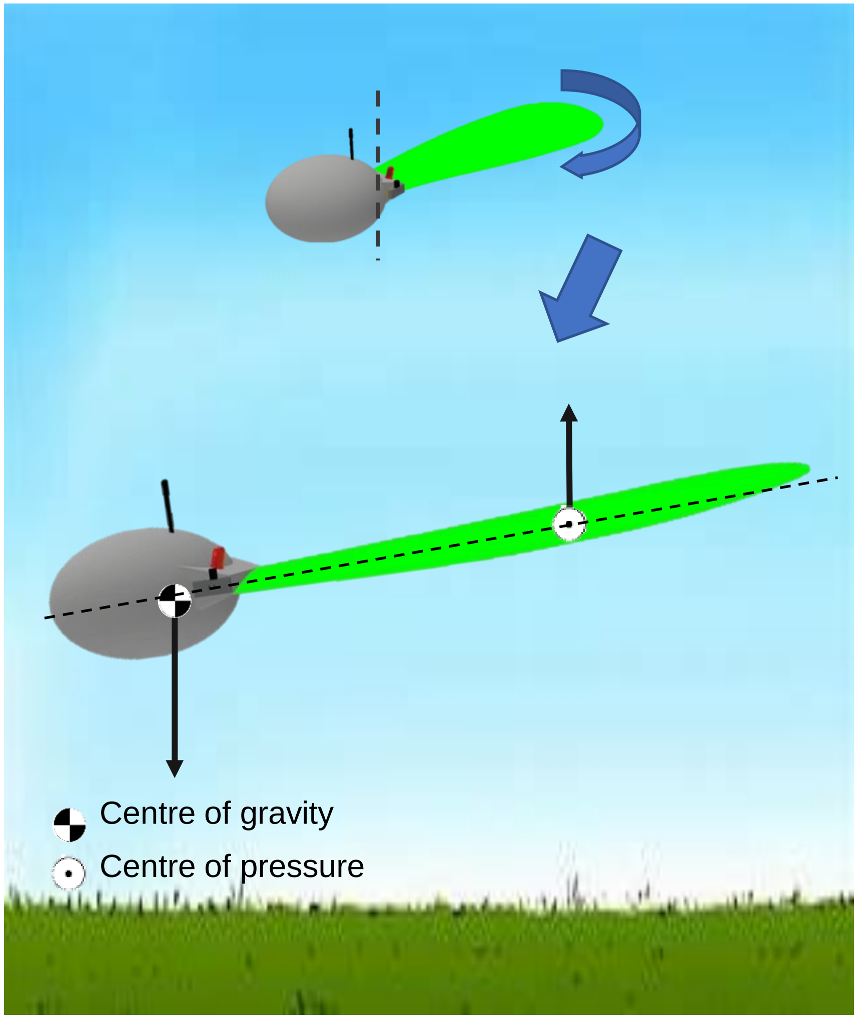
At the tip of the wing



Dihedral Angle

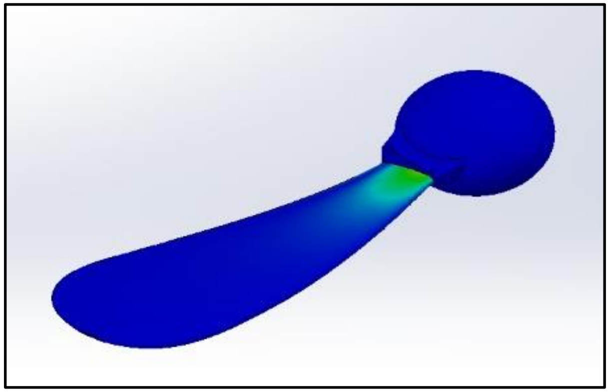


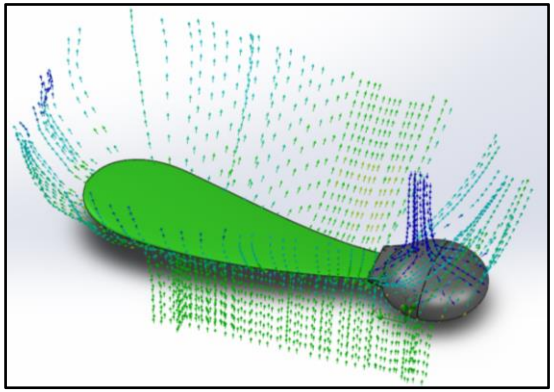
Payload Descent Stability Control Design (2/3)

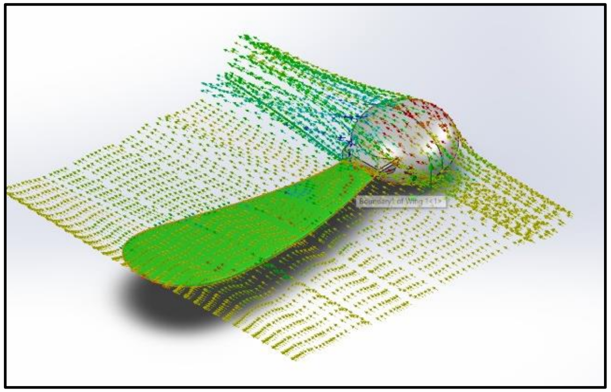


- The centre of mass of the payload is positioned as close to the seed-wing attachment point as possible.
- Nadir direction will be maintained by placing all major electrical components including the battery inside the seed of the payload.
- Due to the initial free fall of the payload, the air resistance generates greater lift/drag on the wing at the centre of pressure, which initiates autorotation about the central axis of the payload.
- Tumbling is prevented by ensuring that the centre of gravity is in place. This is done by securing all the components and restricting their movements during the descent

Payload Descent Stability Control Design (3/3)







Stress Simulation

The seed-wing attachment point being the most critical part of the payload, survives the launch acceleration and the shock force generated as shown in the simulation.

Vertical Flow Simulation

Inputting the downward velocity of the wing in the flow simulation, we verify that no vortices are being generated near the edges while the tangential lift generated is sufficient for autorotation and lift

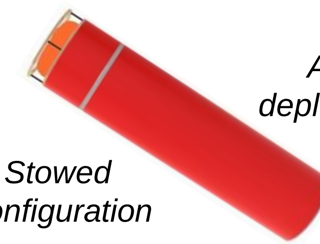
Horizontal Flow Simulation

Inputting the horizontal velocity of the wing in the flow simulation, we verify that that sufficient lift was generated to make autorotation possible.

Container Descent Control Hardware Summary (1/2)

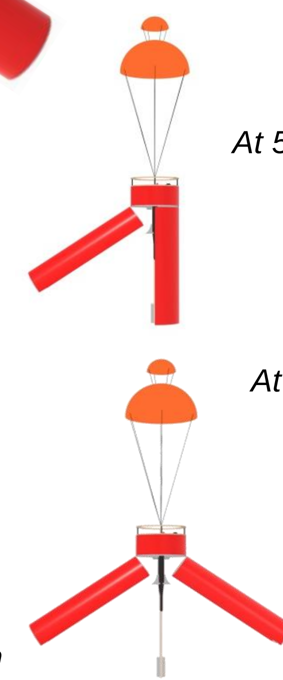
Deployment Method

The CanSat deploys smoothly from the rocket. The container is free from sharp extrusions which aids in smooth deployment. The parachute uses a passive mechanism to deploy itself and limit the container's descent velocity. Before deployment of both payloads, the container descends with a velocity of 15m/s. The nichrome wire mechanism opens the container doors to deploy the payloads at 500m and 400m respectively.



Stowed Configuration

After deployment



At 500m

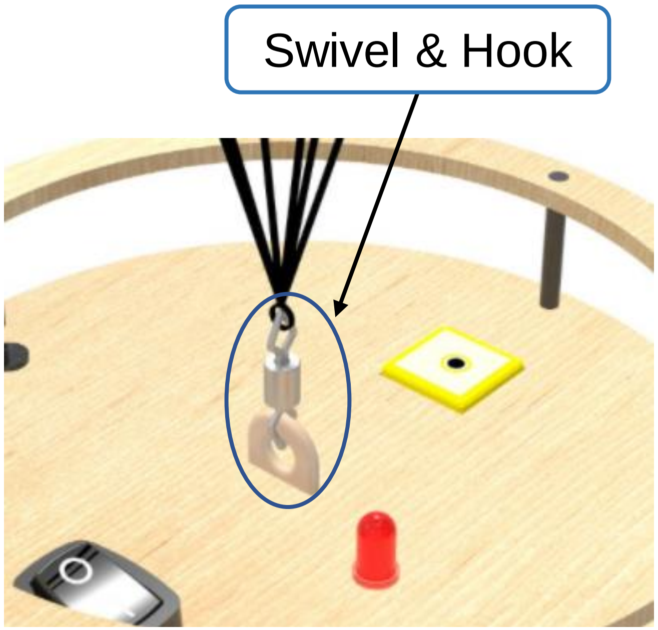
At 400m

Deployed Configuration

Container Descent Control Hardware Summary (2/2)

Key Components, Components Sizing and Colour Selection

The parachute, swivel and hook are the key components for the container's descent control. The radius of the parachute is approximately **85mm and is orange in colour**. A pilot chute is used to release the main parachute. The parachute placed in the parachute compartment, is open on all sides to allow the air to gush into the parachute for its release. A swivel and hook is used to connect the parachute to the container to make the rotation of the parachute independent of the container. Spill hole of radius of **26.5mm** has been introduced.



Descent Rate Estimates (1/11)

DESIGN CALCULATIONS:

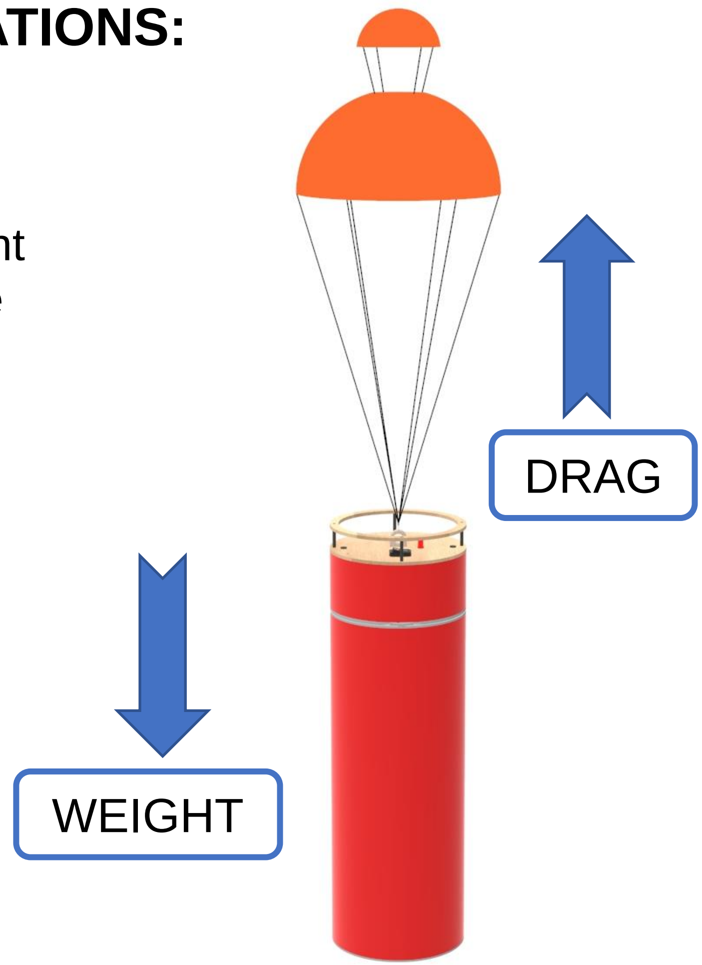
CANSAT AFTER RELEASE:

- The frontal surface area (area dealing with the airflow) is to be calculated for the required descent velocity (**15 m/s**) by applying Newton's law on the parachute-container system.
- We will use the drag equation:

$$\mathbf{F_D} = \frac{1}{2}\rho v^2 C_D A \quad \Rightarrow \quad A = \frac{2\,F_D}{\rho\, v^2\, C_D} \qquad \text{-- (i)}$$

Here,

- Mass of CanSat (m) = **0.6 kg**
- Descent Velocity (v) = **15 m/s**
- Coefficient of drag for parachute(C_D) = **1.75**
- Density of air (ρ) = **1.332** $\mathbf{kg/m^3}$
- Drag Force = F_D
- Projected area of parachute = A



Descent Rate Estimates (2/11)

Now,

$$F_D = mg \quad \text{...(ii)}$$

Inserting equation **(ii) in (i)** we get;

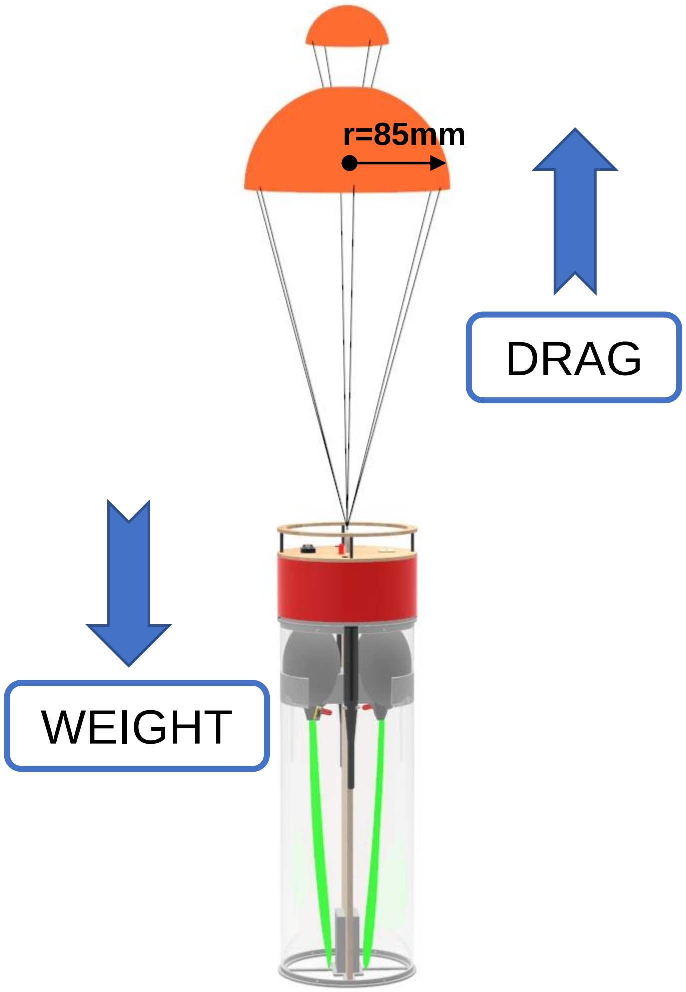
$$\mathbf{A = 0.022\ m^2}$$

But for circular dome,

$$\mathbf{A = \pi r^2}$$

$$\therefore \mathbf{r_{(para)}} \approx 0.085\text{m} = \mathbf{85\ mm}$$

- In order to facilitate stable descent of the CanSat after being deployed, the calculated value of parachute diameter is **170 mm.**



Descent Rate Estimates (3/11)

- A spill hole is created in the parachute to keep the CanSat stable throughout the violent descent and any unnecessary sway.
- The area of the spill hole calculated as 10% of the parachute area, provides better aerodynamic stability.

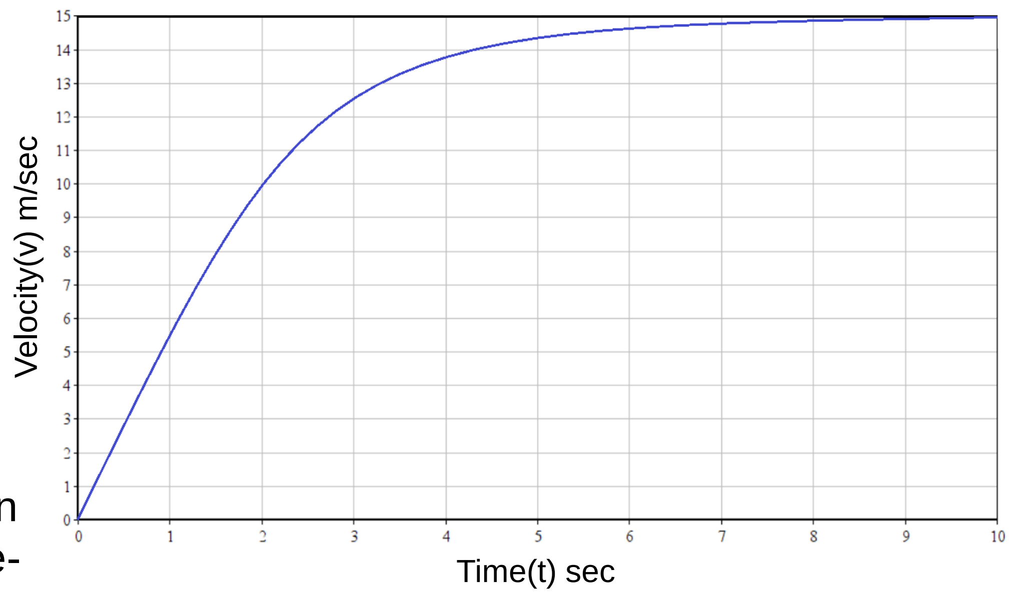
$$\therefore \mathbf{A = 0.0022\ m^2}$$

But $A = \pi r^2$,

$$\therefore \mathbf{r_{(spill)} \approx 26.5\ mm}$$

- After the separation from the rocket, velocity is assumed to be zero at peak. Parachute opens at nearly **650-725 meters**, terminal velocity as mentioned in mission guide is **15 m/s**. From the above-mentioned equation, the parachute has a diameter of **170 mm**. This is shown in the graph.

CanSat after release from rocket



CONTAINER

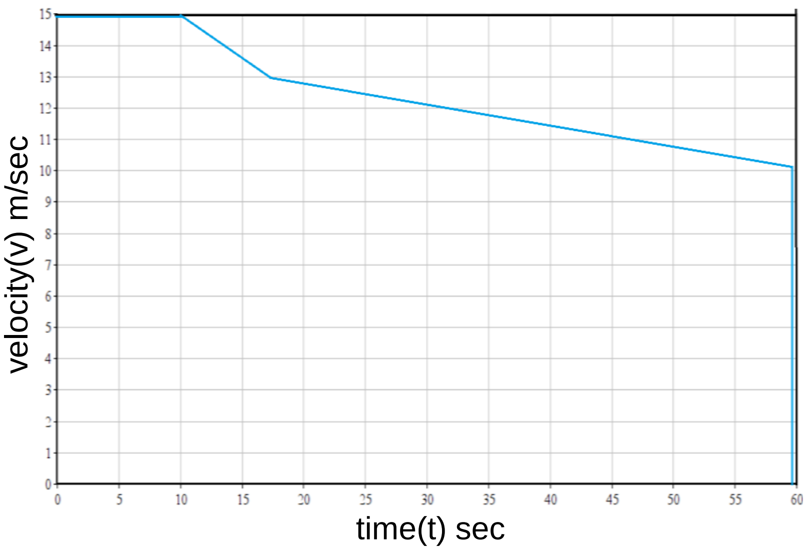
- Descent rate of the container is found by equating drag force to the weight of the Container.

From equation **(i)**

$$v_d = \sqrt{\frac{2mg}{\rho A c_D}} \quad \ldots\text{(iii)}$$

Where,

- Mass of CanSat = m
- Projected area of parachute (A) = **0.022 m^2**
- Mass of one Payload = **0.15 kg**
- Mass of Container = **0.3 kg**



After the release of the first payload, the CanSat mass is reduced to 0.45 kg, using the Drag equation,

$\therefore \boldsymbol{v_{d1}} \approx$ **13 m/s**

After both the payloads are released, the Container mass is 0.3 kg,

$\therefore \boldsymbol{v_{d2}} \approx$ **10.8 m/s**

Descent Rate Estimates (5/11)

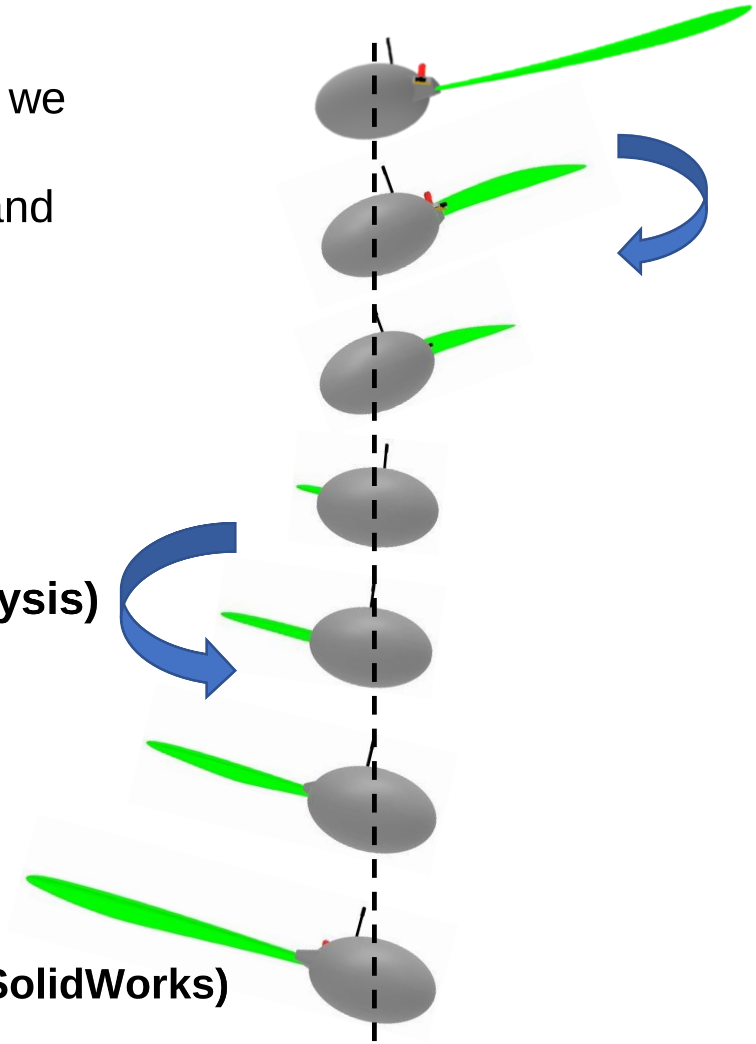
PAYLOAD

Here, we assume an angle of attack of 11° for which we obtain the values of C_L and C_D.
Three main forces – Lift force (F_L), Drag force (F_D) and Weight (mg) will act on the payload.
For lift force and drag force –

$$\mathbf{F_{L/D} = \frac{1}{2}\rho v^2 C_{L/D} A}$$

Where,

- Mass of one payload (m) = **0.15 kg**
- Coefficient of lift (C_L) = **0.910** **(from XFLR analysis)**
- Coefficient of drag (C_D) = **0.039** **(from XFLR analysis)**
- Angle of attack (θ) = **11°**
- Density of air = **1.332 kg/m^3**
- Radius of rotation (r) = **0.229 m**
- Acceleration due to gravity (g) **= 9.81 m/s^2**
- Moment of inertia (I) = **4.88 x 10^{-4} kg-m^2** **(from SolidWorks)**



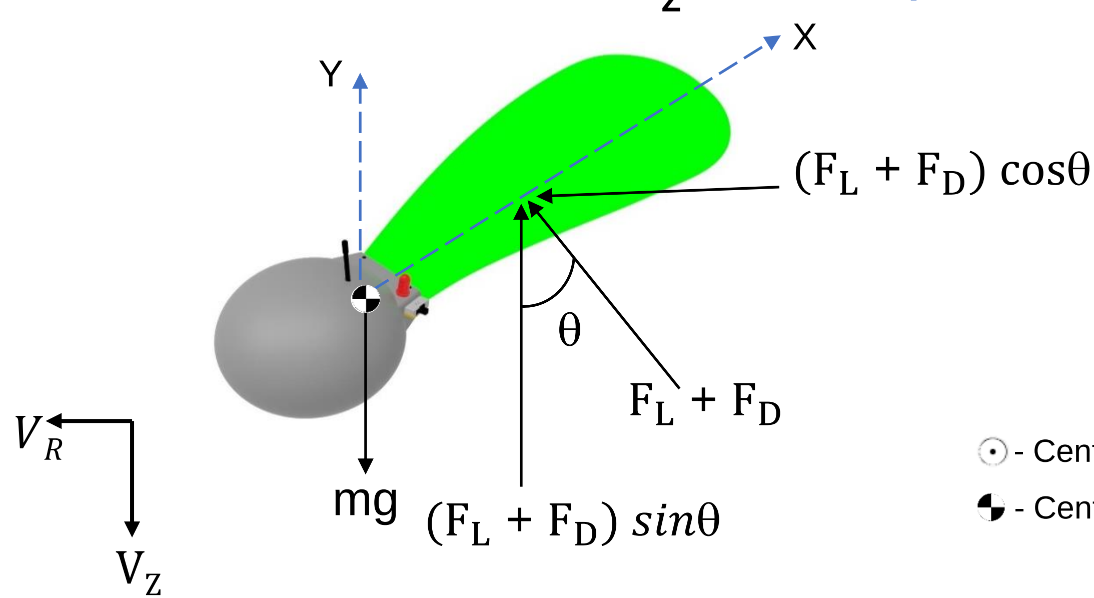
Descent Rate Estimates (6/11)

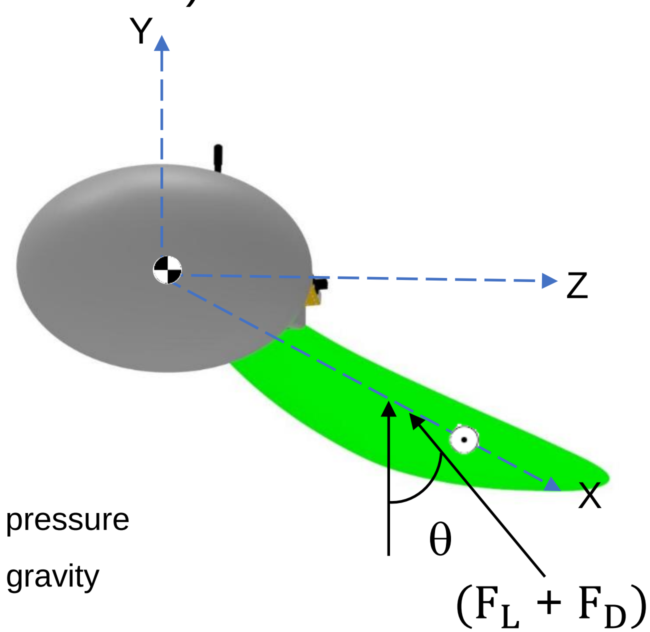
- To calculate the descent velocity, we balance all the forces acting on the payload using Newton's laws of Motion **(θ = 11°)**
- The vertical acceleration of the payload is almost negligible

$$mg = F_L \sin\theta + F_D \sin\theta$$

$$0.15 \times 9.81 = \left(\tfrac{1}{2} \times 1.332 \times V_Z^{\,2} \times \sin(11^\circ) \times 0.910 \times 0.033886\right) + \left(\tfrac{1}{2} \times 1.332 \times V_Z^{\,2} \times \sin(11^\circ) \times 0.039 \times 0.033886\right)$$

$$\therefore \mathbf{V_Z \approx 18.97\ m/s}$$



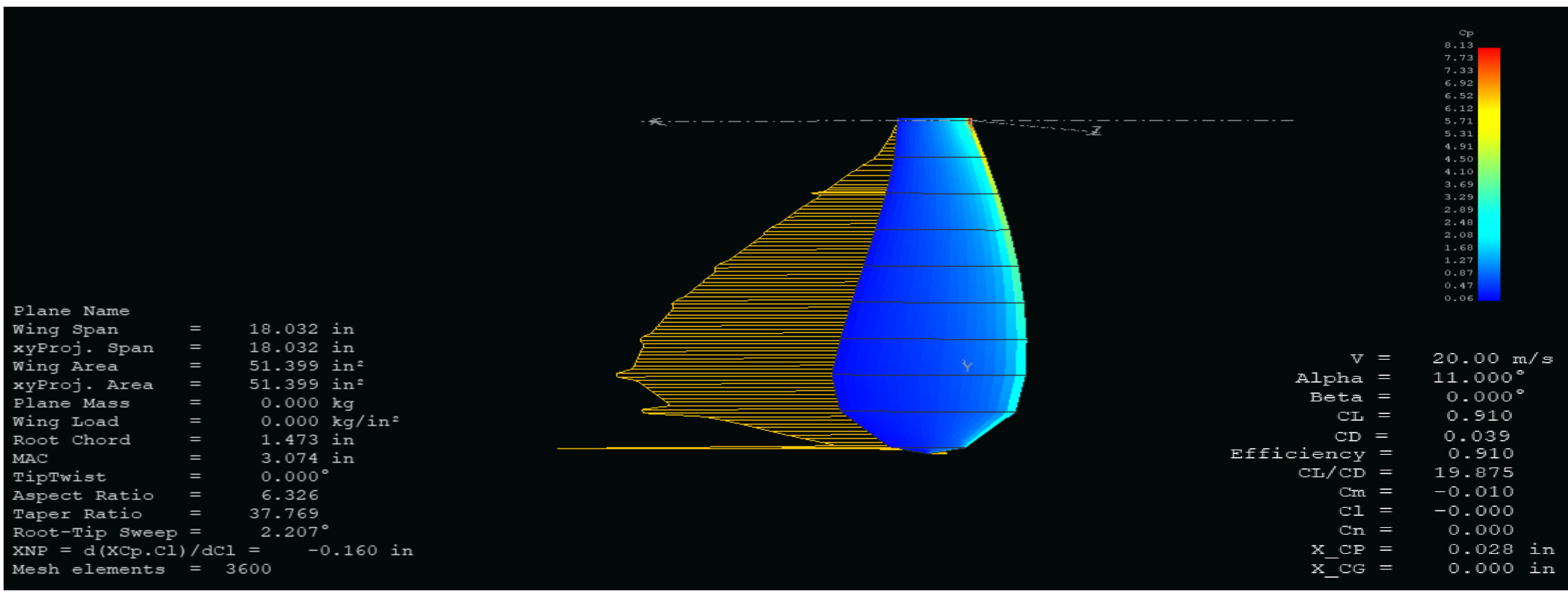


- Centre of pressure
- Centre of gravity

- The individual Lift and Drag forces acting on the wing are calculated as follows:

  Lift Force (F_L) = ($\frac{1}{2}$ x 1.332 x V_Z^2 x 0.910 x 0.033886) = **1.41 N**

  Drag Force (F_D) = ($\frac{1}{2}$ x 1.332 x V_Z^2 x 0.039 x 0.033886) = **0.06 N**
- Total force on the wing = (F_L+ F_D) = 1.41 + 0.06 = **1.47 N**
- The drag force produced by the seed is neglected.



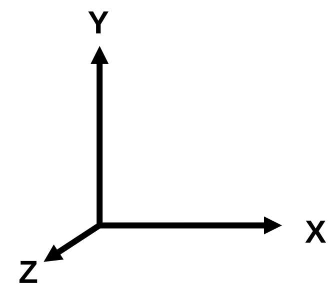
Descent Rate Estimates (8/11)

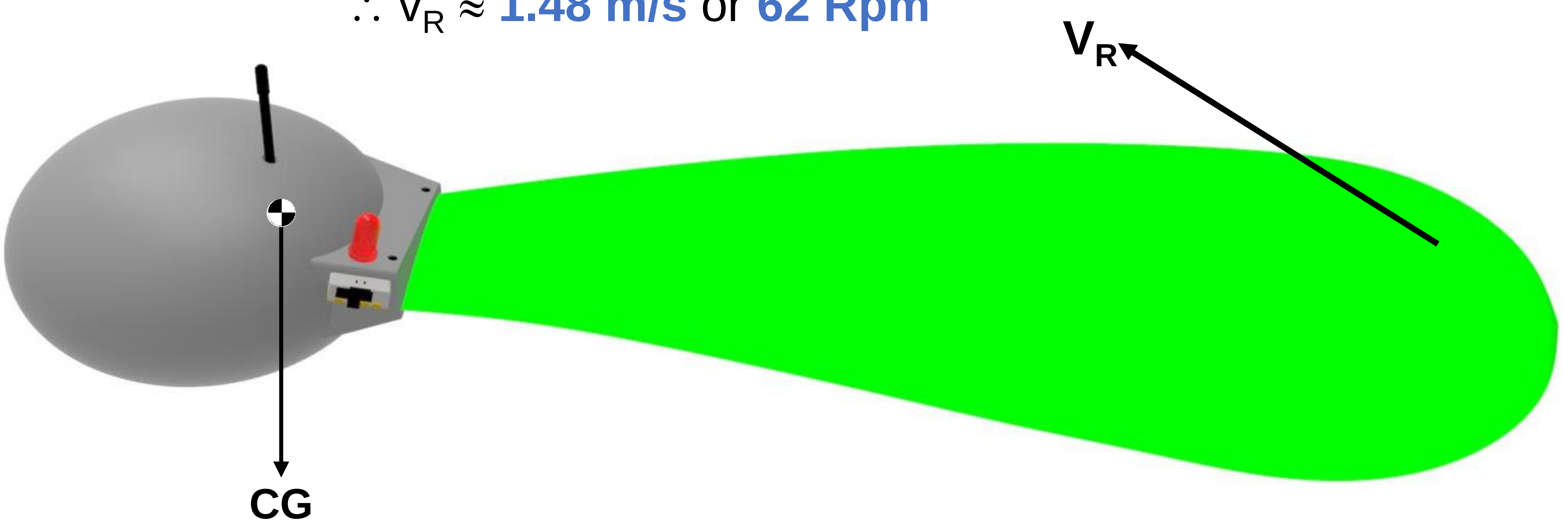
- To calculate the auto-rotation velocity of the payload during descent, we use the formula of Centripetal force
- The angular acceleration of the payload is negligible

$$\therefore \frac{mv_R^{\,2}}{r} = F_L\cos\theta + F_D\cos\theta$$

$$\frac{0.15 \text{ x } v_R^{\,2}}{0.229} = (\frac{1}{2} \text{ x } 1.332 \text{ x } V_Z^{\,2} \text{ x } \cos(11°) \text{ x } 0.910 \text{ x } 0.033886) + (\frac{1}{2} \text{ x } 1.332 \text{ x } V_Z^{\,2} \text{ x } \cos(11°) \text{ x } 0.039 \text{ x } 0.033886)$$

$\therefore v_R \approx$ **1.48 m/s** or **62 Rpm**





Descent Rate Estimates (9/11)

Buffer distance calculation:

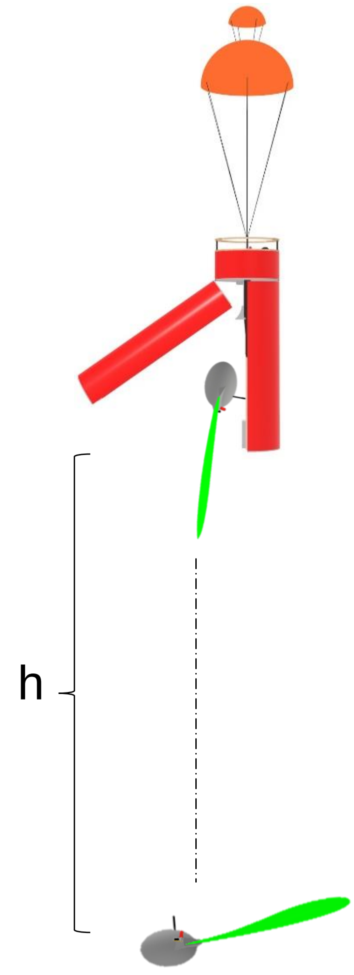
The distance taken by the science payload to balance out all forces acting on it is called buffer distance(h).

- Using energy conservation method (neglecting air resistance)
  Potential Energy (**PE**) = Kinetic Energy (**KE**)

$$Mgh = \frac{1}{2} mv^2 + \frac{1}{2} Iw^2$$

$$0.15 \times 9.81 \times h = \frac{1}{2} \times 0.15 \times (18.97)^2 + \frac{1}{2} \times 4.88 \times 10^{-4} \times (1.48)^2$$

h = 18.34 m (≈ 20 m)



Hence payload will take approximately 20 m to balance all forces and start autorotating.

Descent Rate Estimates (10/11)

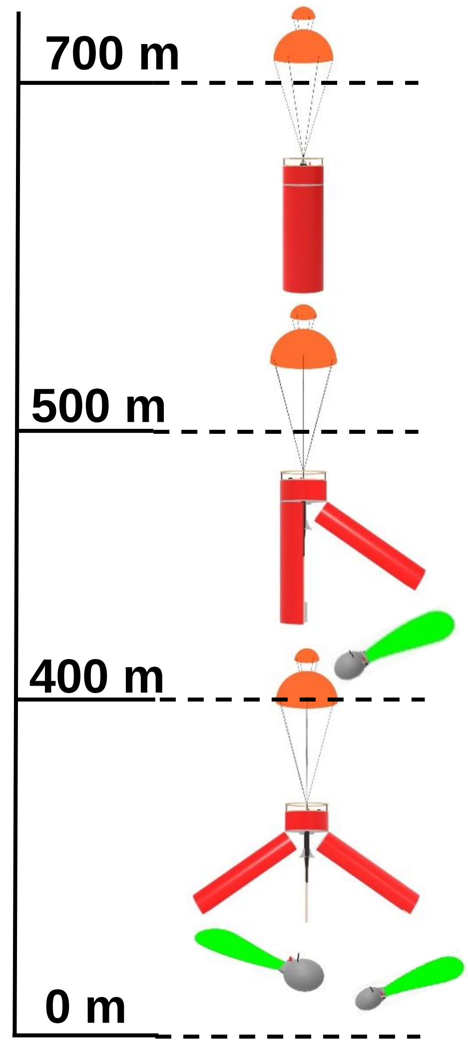
DESCENT TIME CALCULATIONS:

To calculate the time of descent, we use the equation –

$s = ut + \frac{1}{2}at^2$ But $a \approx 0$

- For the first payload
  $s = 480m$, $v = 18.97$ m/s $\Rightarrow$ $\therefore$ **t ≈ 25.3 s**
- For the second payload
  $s = 380m$, $v = 18.97$ m/s $\Rightarrow$ $\therefore$ **t ≈ 20.03 s**
- For the container, the descent is in three stages

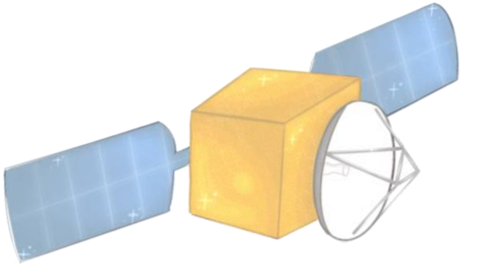
  After deployment from rocket before payload releases
  $s = 200m$ (700m - 500m), $v = 15$ m/s $\Rightarrow$ $\therefore$ **t ≈ 13.3 s**
  After the release of the first payload –
  $s = 100m$ (500m – 400m), $v = 13$ m/s $\Rightarrow$ $\therefore$ **t ≈ 7.7 s**
  After the release of the second payload till ground contact
  $s = 450m$ (450m – 0m), $v = 10.8$ m/s $\Rightarrow$ $\therefore$ **t ≈ 41.7 s**



Descent Rate Estimates (11/11)

Descent Rate Summary

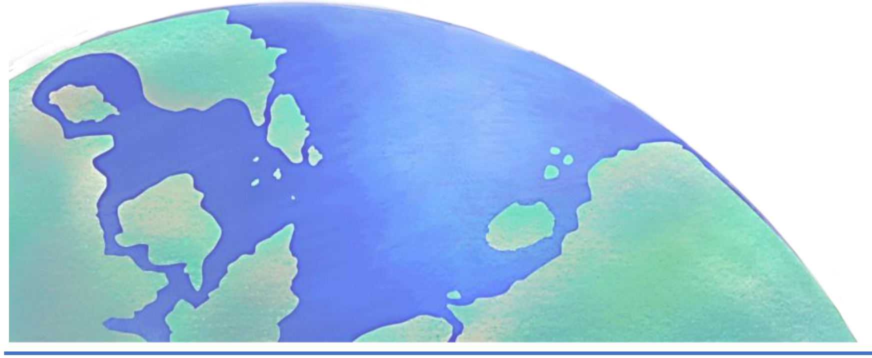
SYSTEM	DESCENT ESTIMATES
Container + Payload	15 m/s
Container after 1st payload is released	13 m/s
Container after 2nd payload is released	10.8 m/s
Payload	Vertical Velocity: 18.97 m/s Auto-rotating Velocity: 1.48 m/s



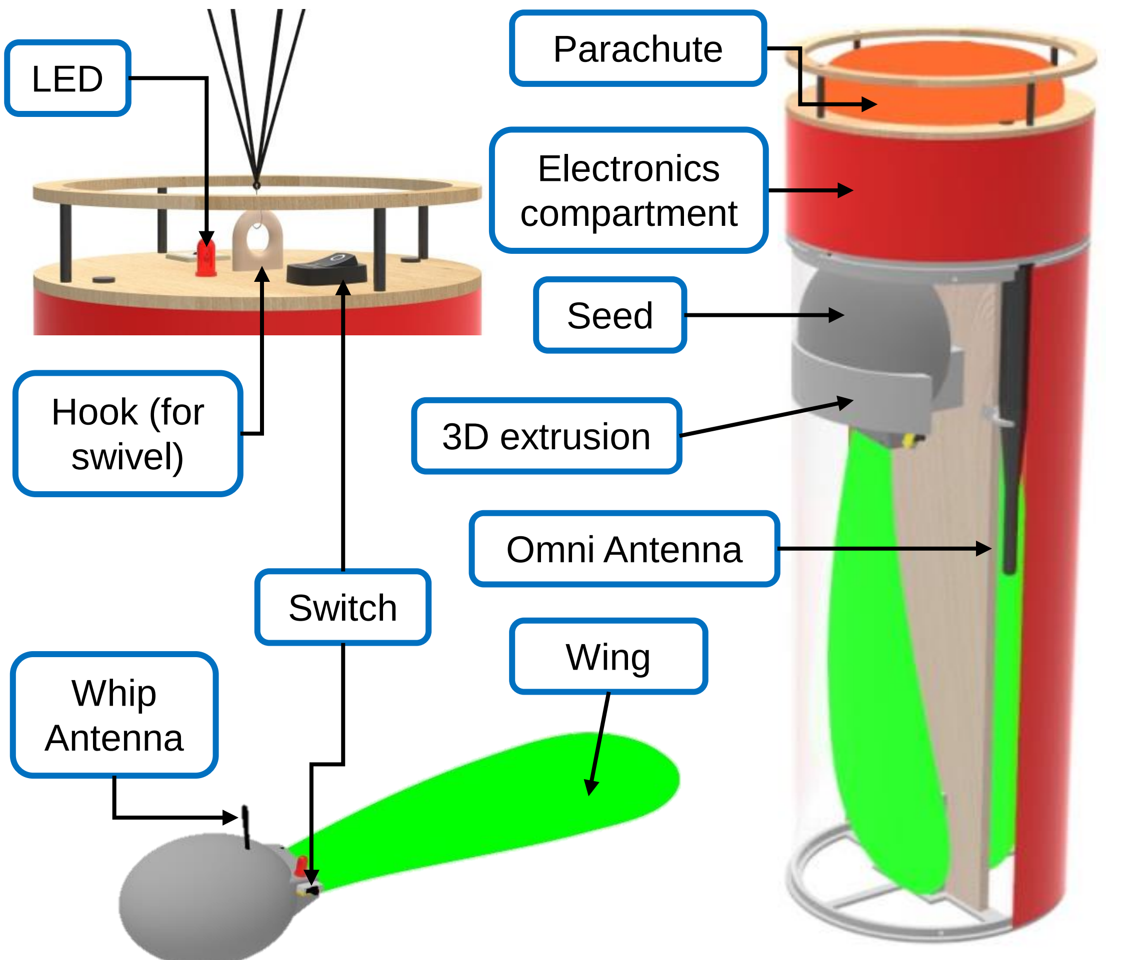
Mechanical Subsystem Design

Presenter's Name:

Vatsal Tapiawala



Mechanical Subsystem Overview



Deployed Configuration ***Undeployed Configuration***

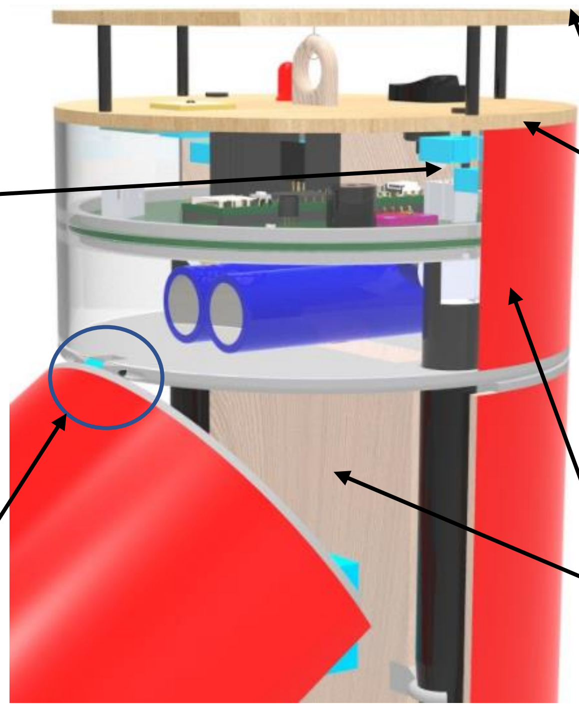
Structure	Material Selection
Container	Balsa with fiberglass coating, carbon fiber rods, 3D printed PETG, Birch plywood, fluorescent Red Monokote
Payload	3D printed PETG, Balsa & fluorescent Green Monokote, carbon fiber
Payload Release Mechanism	Fishing line, nichrome wire and elastic bands

Mechanical Subsystem Changes Since PDR

Container

The pin-locking mechanism for the electronics bay was modified to reduce hindrance

The container door hinges were modified to impart strength



The material of the top ring and the parachute plate was changed from PETG to Birch plywood to make it sturdier

The material for the partition and the electronics bay halves was changed from 3D printed PETG to Balsa due to ease of manufacturing

Payload

No mechanical changes has been made in the Payloads since PDR

Mechanical Subsystem Requirements (1/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR1	Total mass of the CanSat (science payloads and container) shall be 600 grams +/- 10 grams.	Req	Very High	√	√	√	
#CR2	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.	Req	Very High	√	√	√	
#CR3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	Req	Very High	√	√	√	√
#CR4	The container shall be a fluorescent color; pink, red or orange.	Req	Very High	√	√		

Mechanical Subsystem Requirements (2/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR5	The container shall be solid and fully enclose the science payloads. Small holes to allow access to turn on the science payloads is allowed. The end of the container where the payload deploys may be open.	Req	Very High	√		√	
#CR6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Req	Very High	√			√
#CR7	The rocket airframe shall not be used as part of the CanSat operations.	Req	Very High	√			√

Mechanical Subsystem Requirements (3/4)

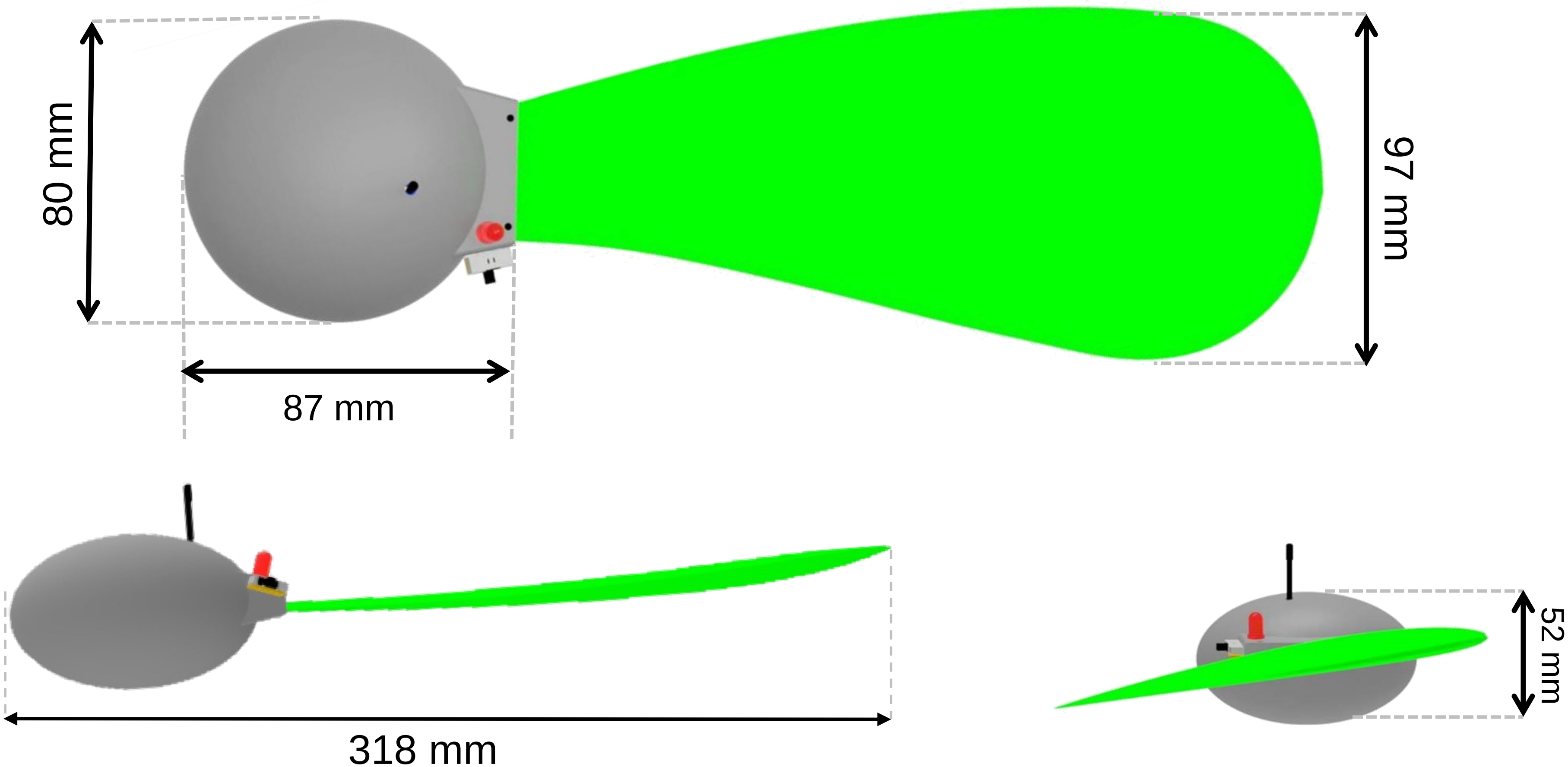
Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR8	The container parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	Req	Very High	√			√
#CR11	All structures shall be built to survive 15 Gs of launch acceleration.	Req	Very High			√	
#CR12	All structures shall be built to survive 30 Gs of shock.	Req	Very High			√	
#CR13	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Req	Very High		√	√	
#CR14	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Req	Very High	√	√		√

Mechanical Subsystem Requirements (4/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR22	The science payload shall descend spinning passively like a maple seed with no propulsion.	Req	Very High	✓	✓	✓	
#CR24	The wing of the science payload shall be colored fluorescent orange, pink or green.	Req	Very High	✓	✓		
#CR38	The container and science payloads must include an easily accessible power switch that can be accessed without disassembling the cansat and science payloads and in the stowed configuration.	Req	High		✓		✓
#CR44	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Req	High		✓		

Payload Mechanical Layout of Components (1/8)

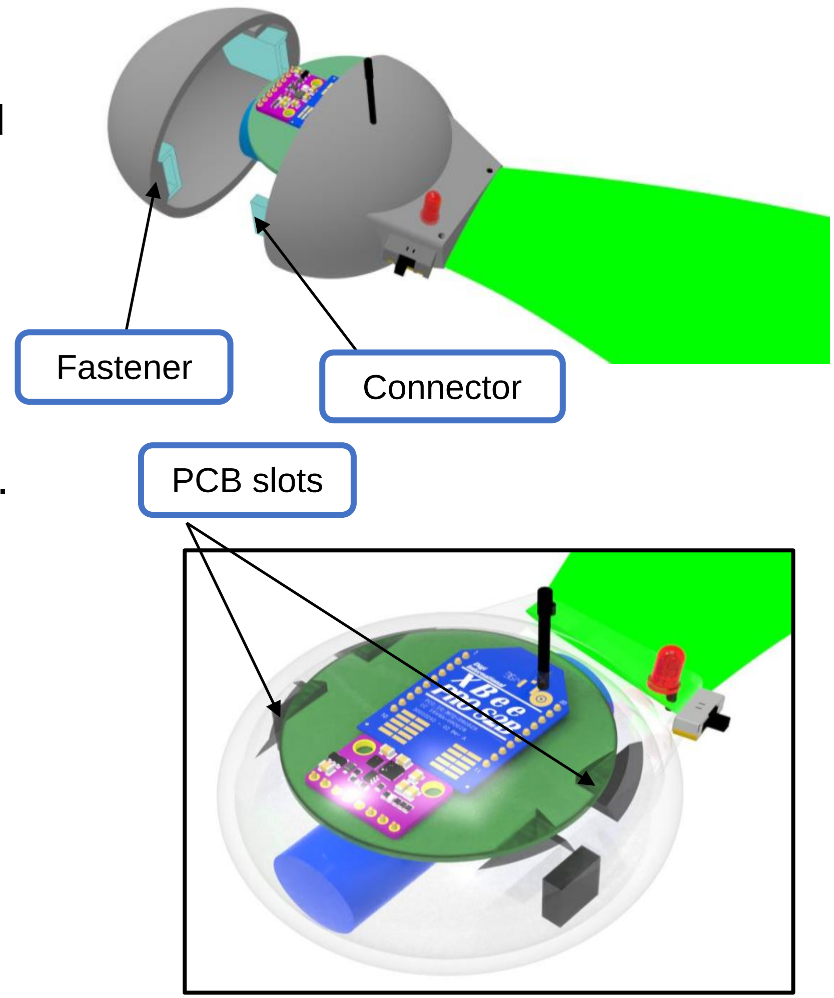
Payload CAD Model



Payload Mechanical Layout of Components (2/8)

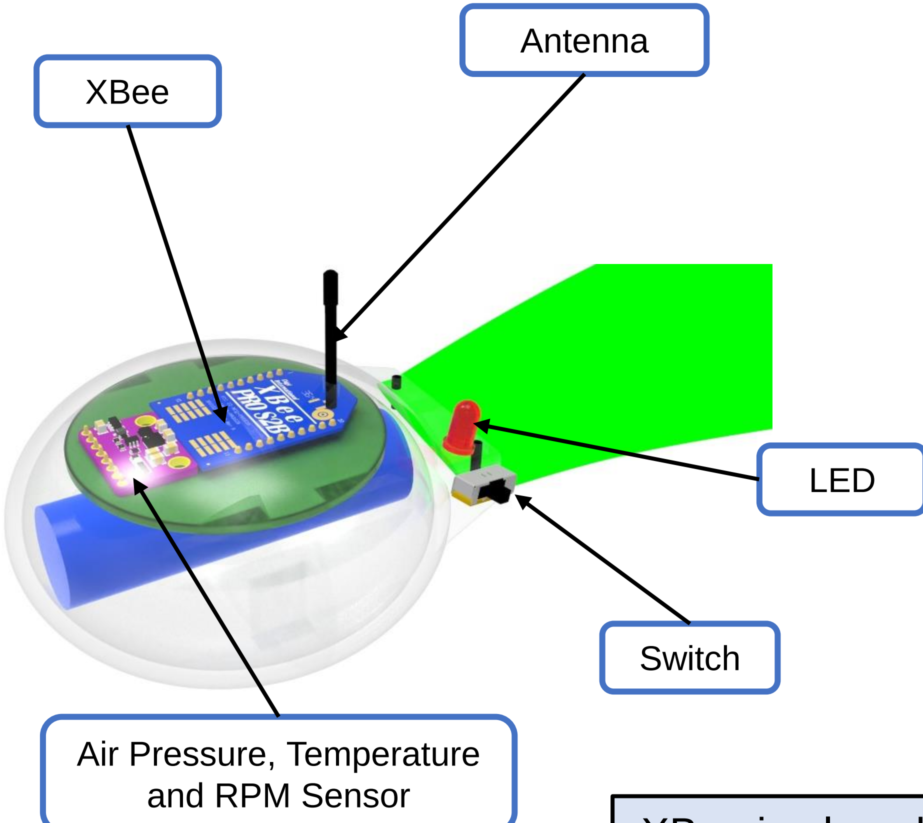
Payload Structure

- Electronic components are mounted in the seed on a single layered two-sided PCB with XBee and 10-DoF board on the top and microcontroller on the bottom, which is held in place with the help of 3D printed PETG slots inside the seed.
- The wing is made of balsa with a layer of green monokote and is connected to the seed through the hollow extrusions on the seed and with the support pins passing through both wing and seed.
- The two halves of the seed are attached using connector-fastener mechanism to keep the PCB and the battery intact.
- The seed is 3D printed using PETG to impart strength.
- The center of mass of the payload is at the seed wing attachment point.
- The battery, being the heaviest component, is placed beneath the PCB to lower the center of gravity.

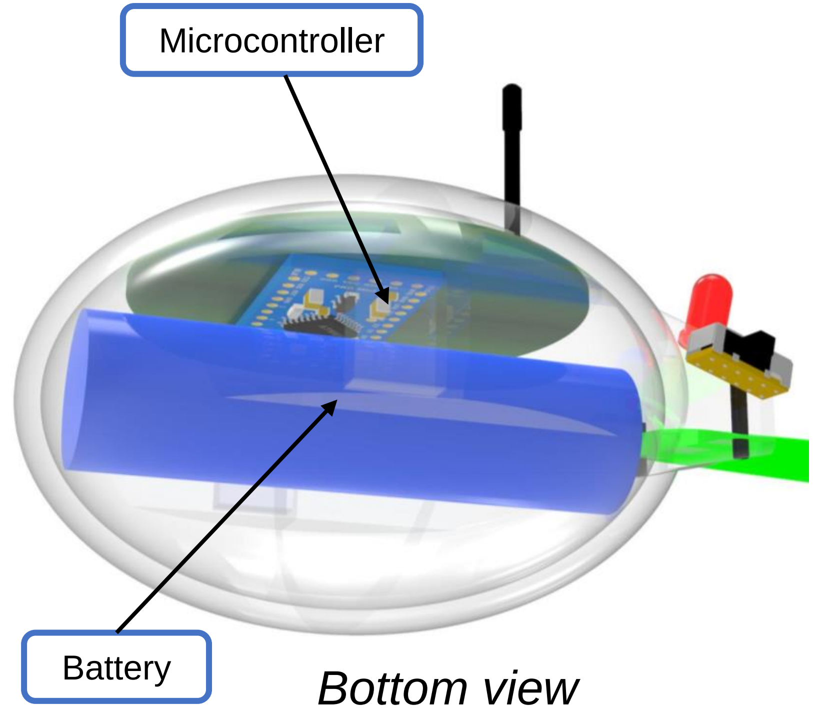


Payload Mechanical Layout of Components (3/8)

Electronic Components



Top view



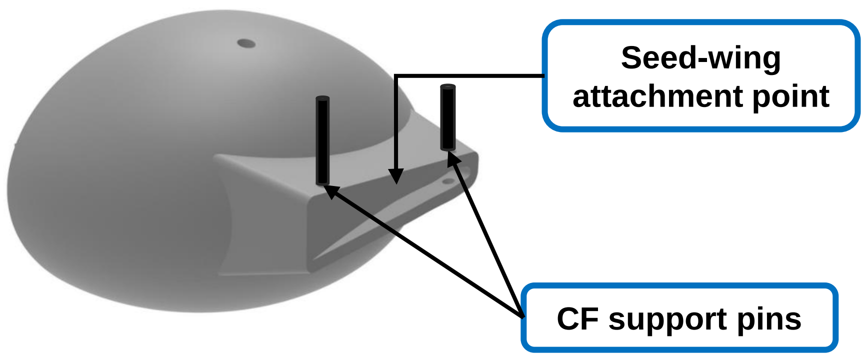
Bottom view

XBee is placed on the upper side of the PCB for easier communication with the container during descent

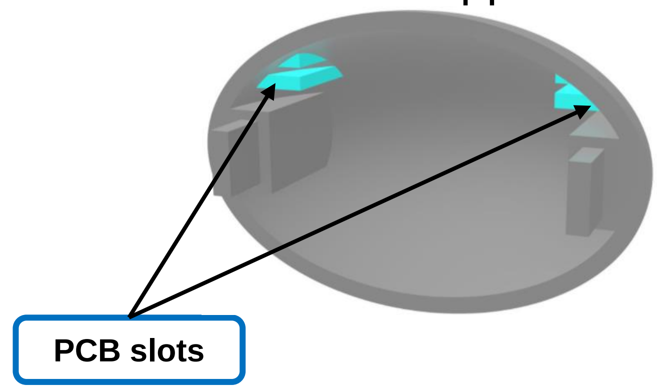
Payload Mechanical Layout of Components (4/8)

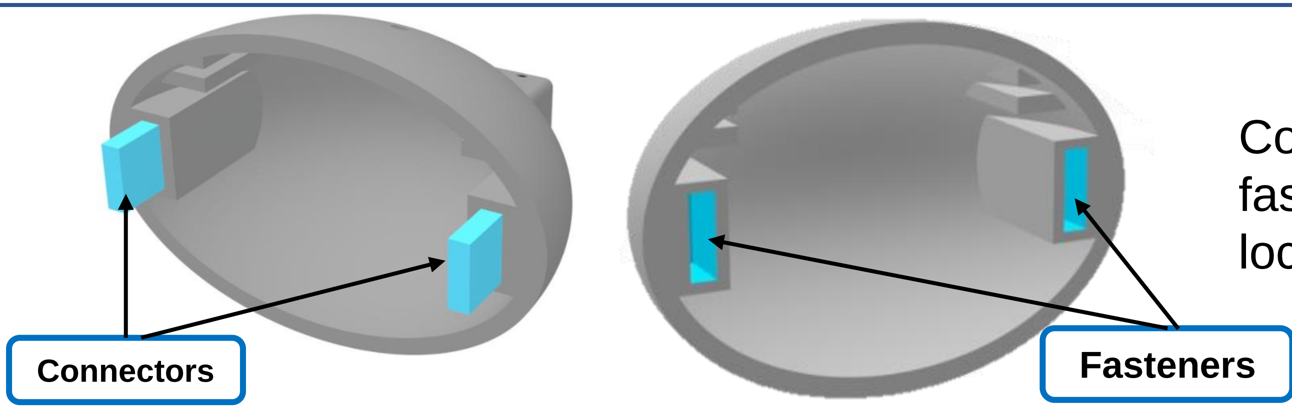
Major Mechanical Parts

An extrusion is made on one half of the seed to attach the wing



Slots are extruded inside the seed halves to support the PCB





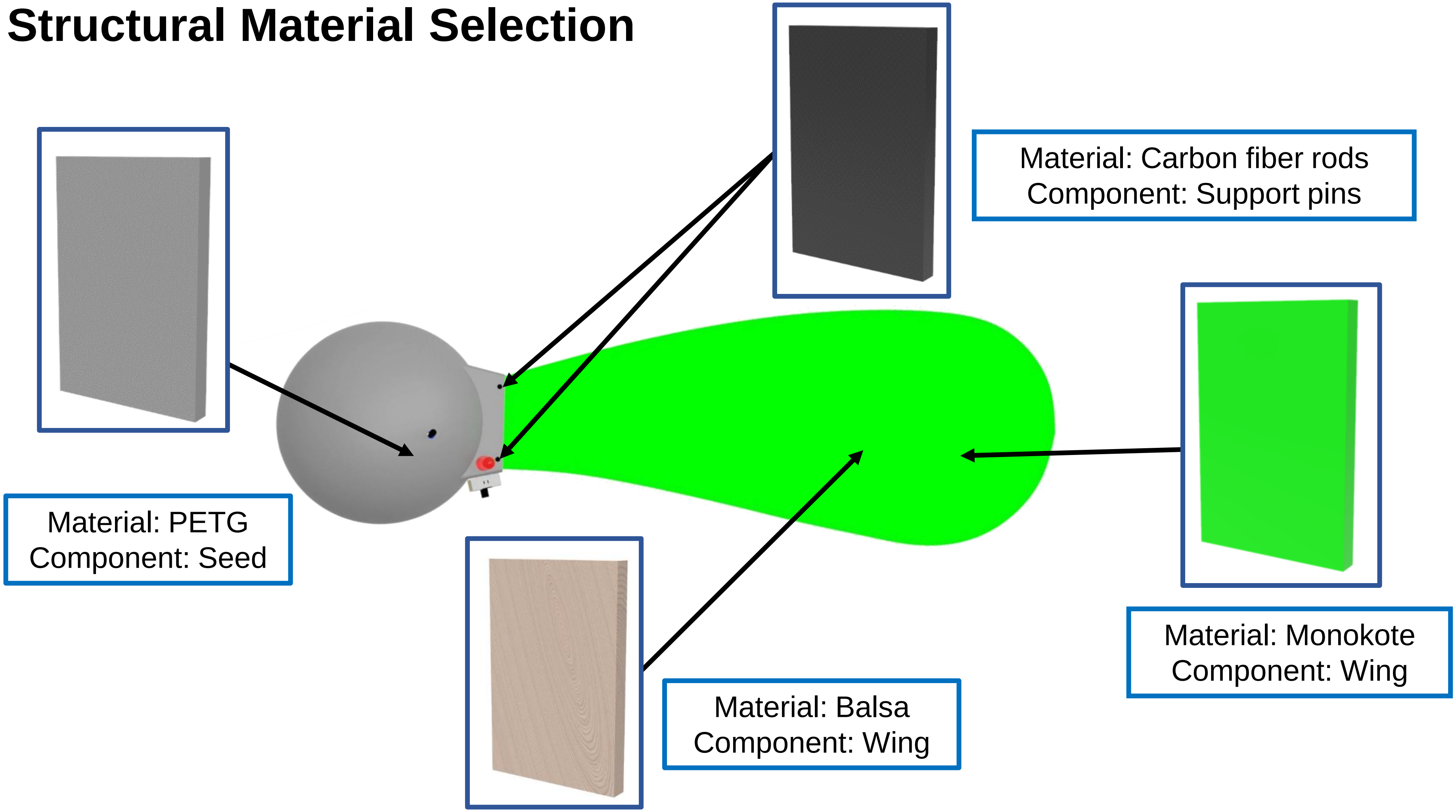
Connectors and fasteners are used to lock the seed

Structural Material Selection

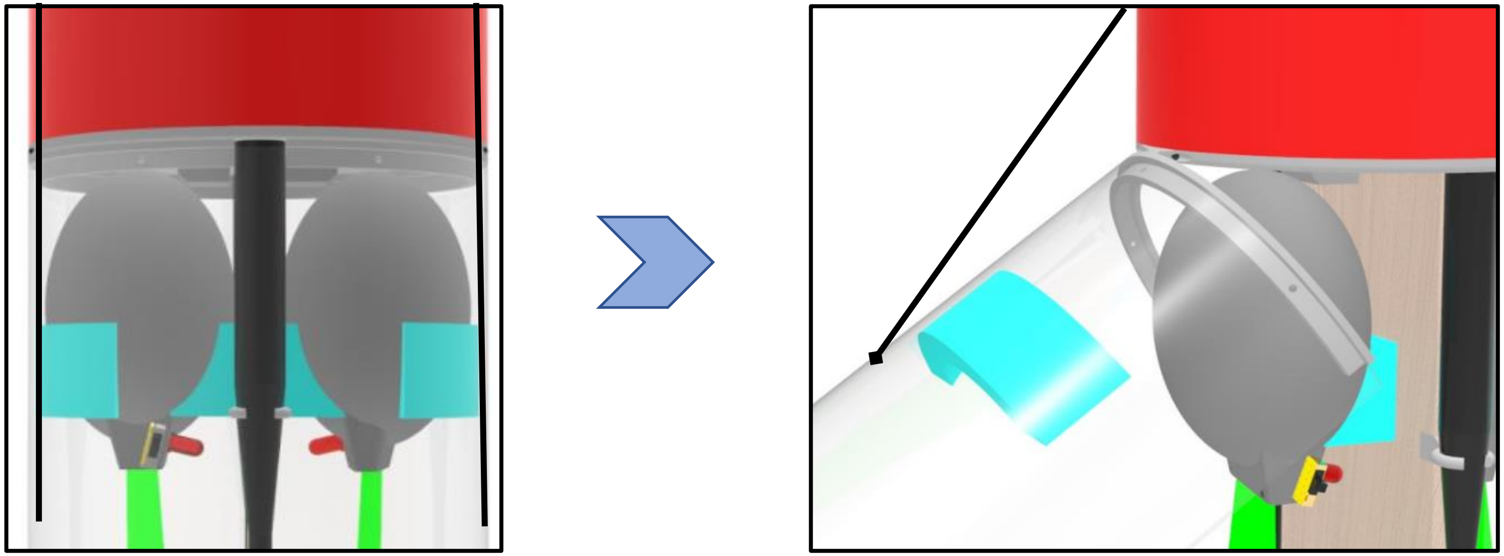
Components	Materials Selected
Payload Seed	3D printed PETG
Payload Wing	Balsa with fluorescent green monokote
Seed-Wing Attachment Point	3D printed PETG

Payload Mechanical Layout of Components (6/8)

Structural Material Selection



Container Attachment Points and Payload stowed configuration(3D extrusions)

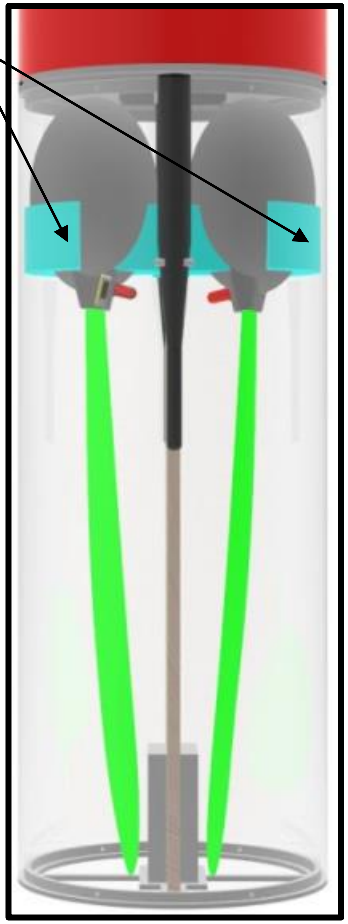


- 3D printed PETG extrusions on either side of partition wall and the inner side of container doors hold the payloads firmly before release
- Fishing wire holds the container doors in stowed configuration until deployment.
- Nichrome wire cuts the fishing line on either sides of the partition at respective altitudes which releases the tension on the elastic bands holding the container doors and deploying the payloads.

Payload Mechanical Layout of Components (8/8)

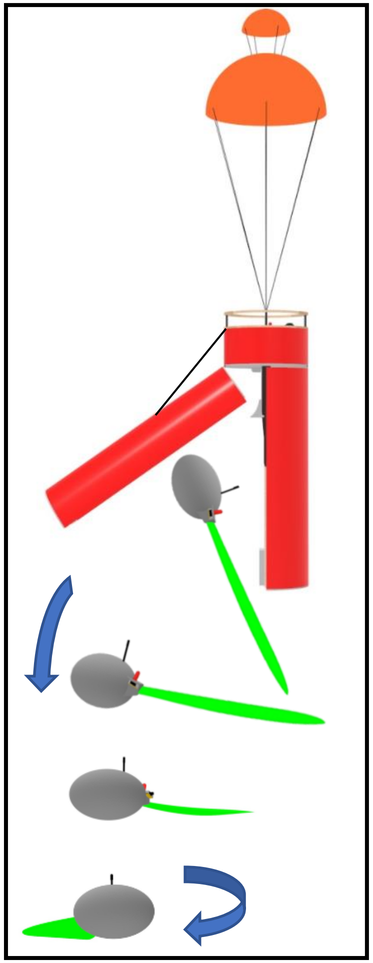
3D extrusions

The fishing line holds the container doors in undeployed position which aid the 3D extrusions to hold the payloads in the container in stowed configuration



Payload in Stowed Configuration

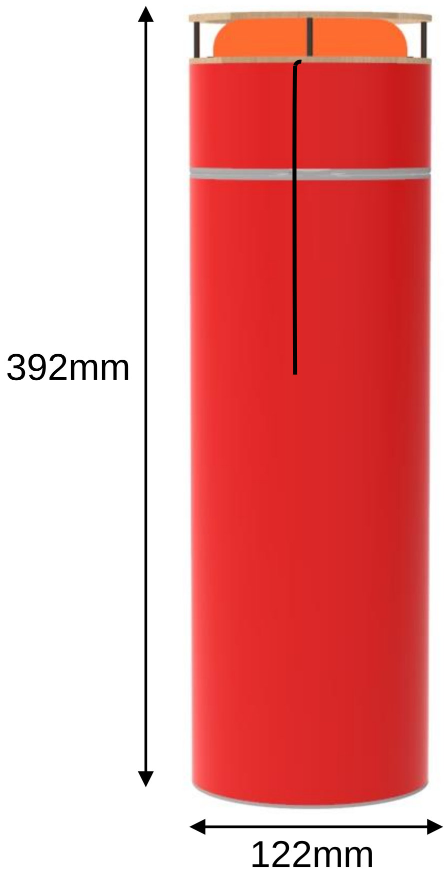
Nichrome wire is breaks the fishing line to aid the container door open and deploy the payloads at different heights

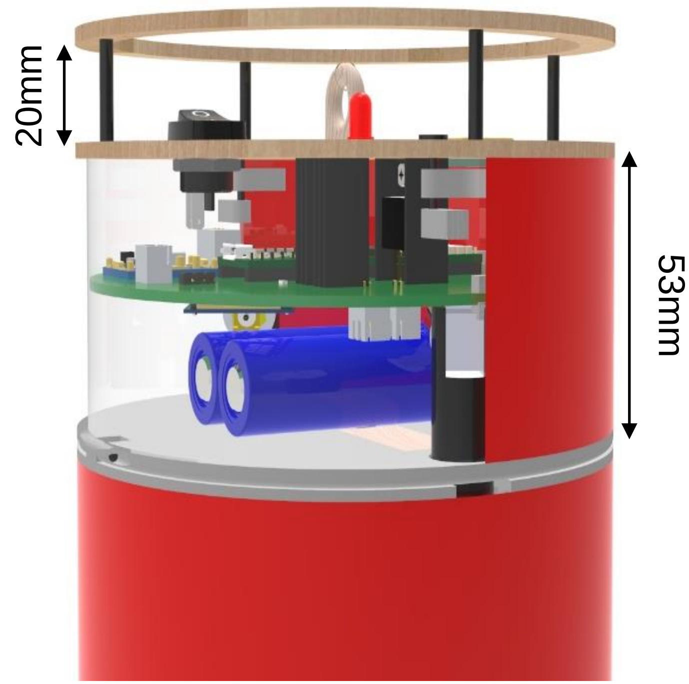


Payload in Deployed Configuration

Container Mechanical Layout of Components (1/10)

Container CAD model with dimensions

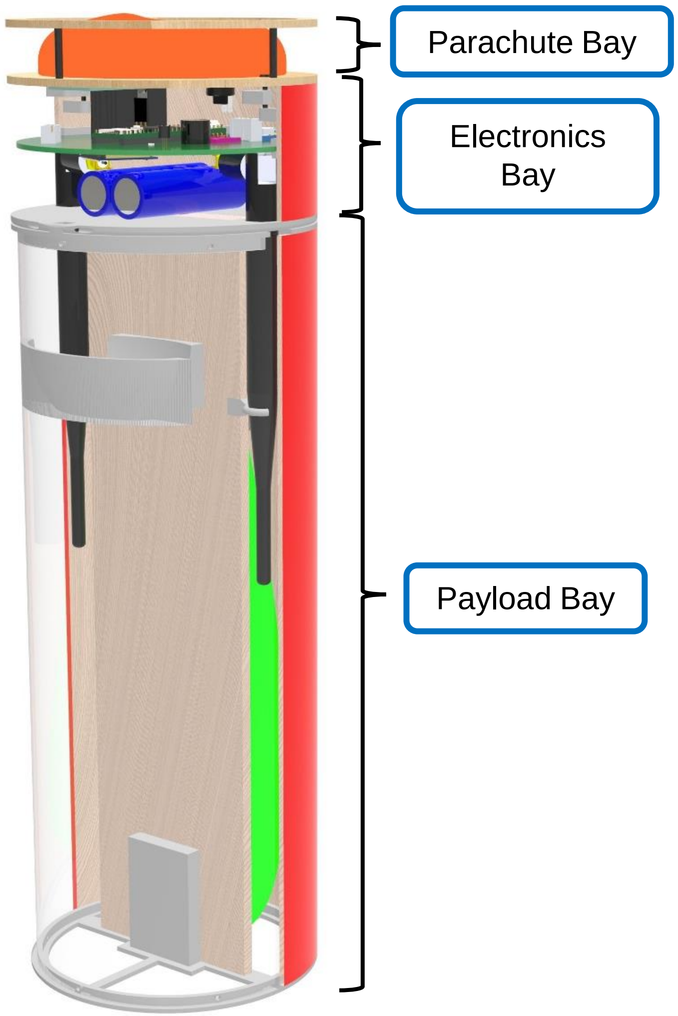




Container Mechanical Layout of Components (2/10)

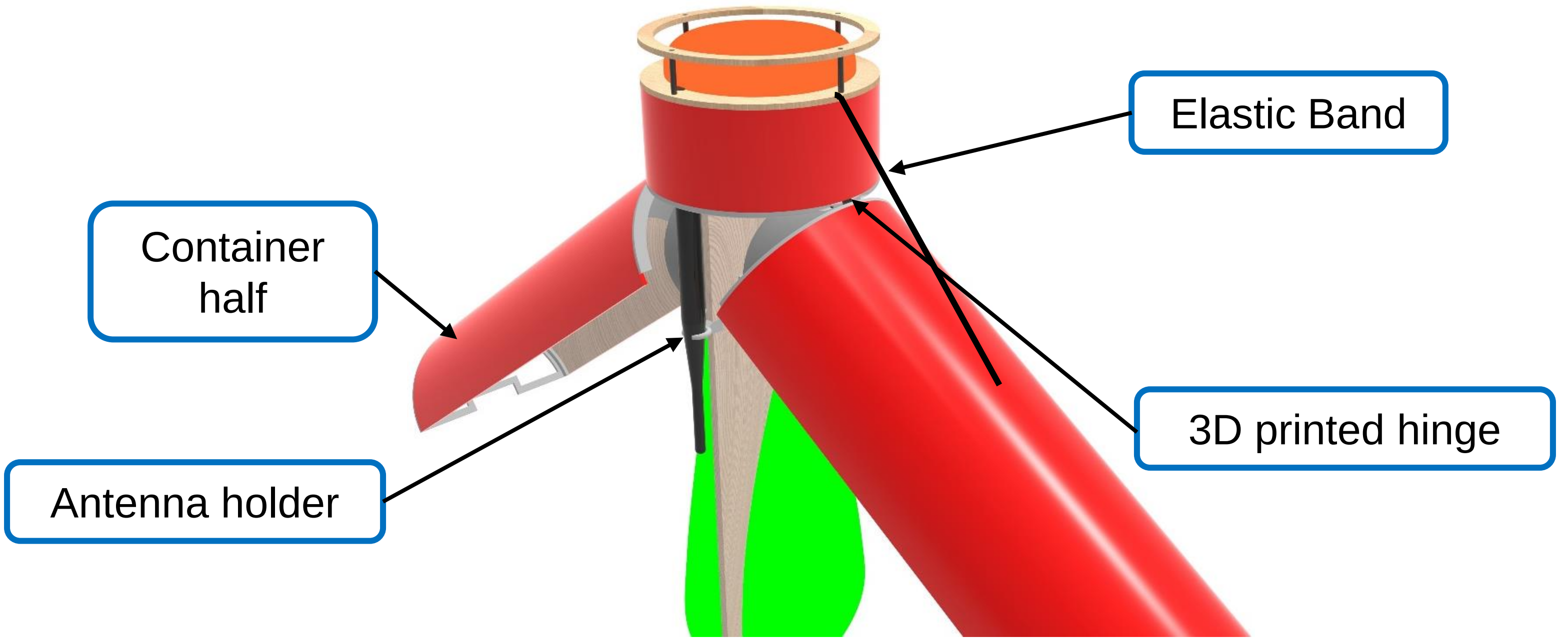
Container Structure

- There are no sharp edges, and the outer surface is smooth. This facilitates an easy deployment from the rocket.
- Divided into three parts - the parachute bay, electronics bay and the payload bay.
- The parachute bay contains the parachute and the swivel.
- The electronics bay houses all the electronics mounted on the PCB which in turn is mounted on the 3D printed PCB slots.
- The payload bay houses the payloads and the antennas.
- The CG of the container is (after the deployment of both the payloads) maintained at the upper part of the container with the help of batteries and electronic components.
- The camera stabilization mechanism is lodged at the bottom of the partition to record the release and descent of the payloads.



Container Mechanical Layout of Components (3/10)

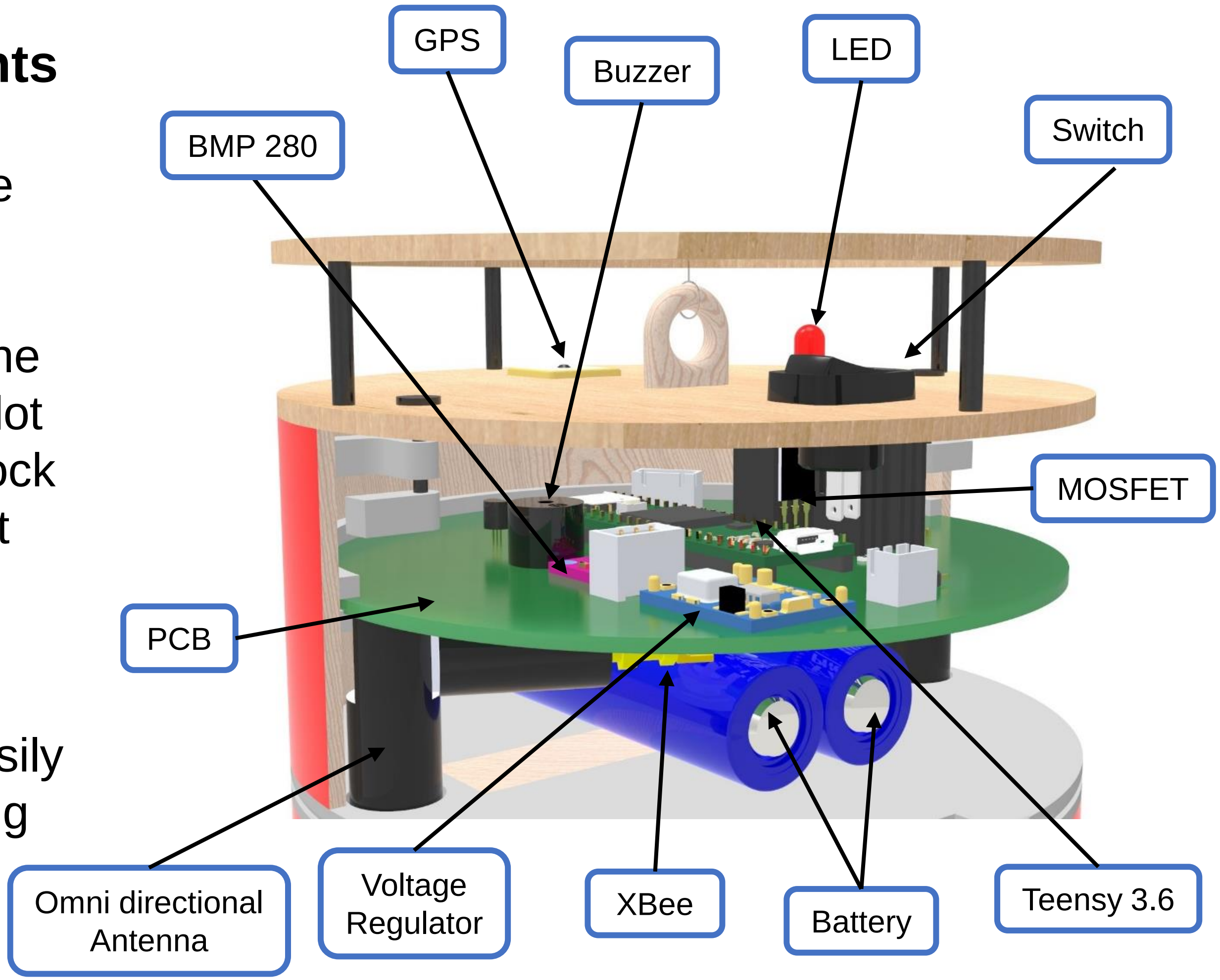
- Fishing lines are used to keep the container in closed configuration while the container descends
- 3D printed hinges and elastic bands are used to open the container door for the release of the science payloads at their respective heights
- The doors of the container keep the payloads intact during the launch such that it is fully enclosed.
- Parachute uses wind resistance as a passive mechanism for deployment



Container Mechanical Layout of Components (4/10)

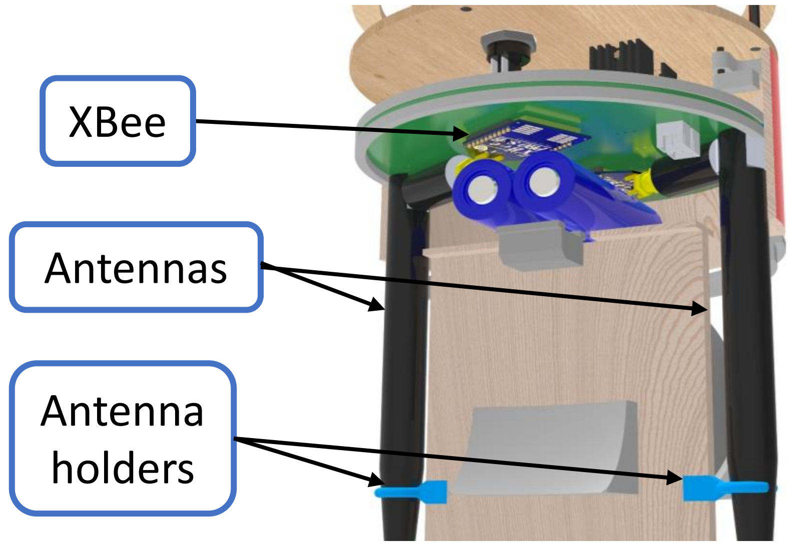
Electronic Components

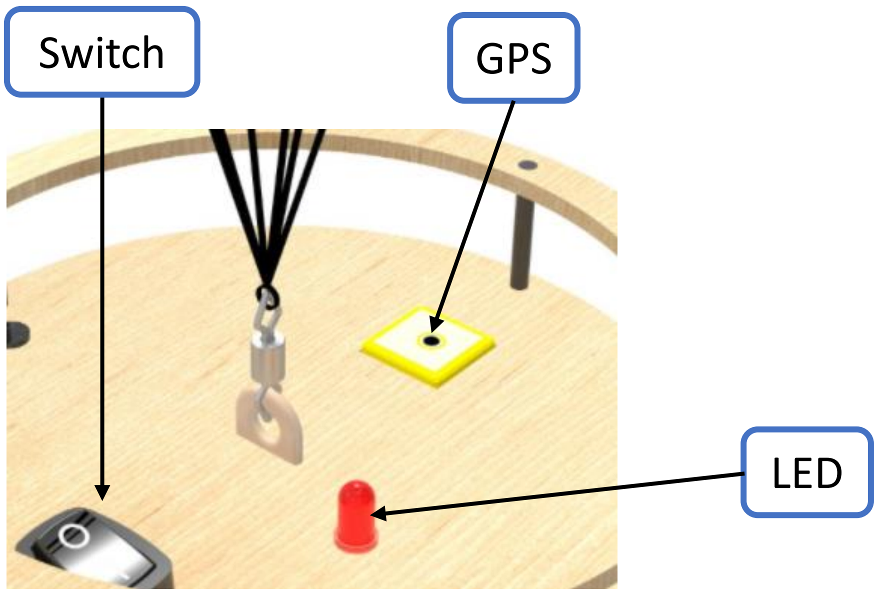
- The electronics bay of the container houses all the electronic components.
- The PCB is placed with the help of 3D printed PCB slot which protects it from shock due to violent deployment from the rocket.
- The batteries are placed below the PCB.
- The electronics bay is easily accessible with pin-locking mechanism.



Container Mechanical Layout of Components (5/10)

- The GPS module, switch and LED are lodged on the parachute plate for easy access.
- The placement of the electronics on PCB facilitates an easy routing.

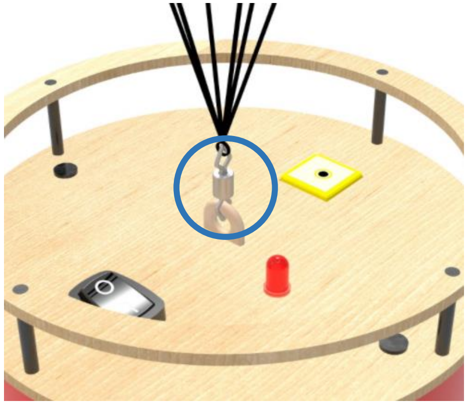




- The XBees and the antennas are placed on the lower side of the PCB for an easy relay with the payloads.
- Antennas are kept in place with the help of antenna holders, which are along the partition of the container

Container Mechanical Layout of Components (6/10)

Major Mechanical Parts and Attachment points

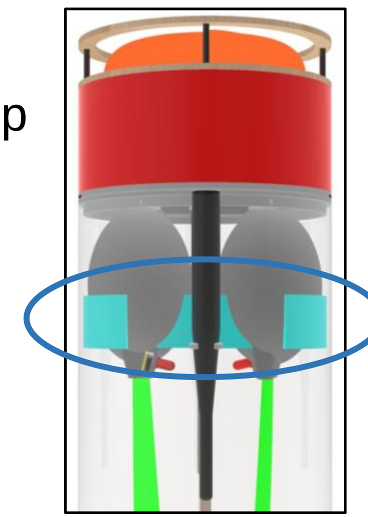


Swivel

- Swivel prevents the parachute strings from getting tangled and ensures free rotation of the parachute about its central axis by making its rotation independent and ensures that the tension on the strings is reduced.

3D printed extrusions

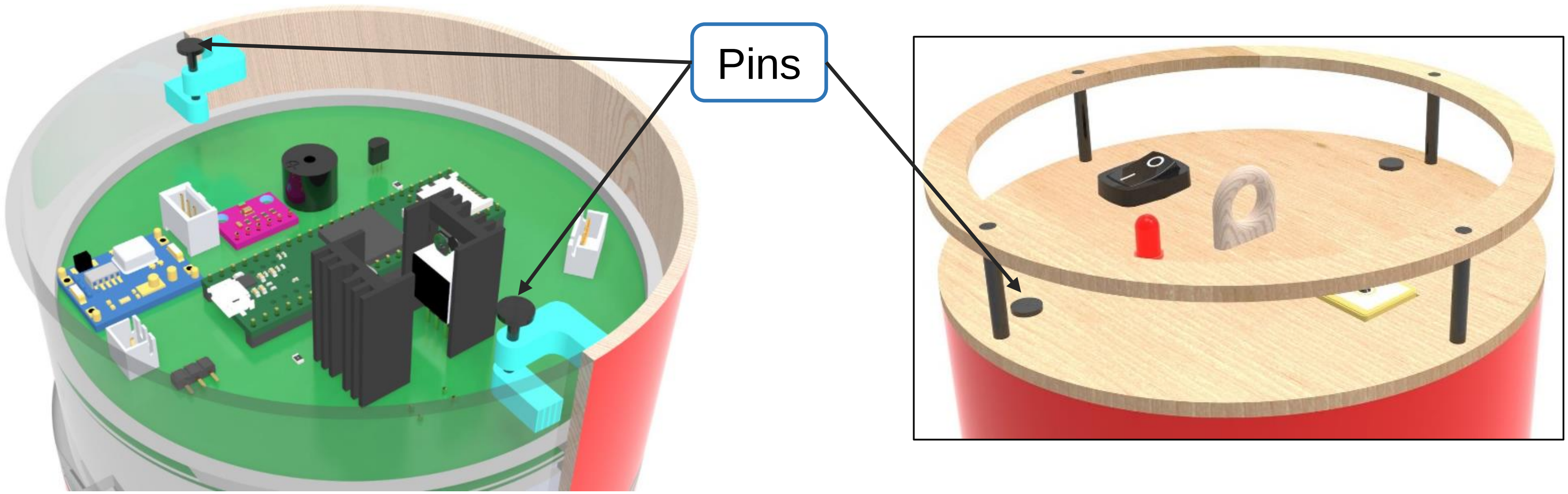
- Each payload is stowed and locked in the container with the help of 3D printed extrusions made from PETG
- The 3D printed extrusions are designed in such a way that the seed fits right into the extrusions when the container is closed (seed facing upwards)
- These extrusions provide stability and rigid support while withstanding the launch.



Major Mechanical Parts and Attachment points

Pin-locking mechanism (Electronic bay)

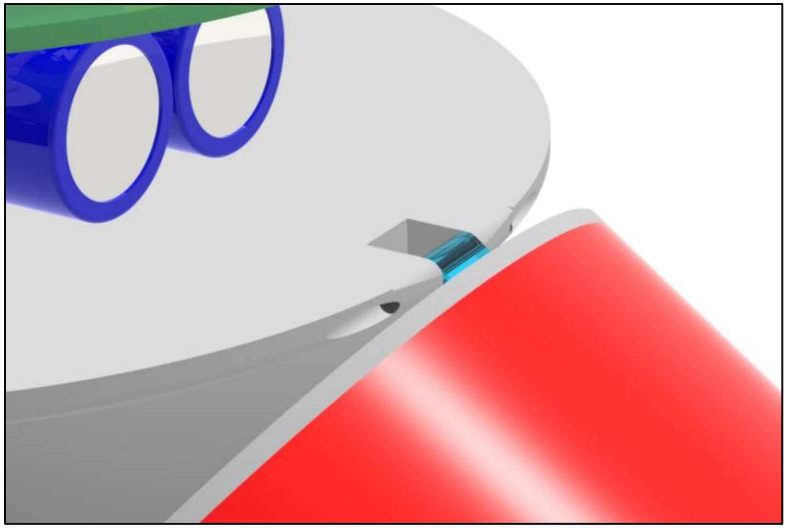
- Pin-locking mechanism is used in electronics compartment.
- This design allows the electronics compartment in the container to be easily accessible in less than a minute without complete disassembly.
- With one half of the electronics compartment being detachable, the two halves are fastened by aligning the holes of the 3D extrusions and passing pin through it.

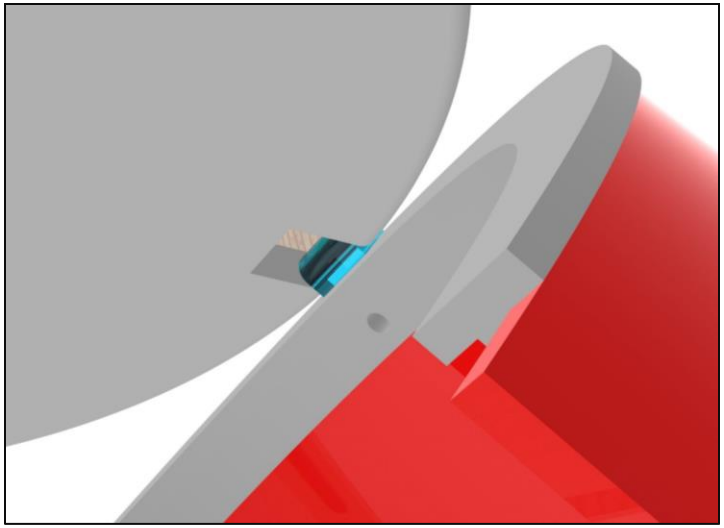


Major Mechanical Parts and Attachment points

Container Door Hinge

- A slot is made on bottom plate of electronic compartment with a carbon fiber rod passing through it.
- 3D printed hinge mounted on the container door lodges in the slot of the bottom plate and the CF rod
- This hinge mechanism provides better strength and movement of door.





Container Mechanical Layout of Components (9/10)

Structural Material Selection:

Component	Material used
Container cover, Electronics compartment	Balsa with fiberglass coating
Top ring, parachute plate	Birch plywood
Bottom ring, 3D extrusion, camera slot, antenna holder, PCB slot	PETG
Parachute	Ripstop nylon
Parachute strings	Nylon ropes
Partition	Balsa

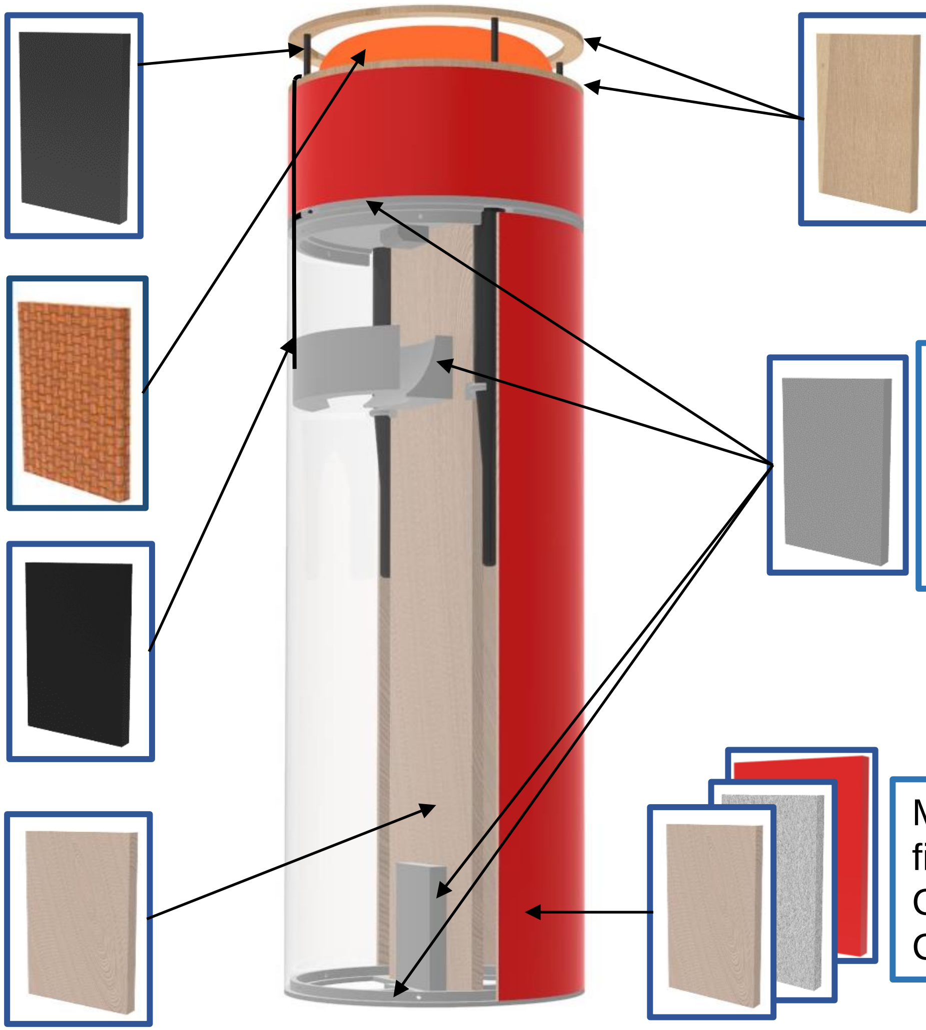
Container Mechanical Layout of Components (10/10)

Material: Carbon fiber rods
Component: Supporting rods

Material: Ripstop Nylon
Component: Parachute

Material: Rubber
Component: Elastic band

Material: Balsa
Component: Divider wall



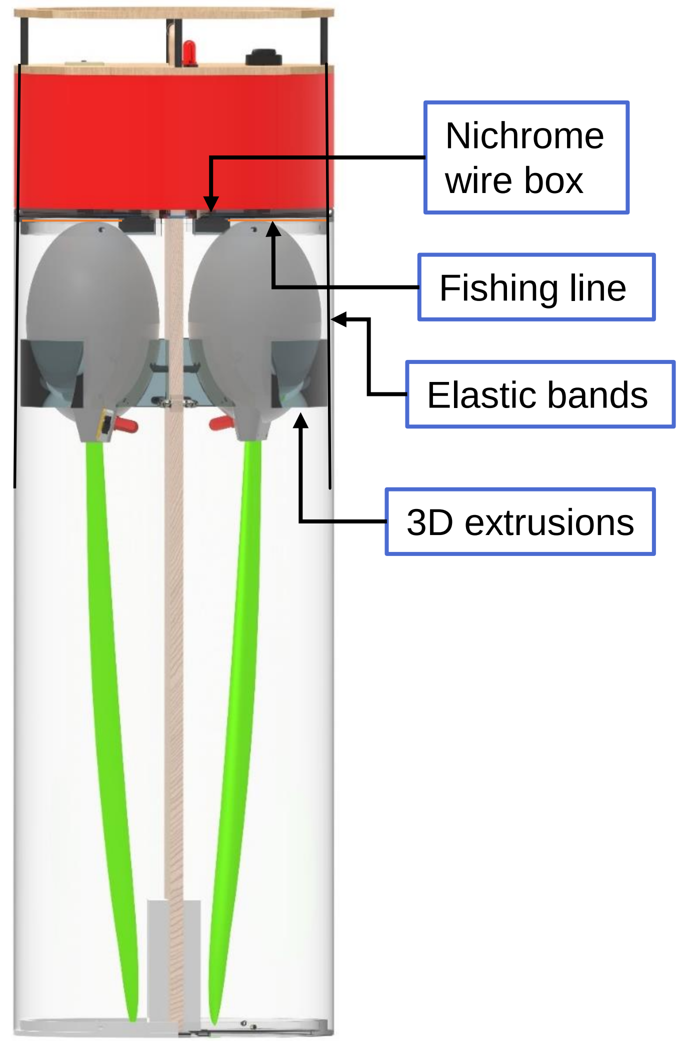
Material: Birch ply
Component: Top ring and parachute plate

Material: 3D printed PETG
Component: door hinge, camera slot, 3D extrusion

Material: Balsa + fiberglass, Red Monokote
Component : Container Cover

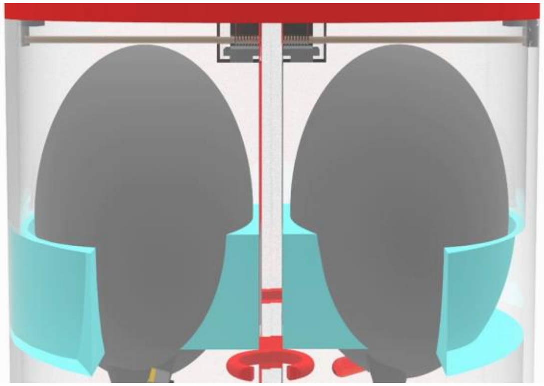
Payload Release Mechanism (1/2)

- 3D printed extrusions hold the payload intact inside the container in a position (seed is facing upwards) to achieve autorotation quickly after release.
- Nichrome wire is used as the release mechanism for the payloads.
- It is placed inside the box provided under the electronics compartment.
- Fishing line keeps each section of the container closed.
- At 500m and 400m, a high current of 1.5A is supplied momentarily to the nichrome wire for each payload respectively.
- The nichrome wire burns and cuts the fishing line.
- The halves of the container open with the help of elastic bands, and the payload is deployed at respective heights from the ground.



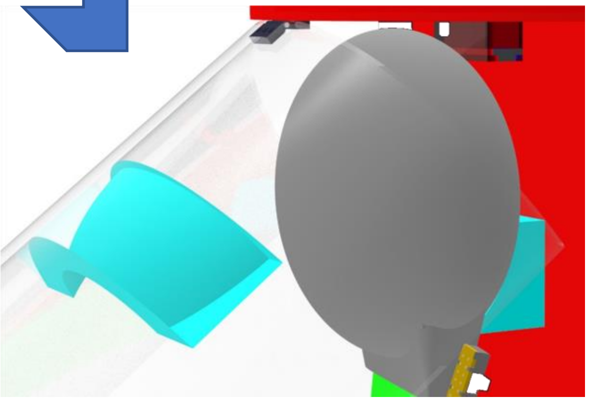
Payload Release Mechanism (2/2)

Release mechanism design:



3D extrusions present on either side of the partition wall and on the inner side of the container doors hold the payloads firmly before release.

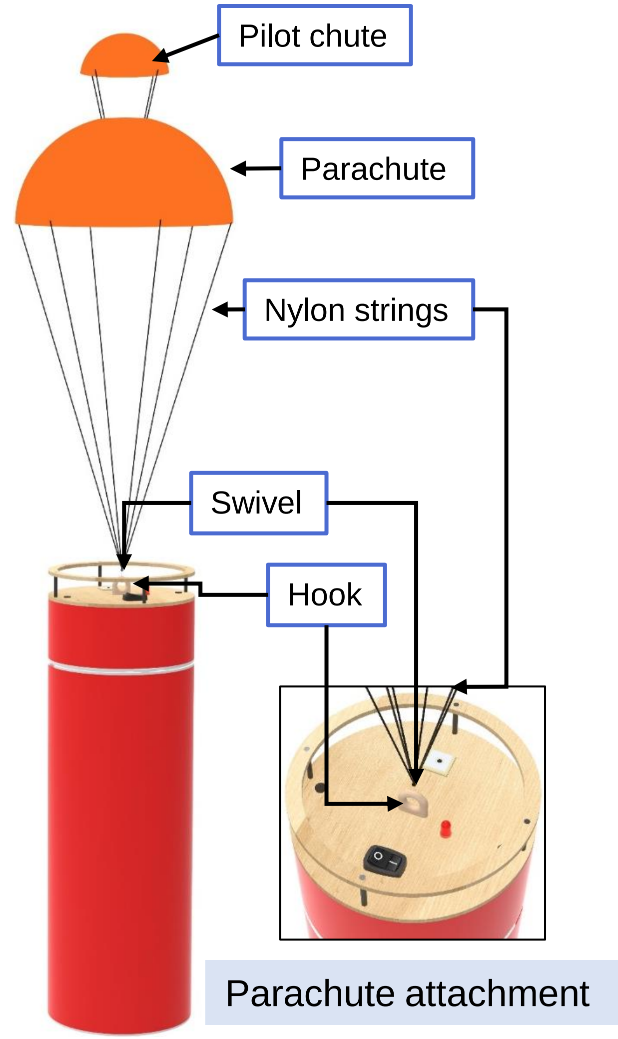
Fishing line connected to the nichrome wire holds the container doors in tension from inside.



Nichrome wire cuts the fishing line, releasing the tension on the elastic band holding the container doors for deploying the payload.

Attachment to container design:

- The parachute is attached to the container with the help of nylon strings.
- The parachute strings will be tied to a swivel, which in turn is attached to a hook placed on the top plate.
- The swivel ensures free rotation of the parachute about its central axis which ensures that the tension on the strings is reduced and prevents the parachute strings from getting tangled.
- The parachute will initially be stowed in the container on the base plate of the parachute compartment.
- After the deployment of the CanSat from the rocket, the air gushes into the parachute **opening it passively**.
- A pilot chute is used as a small auxiliary parachute used to deploy the main parachute.

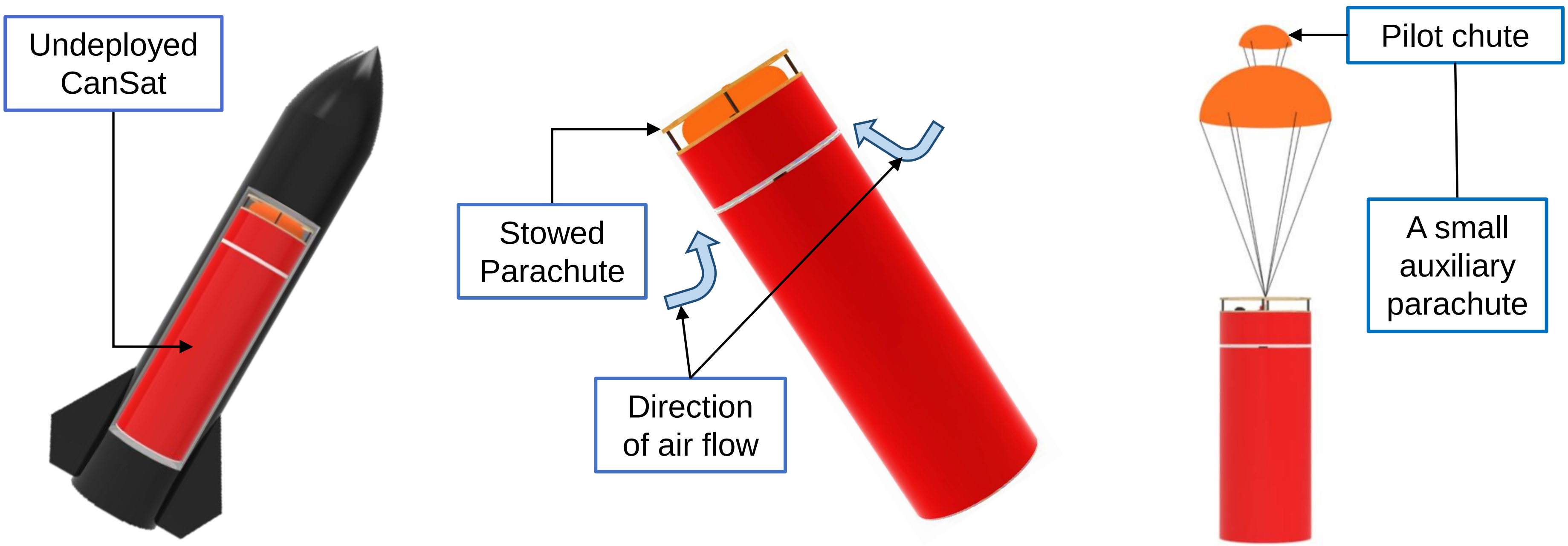


Parachute attachment

Container Parachute Attachment Mechanism (2/2)

Parachute deployment

- Due to the air gushing inside, the parachute immediately rises up and opens.
- The swivel allows free rotation of the parachute to prevent tangling of strings and to reduce the tension on them.



Rocket with undeployed CanSat	CanSat just after deployment	Completely deployed CanSat

3D printed slots in the seed and adhesives are used to hold the PCB and its contents firmly in place.

Electronic components are enclosed in the seed made up of 3D printed PETG.

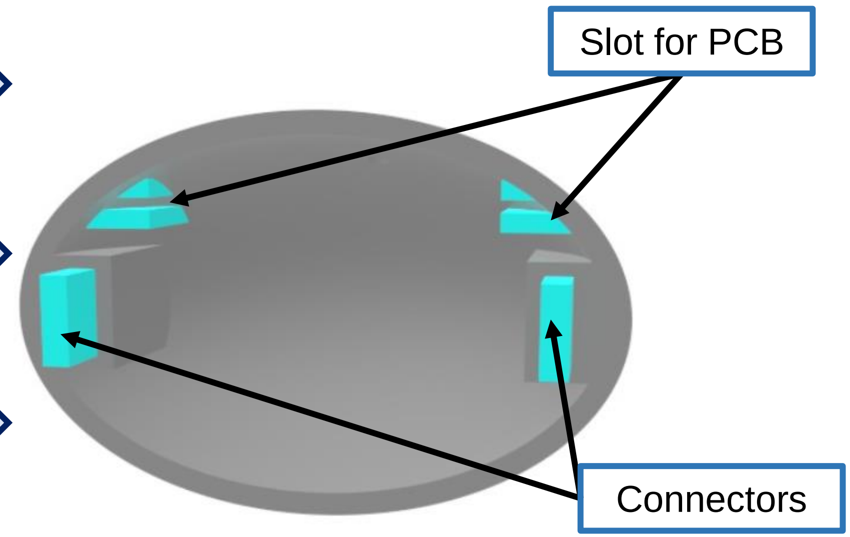
Depending on the component, appropriate methods such as soldering, electric tapes and adhesives are used to secure connections.

The connector-fastener mechanism was further ensured by adding adhesives to prevent the seed disassembly during its descent

The microcontroller is placed on the bottom layer of the PCB.

The battery is stowed below the PCB in the payload to ensure the correct position of CG.

PCB slot measures 17.88 mm in length, 8.98 mm in breadth and 1.68 mm in height and is present along the walls of the payload, two on each halves of the seed.



Both halves of the seed have 3D printed slots for PCB.

Structure Survivability (2/5)

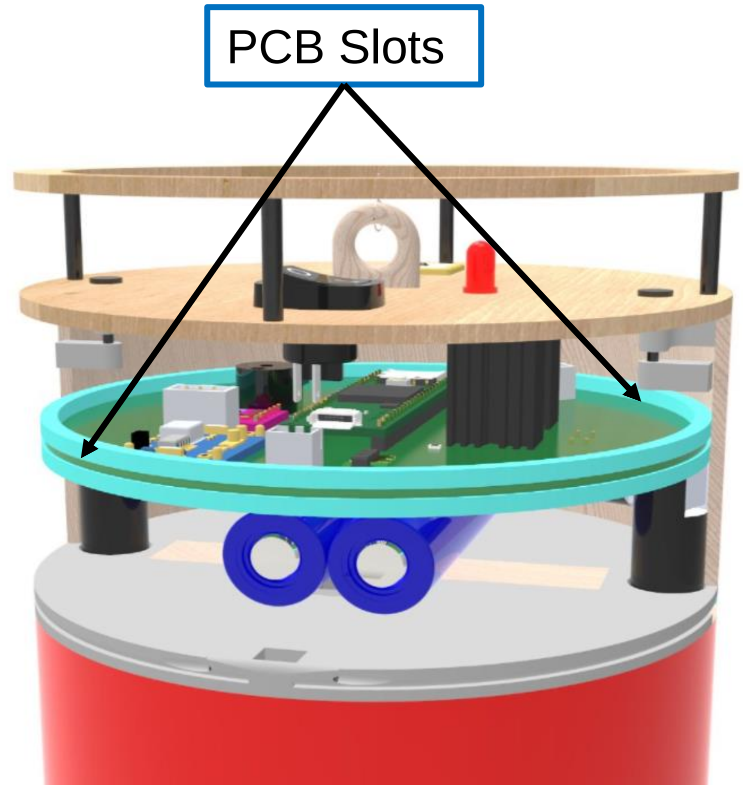
The container PCB is held in the 3D printed PCB slot located in the electronics bay to survive shock and acceleration force.

Except for the hook and swivel, there are no descent control attachments.

The electronics can be accessed using the Pin-locking mechanism and no spring contacts are used for making electrical connections to the battery.

Depending on the component, proper methods such as soldering, nylon screws, electric tapes and adhesives are used to secure connections.

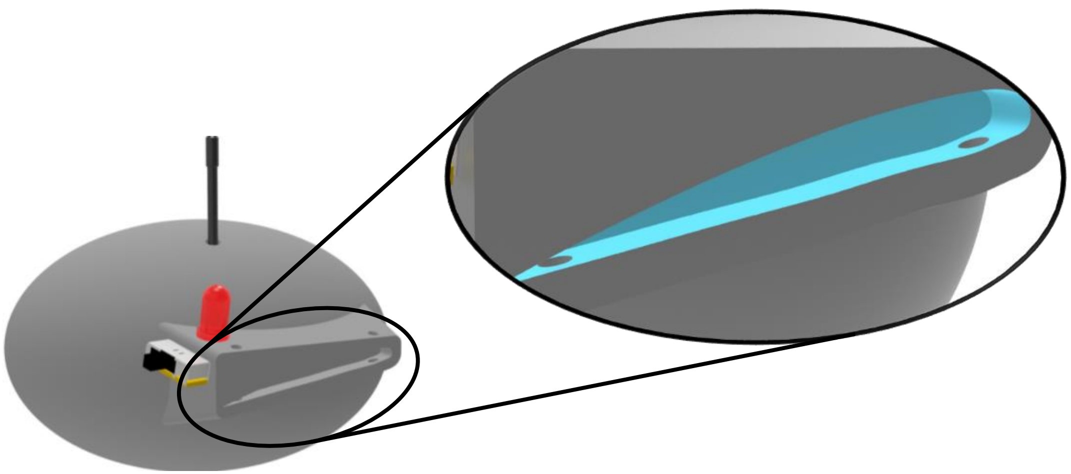
The switch and LED are fixed in the parachute compartment to be accessible at all times. All the container electronics have been mounted using proper techniques.

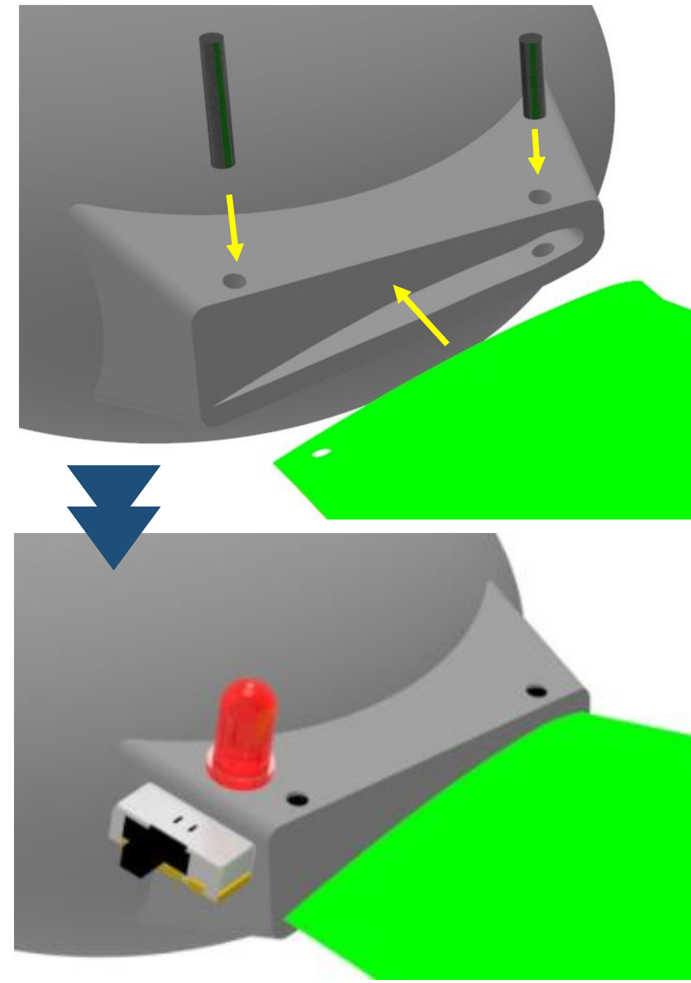


The PCB slot measures 120 mm in diameter and 4 mm in height

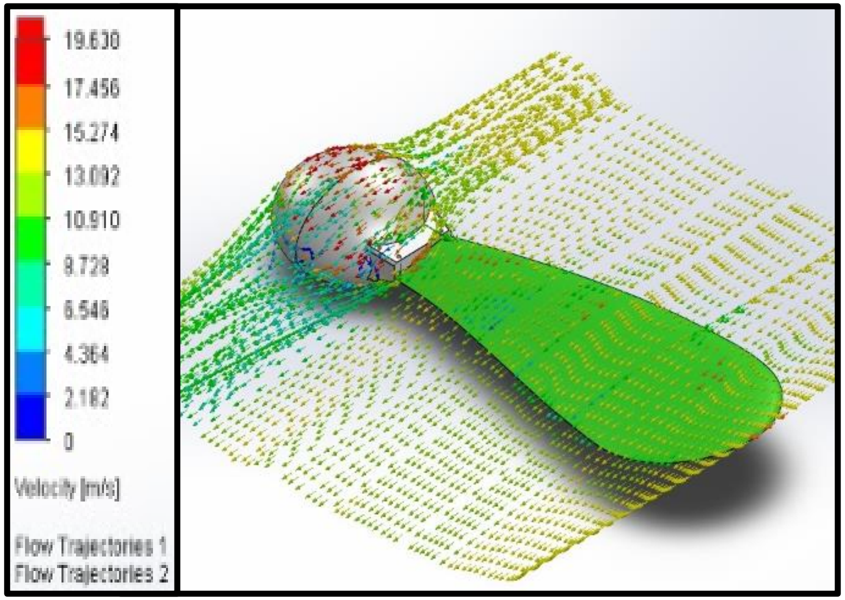
Descent Control Attachment

- In order to attach the wing to the seed, an extrusion was made on one half of the seed known as wing attachment slot.
- The shape of the slot is same as that of the wing root.
- The wing is lodged inside the slot and locked using support CF pins.

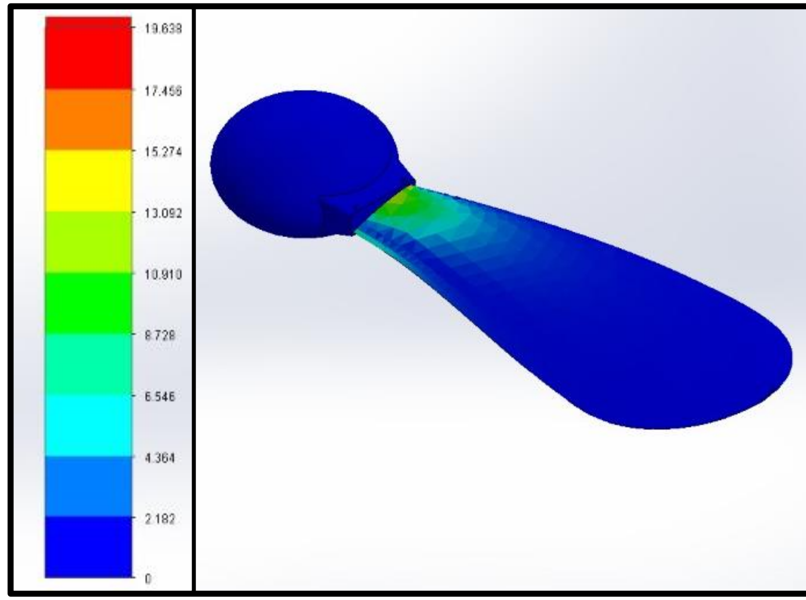




Payload Simulation:



Flow simulation analysis

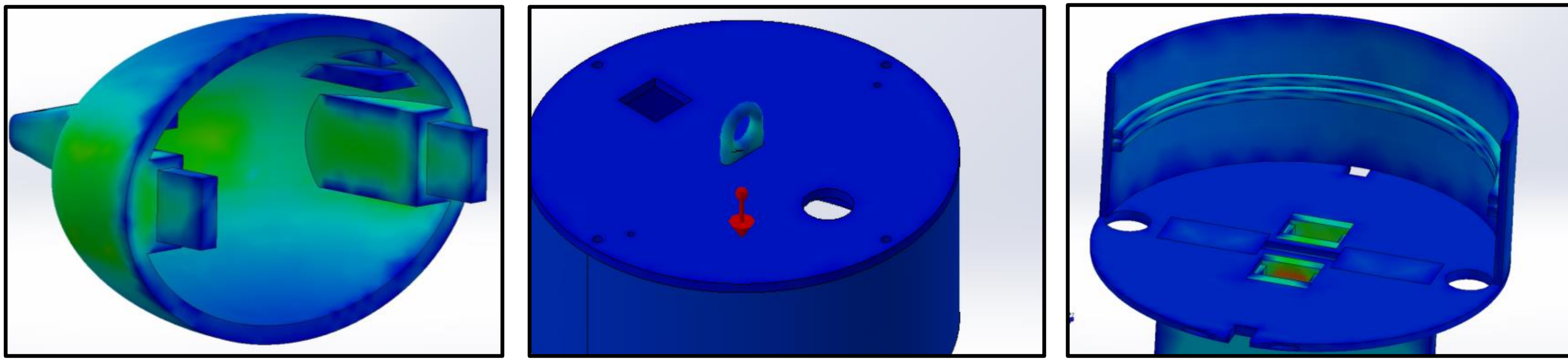


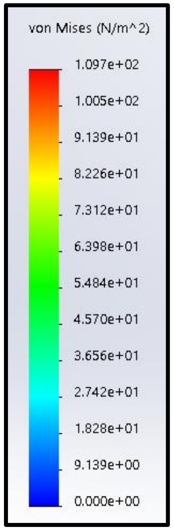
Stress simulation analysis

According to our calculated horizontal velocity of the wing, the flow simulation shows that sufficient lift was generated to make autorotation possible.

Stress simulation analysis was performed on the payload with shock load of 30Gs. The wing, descent control attachments and all the components inside the seed survived the drop test of the payload.

Structure Survivability (5/5)

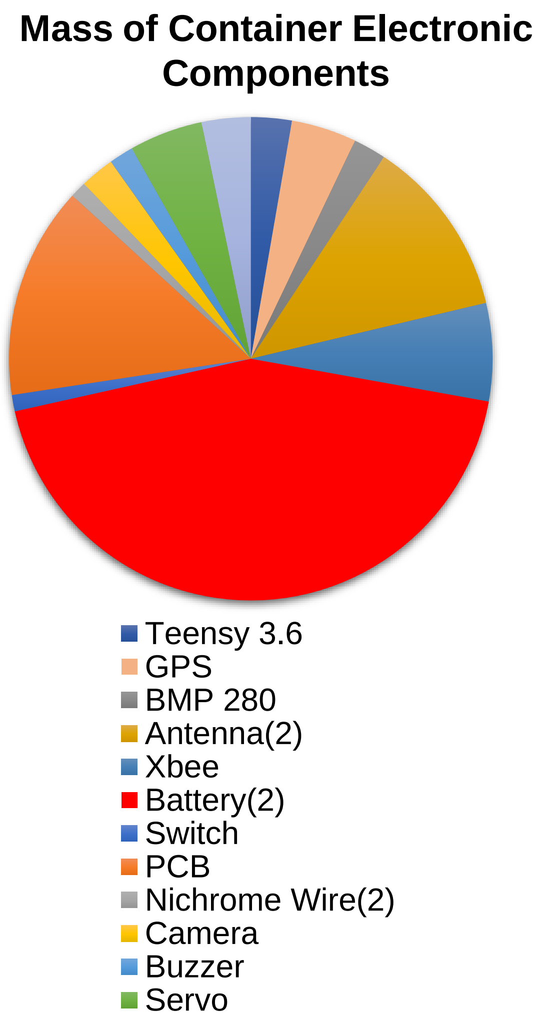




- The infill percentage of PETG for the PCB slots of the container and the payloads was decided after running stress simulations with the desired parameters.
- Simulations were carried out on the container-parachute **descent control attachment** (hook) which was found to survive shock load of 30Gs and launch acceleration of 20 Gs. Later, all the components of the CanSat underwent the environmental tests to verify the same

Mass Budget (1/5)

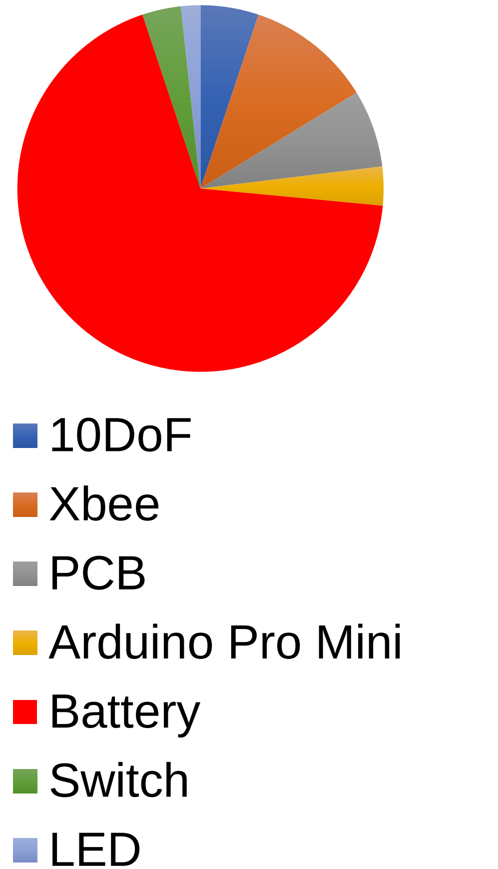
	Component (xNo.)	Mass per component (gm)	Source
Container	Teensy 3.6 +SD card	5±0.1	Data sheet
	GPS	8±0.1	Data sheet
	BMP 280	4±0.1	Data sheet
	Antenna (x2)	22±1	Data sheet
	XBee (x2)	10±0.2	Data sheet
	Battery (x2)	80±1.5	Measured
	Switch	2±0.1	Data sheet
	PCB	25±0.4	Measured
	Nichrome wire (x2)	2±0.1	Measured
	Camera + SD card	4.2±0.1	Data sheet
	Buzzer	3±0.1	Measured
	Servo + Servo arm	9±0.2	Data sheet
	Others	7±1	Measured
	Total	181.2±5gm	



Mass Budget (2/5)

	Component	Mass per component (gm)	Source
Payload (x2)	10DoF	3±0.1	Data Sheet
	XBee	6.5±0.1	Data Sheet
	PCB	4±0.5	Data Sheet
	Arduino Pro Mini	2±0.1	Measured
	Battery	40±0.8	Measured
	Switch	2±0.1	Measured
	LED	1±0.1	Measured
	Total	58.5±1.8gm	

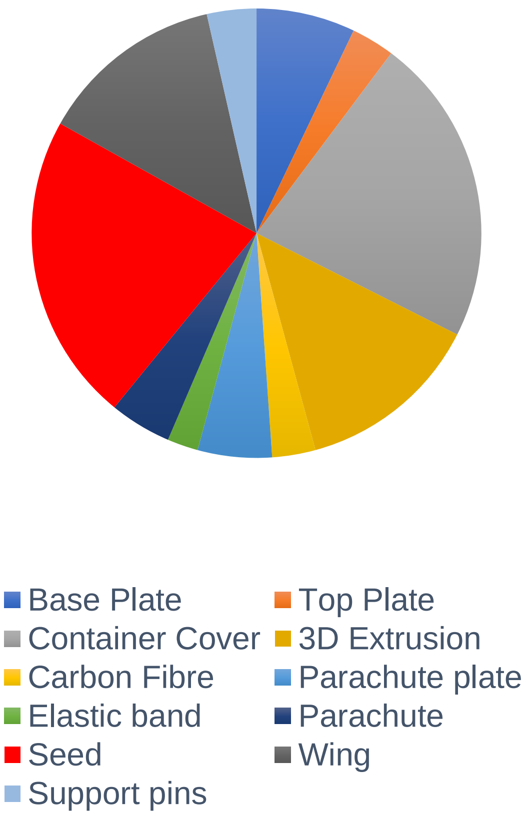
Mass of Payload Electronic Components



Mass Budget (3/5)

	Component	Mass per item (gm)	Source
Container	Base Plate	16±0.6	Measured
	Top ring	7±0.2	Measured
	Container Cover(Balsa + fiberglass composite)	50±1	Measured
	3D Extrusion(PETG)	18±0.8	Measured
	Carbon fiber rods	8±0.1	Data Sheet
	Parachute plate	12±0.8	Measured
	Elastic band	5±0.2	Data Sheet
	Parachute	10±0.2	Measured
	Total	126±3.9gm	
Payload (x2)	Seed	50±1	Measured
	Wing	30±0.5	Measured
	Support pins	4±0.1	Data Sheet
	Total	84±1.6gm	

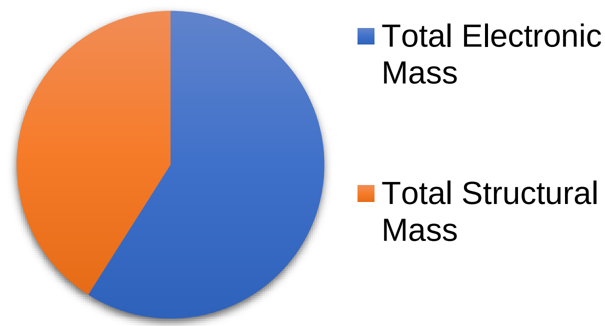
Mass of CanSat structural components



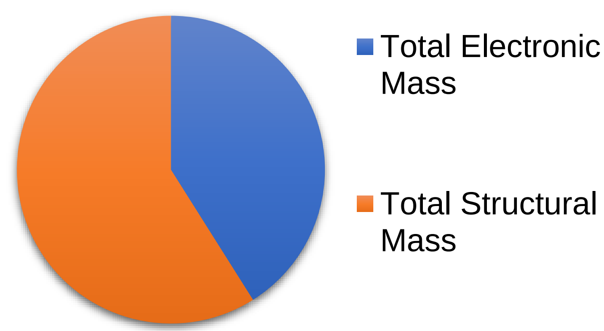
Mass Budget (4/5)

Container		Payload (x2)	
Total Electronic Mass	181.2±5gm	Total Electronic Mass	117±3.6
Total Structural Mass	126±3.9	Total Structural Mass	168±3.2gm
Total Mass	307.2±8.9	Total Mass	285±6.8
Total Mass of CanSat		592.2±15.7	

Container



Payload



Mass Budget (5/5)

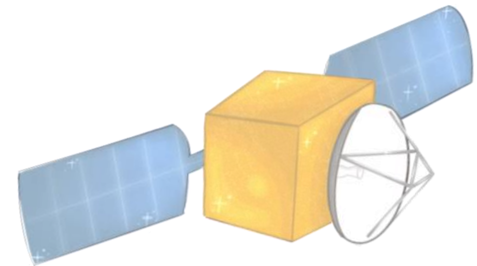
Total Mass of CanSat	592.2gm

- **Total Mass Margin of CanSat = $|600–592.2| = 7.8$gm**

<u>Correction method</u>

- If the mass of the CanSat <590gm, a ballast weight will be added to the seed at the center of gravity to maintain stability.
- If the mass of the CanSat >610gm, container with thinner walls will be used.

This will ensure that the total mass of CanSat is 600 ± 10gm and the competition requirement is fulfilled.



Communication and Data Handling (CDH) Subsystem Design

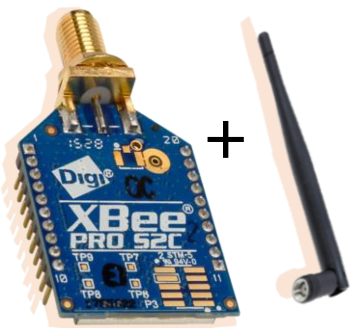
Presenter's Name: Shweta Chavan

CDH Overview (1/2)

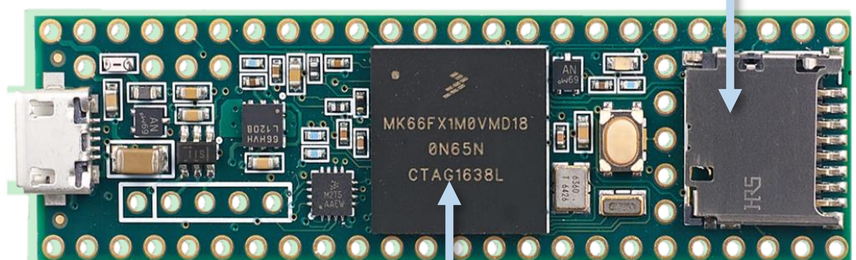
Container Overview

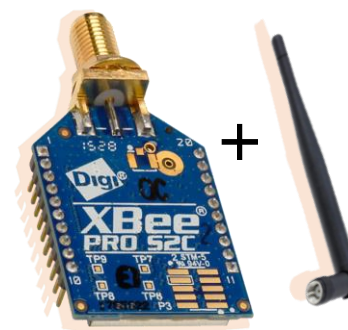
<u>Built-In RTC</u>:
Helps in keeping track of total mission time

The in-built SD Card Slot houses the San Disk SD Card which stores the telemetry data



Teensy 3.6





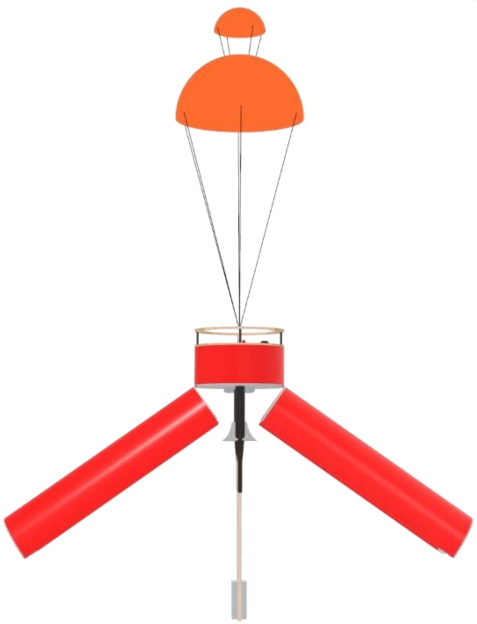
Transmission of data from Container to XBee at Ground Station

The brain of the whole subsystem efficiently handles the data between communication and sensor subsystem

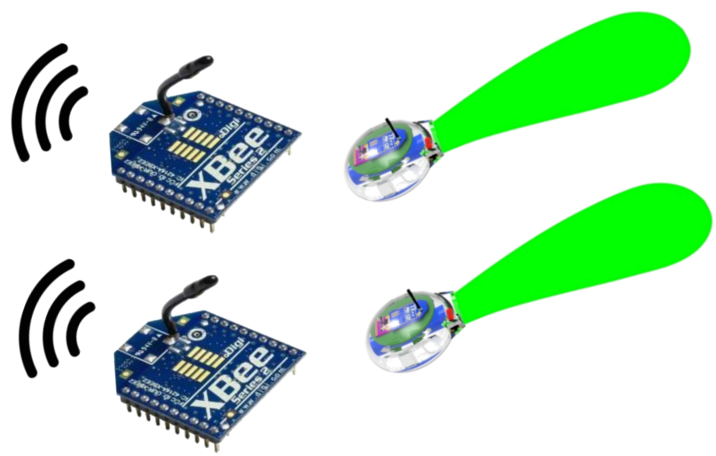
Transmission of data from XBee in Payloads to Container XBee

CDH Overview (2/2)

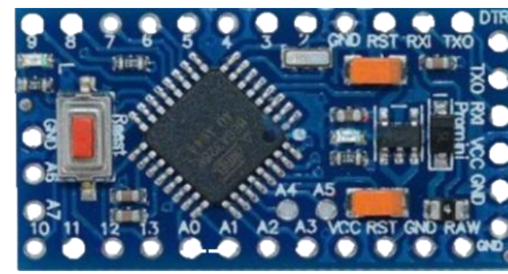
Payload Overview



Transmission of all telemetry data



Arduino Pro Mini



The main control centre for the Sensor System in payloads

XBee transmits sensor data collected by Arduino Pro Mini to the XBee present in the container

Arduino Pro Mini present in the payload sends the payload sensor data via the XBee

CDH Changes Since PDR

No changes have been made to the Communication and Data Handling (CDH) Subsystem Design since the PDR.

CDH Requirements (1/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR19	XBee radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBee radios are also allowed.	Req	Very High		√		
#CR20	XBee radios shall have their NETID/PANID set to their team number.	Req	Very High		√		
#CR21	XBee radios shall not use broadcast mode.	Req	Very High		√		
#CR25	The science payload shall measure altitude using an air pressure sensor.	Req	Very High	√		√	√
#CR26	The science payload shall measure air temperature.	Req	Very High	√		√	√

CDH Requirements (2/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR27	The science payload shall measure rotation rate as it descends.	Req	Very High	√		√	√
#CR28	The science payload shall transmit all sensor data once per second.	Req	Very High	√		√	√
#CR29	The science payload telemetry shall be transmitted to the container only.	Req	Very High		√	√	√
#CR31	The container shall include electronics to receive sensor payload telemetry.	Req	Very High	√		√	√
#CR32	The container shall include electronics and mechanisms to release the science payloads.	Req	Very High	√		√	√

CDH Requirements (3/4)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR33	The container shall include a GPS sensor to track its position.	Req	Very High	✓		✓	✓
#CR34	The container shall include a pressure sensor to measure altitude.	Req	Very High	✓		✓	✓
#CR35	The container shall measure its battery voltage.	Req	Very High	✓		✓	✓
#CR36	The container shall transmit its telemetry and the payload telemetry received once per second in the format described in the Telemetry Requirements section.	Req	Very High	✓	✓	✓	

CDH Requirements (4/4)

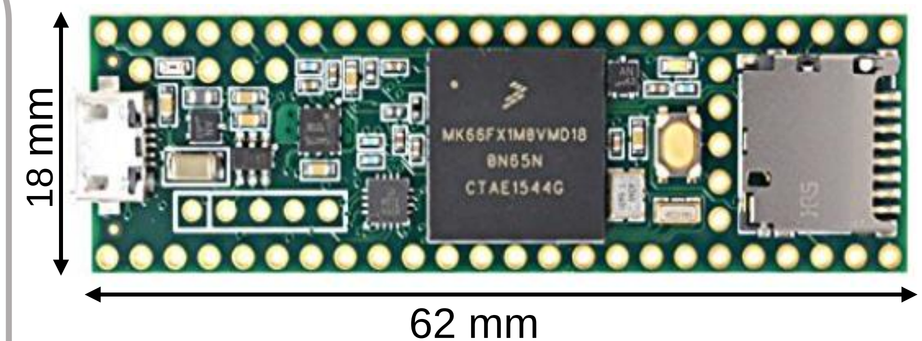
Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR37	The container shall stop transmitting telemetry when it lands.	Req	Very High		✓	✓	
#CR40	An audio beacon is required for the container. It may be powered after landing or operate continuously.	Req	Very High	✓	✓		
#CR60	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Req	Very High		✓		

Container Processor & Memory Selection (1/3)

Microcontroller	Supply Voltage (V)	Processor Speed (MHz)	Boot Time (s)	Memory	Data Interfaces	Cost (₹)
Teensy 3.6	**3.6-6**	**180**	**1**	**256KB - Flash 1MB - RAM 4KB - EEPROM**	**UART - 6 SPI - 3 I2C - 4**	**2900.00**

Selected Microcontroller : Teensy 3.6

- **It has 22 PWM pins, 25 analog input pins, 2 analog output pins and 62 digital pins**
- Extensive compatibility with Arduino IDE and ease of programming
- Possess built-in real time clock which is used to calculate total time of the mission
- Contains an on-board SD card slot
- Multiple communication interfaces



Overall, Teensy 3.6 is perfect for the mission application, as it is lightweight, fast, has multiple interfaces and communication channels with simplicity in programming.

Container Processor & Memory Selection (2/3)

Features of Teensy 3.6

Supply voltage	3.6 to 6V
Boot Time	1s
Power Consumption	0.522Wh
Weight	4.9gm
Processor Speed	180MHz
Total No. of pins	62
Data Bus Width	32 Bit
Dimensions (in mm)	62.3*18.0*4.2
I2C Interfaces	4
SPI Interfaces	3
UART Interfaces	6
No. of PWM Pins	22
Flash Memory	1024KB
RAM	256KB
EEPROM	4KB
Operating Voltage	3.3V

Container Processor & Memory Selection (3/3)

Component Name	Data transfer rate (MBps)	Weight (gm)	Storage (GB)	Cost (₹)
SanDisk Micro SD Card	98	<1	16	350.00

Selected Memory: SanDisk Micro SD Card

- Fulfils the mission requirements
- High data transfer rates
- Easily accessible
- Easy availability and low cost

- **Read Speed (MBps) : 40**
- **Write Speed (MBps) : 10**

Container Real-Time Clock

Component Name	Size	Weight	Hardware/ Software	Interface	Cost (₹)
Teensy 3.6 Internal RTC	**Included on the Microcontroller**		**Hardware**	**-**	**No additional cost**

Selected RTC : Teensy 3.6 Internal RTC

- Sufficient as per requirement
- No extra component required
- In reset condition, Teensy 3.6 reads for the last data that is available in memory
- **Reset tolerance:** the data of payload and container will be saved in the internal EEPROM of the Teensy 3.6 during the power failure, in this way data loss will be prevented
- Frequency of Crystal Oscillator is **32.768 kHz**

The RTC is powered by a separate 3V CR2032 coin cell

Container Antenna Selection (1/2)

Model	Gain (dBi)	Dimensions (mm)	VSWR	Impedance (Ω)	Range (Km)	Interface	Cost (₹)
2.4GHz Male Omni Antenna	5	Height: 210	≤2	50	1.75	RP – SMA	550.00

Selected Antenna : 2.4GHz Male Omni Antenna

- Interface compatible with XBee
- Suitable radiation pattern
- High gain
- Economically feasible

- **Weight** of the Antenna is **11 grams**
- **Height** of the Antenna is **210 mm**

These dimensions are compatible with the mechanical design of our CanSat

The 2.4GHz Male Omni Antenna is used for the Container-to-Ground link as well as Container-to-Payload link.

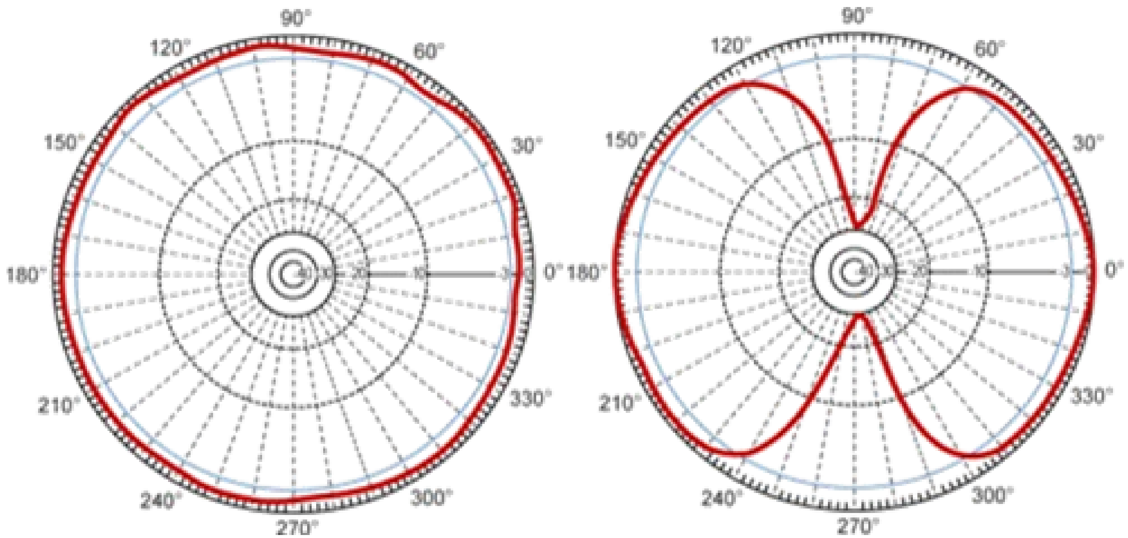
Container Antenna Selection (2/2)

Performance

- Maximum Voltage Standing Wave Ratio (VSWR) value is **1.92:1**. This value increases the performance significantly such that **90.1%** of power is transmitted to the antenna while **9.9%** is reflected to the Tx radio
- Sufficient polarization rates:

➢ Horizontal Polarization Beam Width: **360°**

➢ Vertical Polarization Beam Width: **152°**



Azimuthal Elevation

Radiation pattern of the 2.4GHz Male Omni Antenna

Container Radio Configuration (1/3)

Model	Operating Frequency	Supply Voltage (V)	Range (Km)	RF Data Rate (Kbps)	Transmit Power (mW)	Sensitivity (dBm)	Cost (₹)
XBee Pro S2C	2.4 GHz	2.7-3.6	3.2	250	63	-101	2150.00

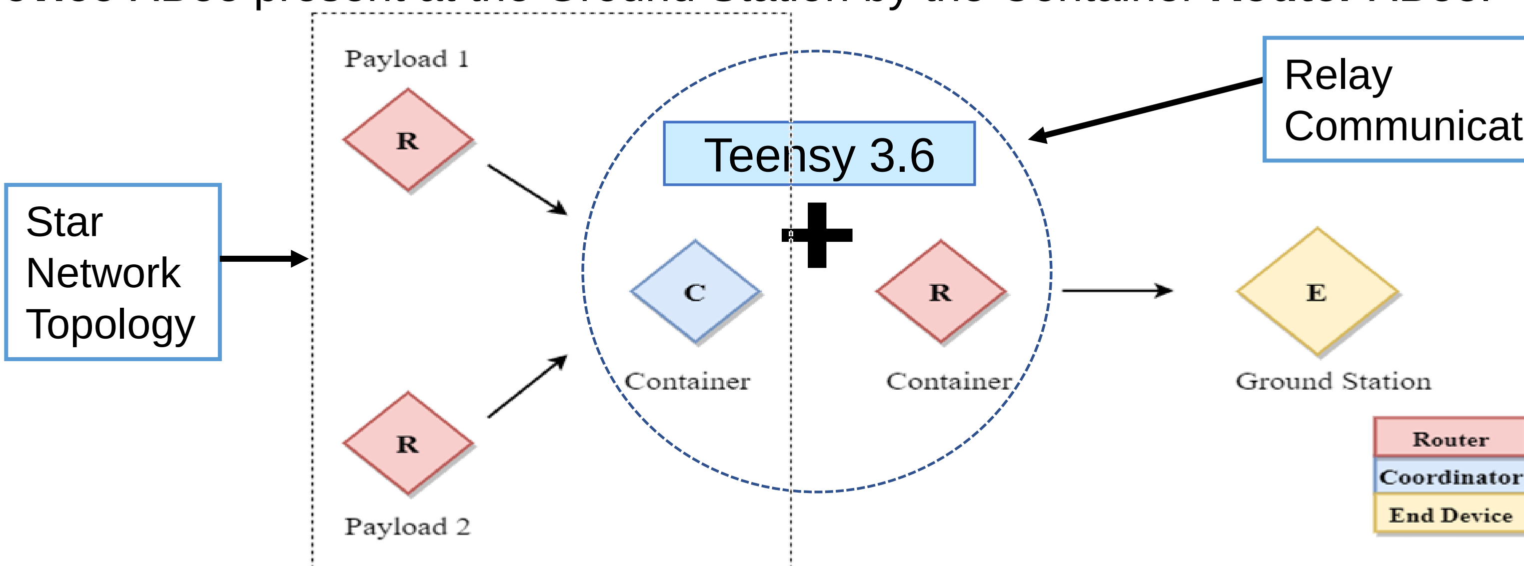
Selected Radio : XBee Pro S2C

- Sufficient transmit power
- Easy to configure
- Low cost and easily available
- Reliable experience
- The XBee Pro S2C variant has an RP-SMA antenna connector

XBee-Pro S2C is used for the Container-to-Ground link as well as Container-to-Payload link

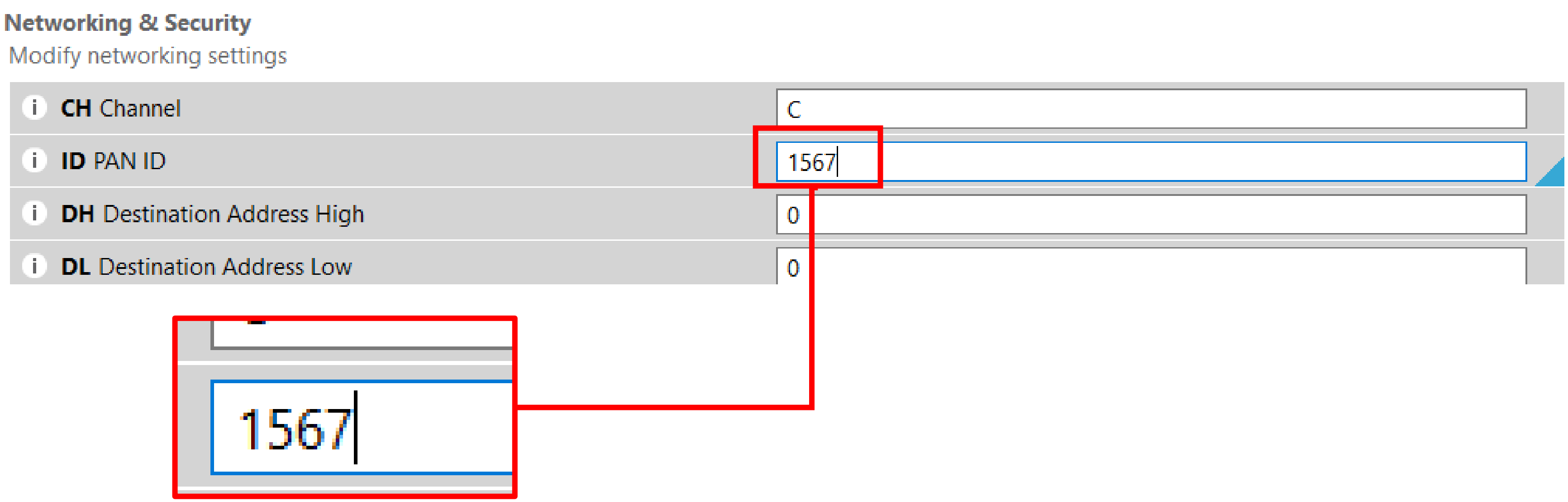
Container Radio Configuration (2/3)

- The relay communication in the container takes place with the help of two XBees and microcontroller (Teensy 3.6).
- The two **Router** XBees of the payload will transmit their respective telemetry data to the **Coordinator** XBee present in the container. This is achieved by setting the three XBees in a **Star Network Topology.**
- The Container **Coordinator** XBee will relay the transmitted data to the **Router** XBee of the Container with the help of Teensy 3.6.
- Next, all the telemetry data (Container + Payload) will be transmitted to the **End-Device** XBee present at the Ground Station by the Container **Router** XBee.



Container Radio Configuration (3/3)

- The NETID/PANID of the Container **Router** and Ground Station **End-Device** XBee is set as the Team ID **#1567** using XCTU software.
- Data is transmitted at a frequency of **1 Hz** as per the mission guidelines.
- Both the XBees communicate in **unicast mode** not in broadcast mode.
- Transmission is controlled using flight software of container during each phase of descent with the help of the two XBee modules.
- **After landing the audio beacon is activated and transmission is ceased.**



- The antenna range while testing was found to be **1.4 km**

Container Telemetry Format (1/4)

Sr No.	Field	Explanation	Resolution
1	<TEAM_ID>	Assigned team identification	1567
2	<MISSION_TIME>	Time since initial power up	1s
3	<PACKET_COUNT>	Count of transmitted packets (maintained after processor reset)	1
4	<PACKET_TYPE>	ASCII character representing telemetry	-
5	<MODE>	Exhibit the mode of the CanSat	-
6	<SP1_RELEASED>	Exhibit the state of release of Payload1	-
7	<SP2_RELEASED>	Exhibit the state of release of Payload 2	-
8	<ALTITUDE>	Altitude relative to the ground level	0.1 meters
9	<TEMP>	Sensed temperature	0.1 °C
10	<VOLTAGE>	Voltage of CanSat power bus	0.1 volts
11	<GPS_TIME>	GPS receiver generated UTC time	1 second
12	<GPS_LATITUDE>	Latitude generated by GPS receiver	0.0001 degree

Container Telemetry Format (2/4)

Sr No.	Field	Explanation	Resolution
13	<GPS_LONGITUDE>	Longitude generated by GPS receiver	0.0001 degree
14	<GPS_ALTITUDE>	Altitude generated by GPS receiver above mean sea level	0.1 meters
15	<GPS_SATS>	Number of GPS satellites being tracked by the GPS receiver	1
16	<SOFTWARE_STATE>	Operating state of the software	1
17	<SP1_PACKET_COUNT>	Count of transmitted packets of payload 1 (maintained after processor reset)	1
18	<SP2_PACKET_COUNT>	Count of transmitted packets of payload 2 (maintained after processor reset)	1
19	<CMD_ECHO>	Fixed text command ID and argument of the last received command	-
20	<BONUS DIRECTION>	Direction pointed by the camera relative to the earth's magnetic North specified in degrees	1 degree

Container Telemetry Format (3/4)

- Data will be transmitted at the rate of **1Hz** in bursts
- The telemetry data file for container will be named as **Flight_1567_C.csv**, where **1567** is our **Team ID**
- The telemetry data shall be transmitted with ASCII comma separated fields followed by a carriage return
- The first four telemetry fields are common to both Container and Payloads

- The container telemetry frames are represented in the following format:

  <TEAM_ID>, <MISSION_TIME>, <PACKET_COUNT>, <PACKET_TYPE>, <MODE>, <SP1_RELEASED>, <SP2_RELEASED>, <ALTITUDE>, <TEMP>, <VOLTAGE>, <GPS_TIME>, <GPS_LATITUDE>, <GPS_LONGITUDE>, <GPS_ALTITUDE>, <GPS_SATS>,<SOFTWARE_STATE>,<SP1_PACKET_COUNT>, <SP2_PACKET_COUNT>, <CMD_ECHO>,<BONUS_DIRECTION>

- The relayed payload telemetry frames are represented in the following format:

  <TEAM_ID>, <MISSION_TIME>, <PACKET_COUNT>, <PACKET_TYPE>, <SP_ALTITUDE>, <SP_TEMP>, <SP_ROTATION_RATE>

Container Telemetry Format (4/4)

- Example format for the Container Telemetry:

<1567>, <13:22:42>, <42>, <C>, <F>, <R>, <R>, <302.35>, <23.4>, <9.12>, <17:47:36.0>, <02132.0341>, <4897.5625>, <332.12>, <5>, <3>, <SP2_RELEASE>, <53>, <32>, <CXON>,<10>

- Example format for the respective relayed Payload Telemetry:

<1567>, <13:22:42>, <23>, <S1>, <362.13>, <23.42>, <32.21> (For Payload1)

<1567>, <13:22:42>, <12>, <S2>, <322.12>, <23.41>, <21.42> (For Payload2)

All the presented telemetry formats and examples match the Competition Guide Requirements

Container Command Formats

Command	Example	Description
CMD,<TEAM_ID>,CX,<ON_OFF>	CMD,1567,CX,ON	Container Telemetry ON
	CMD,1567,CX,OFF	Container Telemetry OFF
CMD,<TEAM_ID>,ST,<UTC_TIME>	CMD,1567,ST,13:10:50	Sets the mission time
CMD,<TEAM_ID>,SP1X,<ON_OFF>	CMD,1567,SP1X,ON	Triggers Container to relay Payload 1 telemetry data
	CMD,1567,SP1X,OFF	Turns OFF relay communication from Payload 1
CMD,<TEAM_ID>,SP2X,<ON_OFF>	CMD,1567,SP1X,ON	Triggers Container to relay Payload 2 telemetry data
	CMD,1567,SP1X,OFF	Turns OFF relay communication from Payload 2
CMD,<TEAM_ID>,SIM,<MODE>	CMD,1567,SIM,ENABLE	Enable Simulation mode
	CMD,1567,SIM,ACTIVATE	Activate Simulation mode
	CMD,1567,SIM,DISABLE	Disable Simulation mode
CMD,<TEAM_ID>,SIMP,<PRESSURE>	CMD,1567,SIMP,101325	Provides simulation mode pressure data
CMD,<TEAM_ID>,<SP1_SP2>,RELEASE	CMD,1567,SP1,RELEASE	Release Payload 1
	CMD,1567,SP2,RELEASE	Release Payload 2

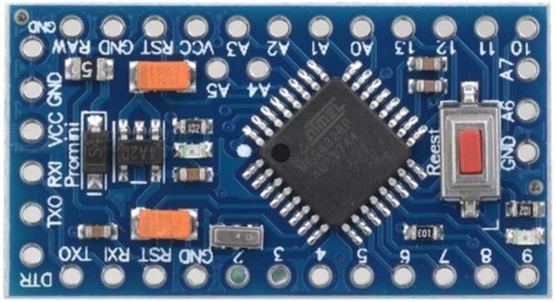
- **All the Container Commands match the mission requirements**

Payload Processor & Memory Selection (1/2)

Microcontroller	Supply Voltage (V)	Processor Speed (MHz)	Boot Time (s)	Memory	Data Interfaces	Cost (₹)
Arduino Pro Mini	3.3-12	8	4.84	32KB - Flash 2KB - RAM 1KB - EEPROM	UART - 2 SPI - 1 I2C - 1	200.00

Selected Microcontroller : Arduino Pro Mini

- **6 analog pins with 10 bit resolution and 14 digital pins**
- Better performance/price ratio
- Fulfils the mission requirement
- Fulfils the space constraints



- There is no memory card used in the payload

Payload Processor & Memory Selection (2/2)

Features of Arduino Pro Mini

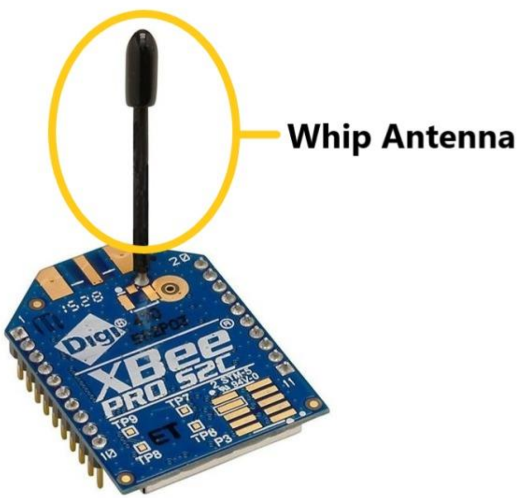
Supply voltage	3.6 to 6V
Boot Time	4.84s
Power Consumption	0.132Wh
Weight	2gm
Processor Speed	8MHz
Total No. of pins	14
Data Bus Width	8 Bit
Dimensions (in mm)	33*18
I2C Interfaces	1
SPI Interfaces	1
UART Interfaces	2
No. of PWM Pins	6
Flash Memory	32KB
RAM	2KB
EEPROM	1KB
Operating Voltage	3.3V

Payload Antenna Selection (1/2)

Model	Gain (dBi)	Dimensions (mm)	Range (Km)	VSWR	Interface	Cost (₹)
Integrated whip Antenna	1.5	Height : 25	1	≤2	Integrated	No additional cost

Selected Antenna : Integrated whip Antenna

- Interface compatible with XBee
- Suitable radiation pattern
- Satisfies space constraints (Pre-soldered with XBee)
- Fulfils all mission requirements
- No additional cost

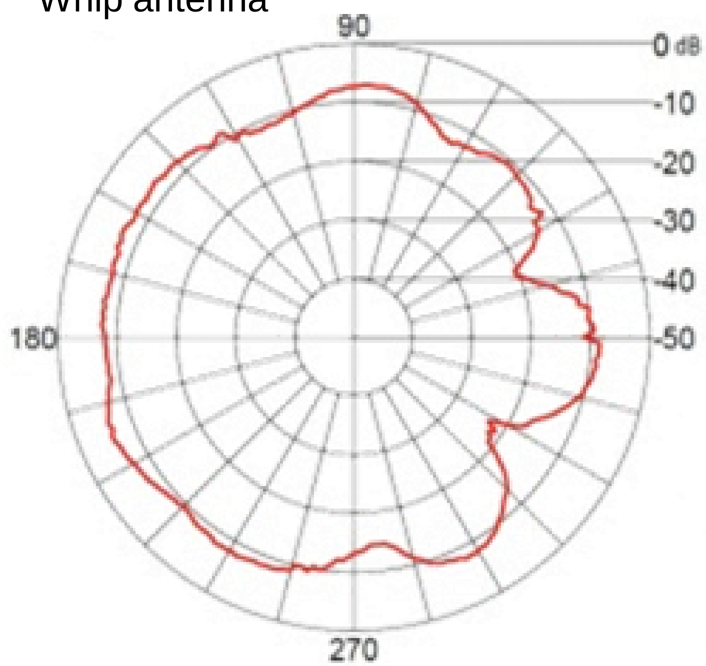


- **Weight** of the Antenna is **4 grams**
- **Height** of the Antenna is **25 mm**

These dimensions are compatible with the mechanical design of our CanSat

Payload Antenna Selection (2/2)

Whip antenna



Radiation pattern of Integrated Whip Antenna

Performance:

- It provides sufficient gain and has a range approximate of **800m**
- All the antenna features are adequate for system performance.

Payload Radio Configuration (1/2)

Model	Operating Frequency (GHz)	Supply Voltage (V)	Range (Km)	RF Data Rate (Kbps)	Transmit Power (mW)	Sensitivity (dBm)	Cost (₹)
XBee Pro S2C	2.4	2.7-3.6	3.2	250	63	-101	2150.00

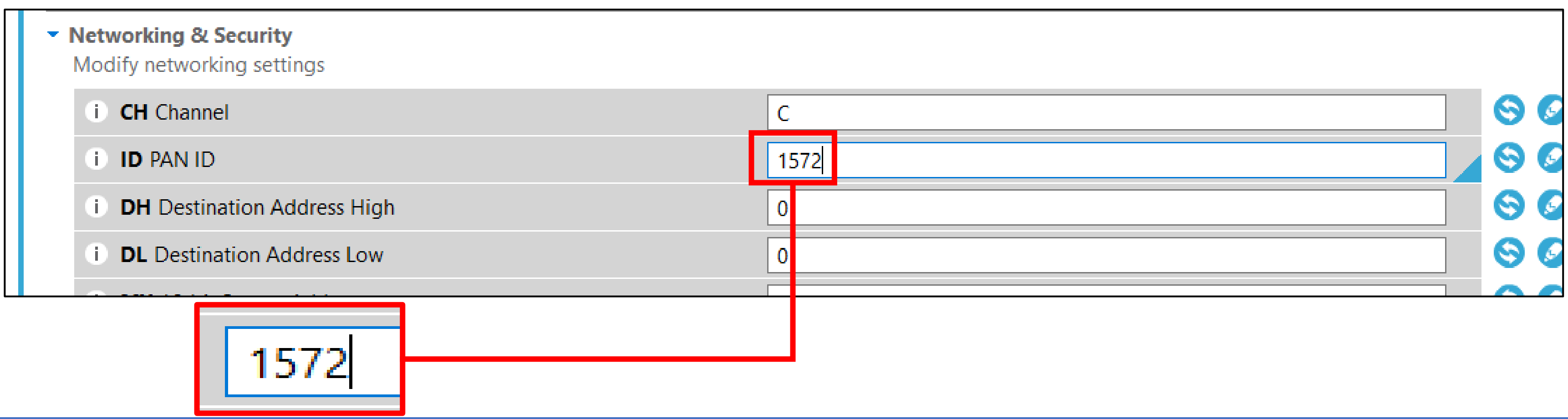
Selected Radio : XBee Pro S2C

- Sufficient transmit power
- Low cost and easily available
- Easy to configure
- Reliable experience
- The XBee Pro S2C variant has an integrated Whip-Antenna

The payload XBees will be configured as Router and will be connected in star topology

Payload Radio Configuration (2/2)

- The XBees in the payloads are set as **Router** and the container XBee which receives the transmitted telemetry is set as **Coordinator**.
- The three XBees are configured in **Star Topology Network** for this purpose.
- The three XBees in star network communicate in **unicast mode,** not in broadcast mode.
- The NETID/PANID of the three XBees in the star network are set as Team ID+5.
- The Team ID is **#1567** so the NETID/PANID is set as **#1572**.
- The transmission is controlled with the help of the payload flight software during each phase of decent.
- **It starts transmitting telemetry which ceases after 5 minutes as per mission guidelines**.
- Data is transmitted at a frequency of **1 Hz** as per the mission guidelines.



Payload Telemetry Format (1/2)

Sr No.	Field	Explanation	Resolution
1	<TEAM_ID>	Assigned team identification	1567
2	<MISSION_TIME>	Time since initial power up	1s
3	<PACKET_COUNT>	Count of transmitted packets (maintained after processor reset)	1
4	<PACKET_TYPE>	ASCII character representing telemetry	-
5	<SP_ALTITUDE>	Altitude generated by GPS receiver above mean sea level	0.1 meters
6	<SP_TEMP>	Sensed temperature	0.1 °C
7	<SP_ROTATION_RATE>	Science payload rotation rate around the axis perpendicular to the center of the rotor	1 rpm

Payload Telemetry Format (2/2)

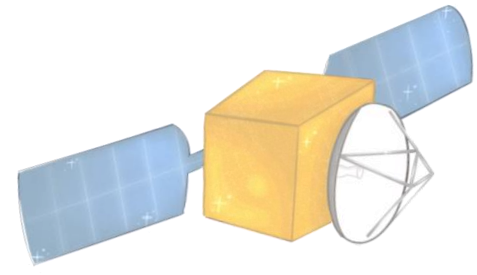
- Science Payloads shall transmit telemetry data to the Container which will then be relayed to the ground station
- The telemetry data file for payloads will be named as **Flight_1567_S1.csv**, and **Flight_1567_S2.csv** where **1567** is our **Team ID**
- Data will be transmitted at the rate of **1Hz** in bursts
- The telemetry data shall be transmitted with ASCII comma separated fields followed by a carriage return in the following format:

<TEAM_ID>,<MISSION_TIME>,<PACKET_COUNT>,<PACKET_TYPE>, <SP_ALTITUDE>,<SP_TEMP>, <SP_ROTATION_RATE>

Eg. (Payload1): <1567>,<13:22:42>,<23>,<S1>,<362.13>,<23.42>,<32.21>

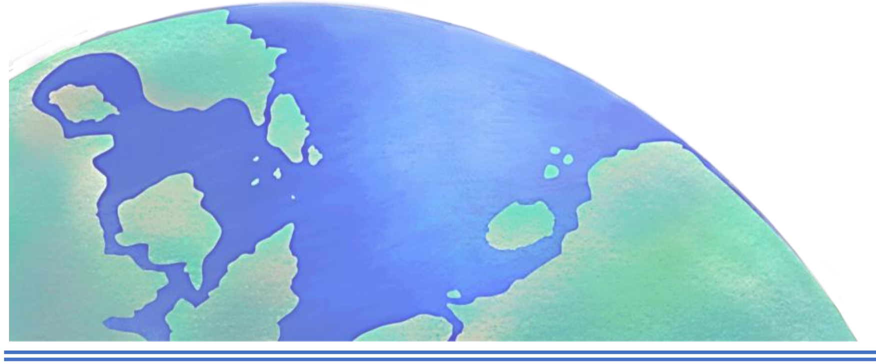
Eg. (Payload2): <1567>,<13:22:42>,<12>,<S2>,<322.12>,<23.41>,<21.42>

All the presented telemetry formats and examples match the Competition Guide Requirements



Electrical Power Subsystem (EPS) Design

Presenter's Name: Shweta Chavan



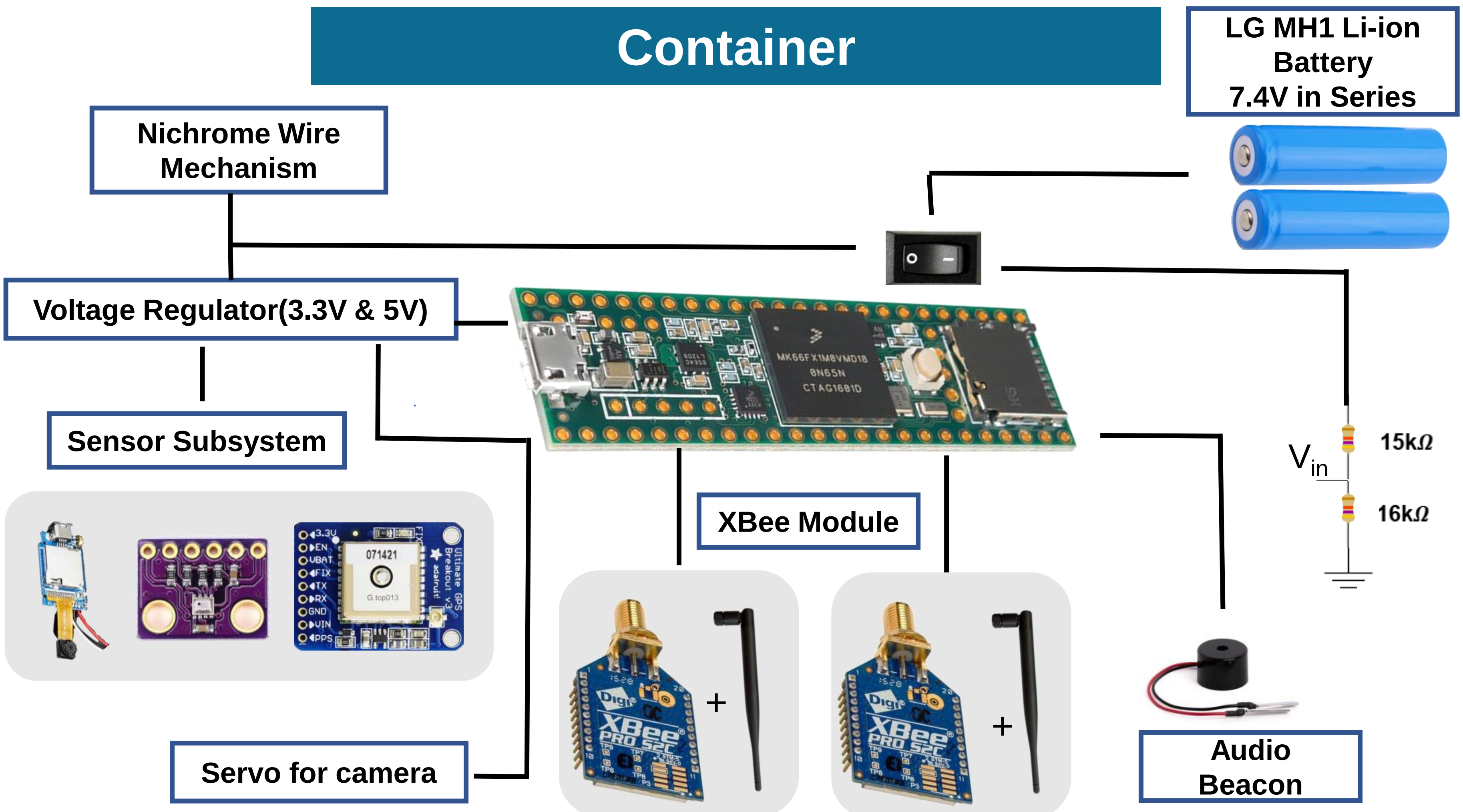
EPS Overview (1/4)

Component	Purpose	Voltage
Power Switch	To manually switch on/off the circuit	-
Lithium-ion Battery	Power Source	3.7V
BMP280	To determine air pressure, temperature and altitude of the container	3.3V
Adafruit Ultimate GPS Module	To determine position of container using Global Positioning System(GPS)	5V
BUZZER	Emits sound on reaching ground level	5V
Teensy 3.6	Microcontroller Container	5V
XBee Pro S2C	Transceiver between Payload-Container-Ground Station	3.3V
Adafruit Spy Camera	To capture the release of the payloads	5V

EPS Overview (2/4)

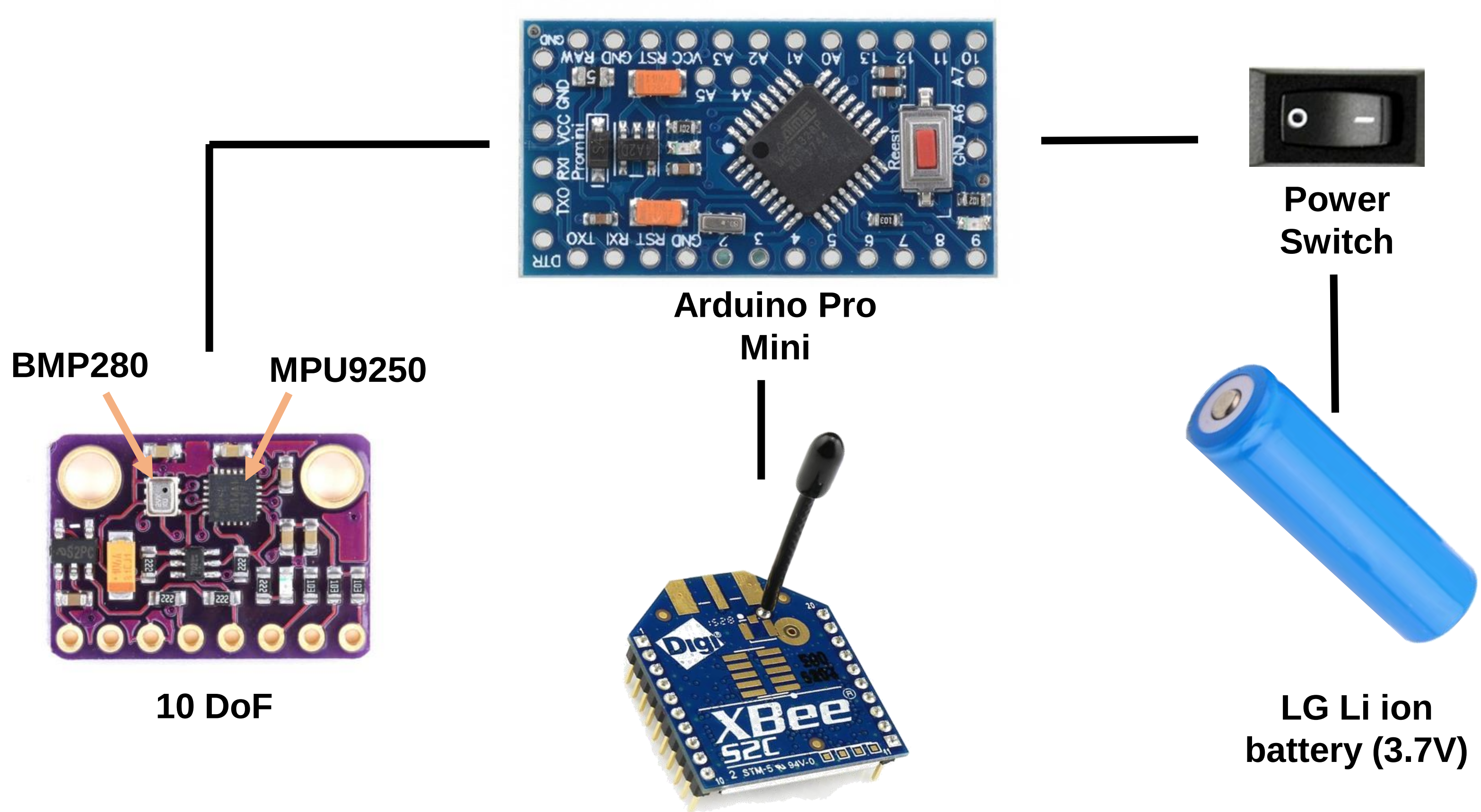
Component	Purpose	Voltage
Voltage Divider	To measure the voltage using the Analog pin of Teensy 3.6 by dividing voltage	-
Servo	To activate camera mechanism	5V
Nichrome Wire Release Mechanism	To release the science payloads	7.4V
10-DoF module (BMP 280 + MPU 9250)	To determine the barometric and rpm readings of payload	3.3V
Arduino Pro Mini	Microcontroller Payload	3.3V

EPS Overview (3/4)



EPS Overview (4/4)

Payload



EPS Changes Since PDR

No changes have been made to the Electric Power (EPS) Subsystem Design since the PDR.

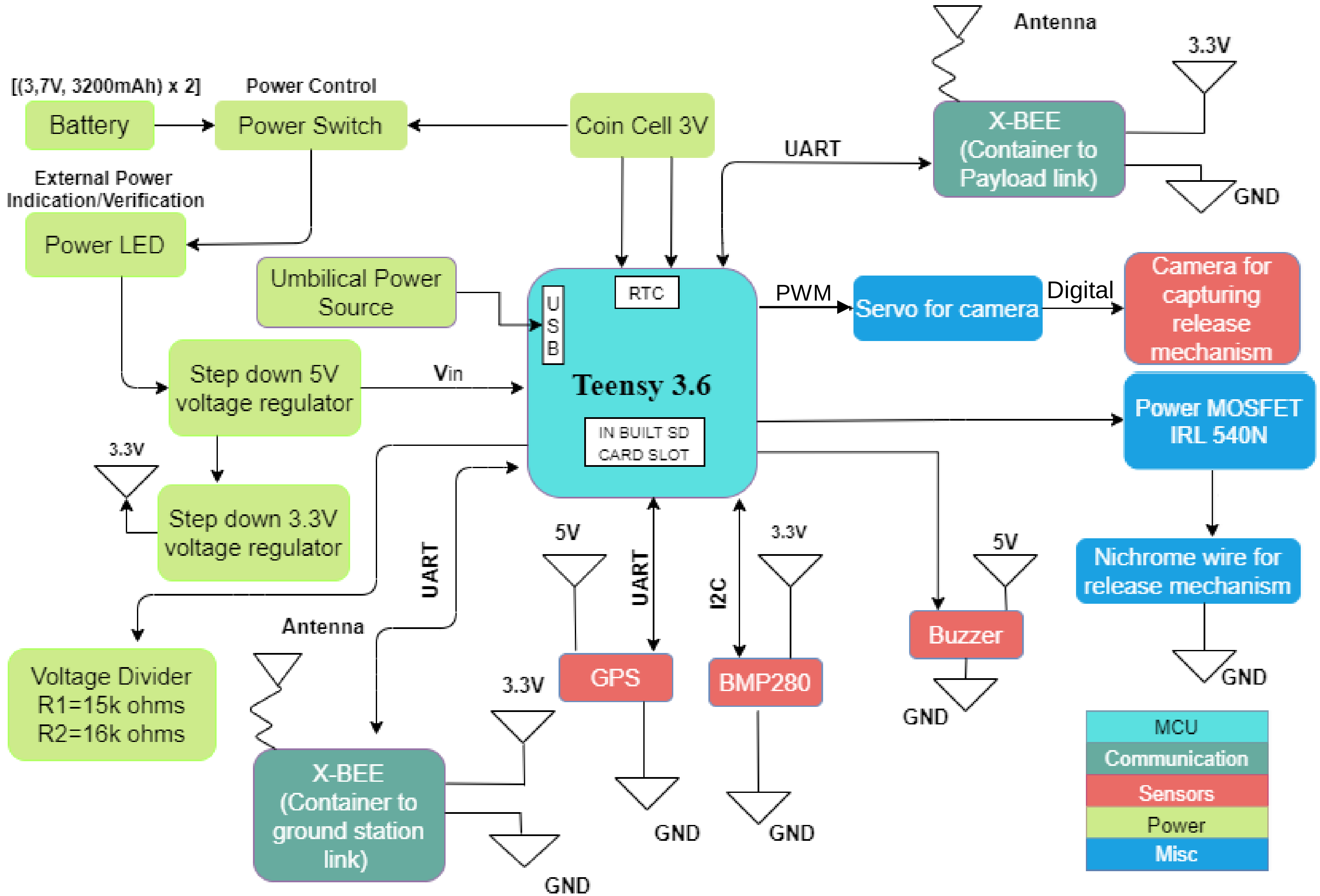
EPS Requirements (1/2)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR38	The container and science payloads must include an easily accessible power switch that can be accessed without disassembling the cansat and science payloads and in the stowed configuration.	Req	High		√		√
#CR39	The container must 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.	Req	High		√		√
#CR42	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.	Req	Very High	√	√	√	

EPS Requirements (2/2)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR44	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.	Req	High		✓		
#CR47	The Cansat shall operate for a minimum of two hours when integrated into the rocket.	Req	High		✓		
#BNS1	A video camera shall be integrated into the container and point toward the ground. The camera shall capture the release of both science payloads and capture the descent of the science payloads. The video shall be spin stabilized with the view not rotating more than +/- 30 degrees. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the container is retrieved.	Bonus Requirement	Medium	✓		✓	✓

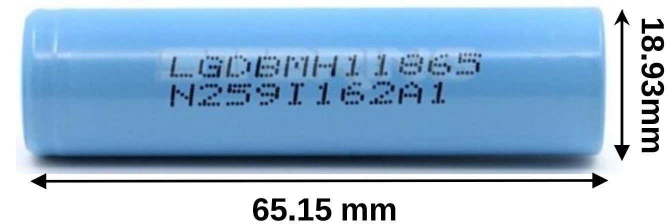
Container Electrical Block Diagram

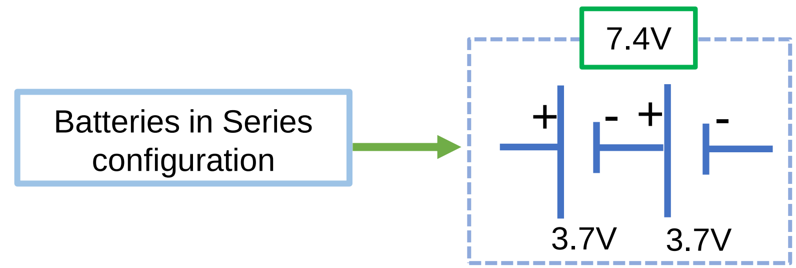


Container Power Source (1/2)

Selected Battery : LG MH1 Li-ion Battery

Battery Chemistry	Lithium-ion
Weight	80gm
Voltage	7.4V
Current Capacity	3200mAh
Discharge Current	10A
Configuration	Series
No of Cells	2
Power	23.48 Wh
Operating Temperature	-20℃ to 60℃
Cost	₹490.00



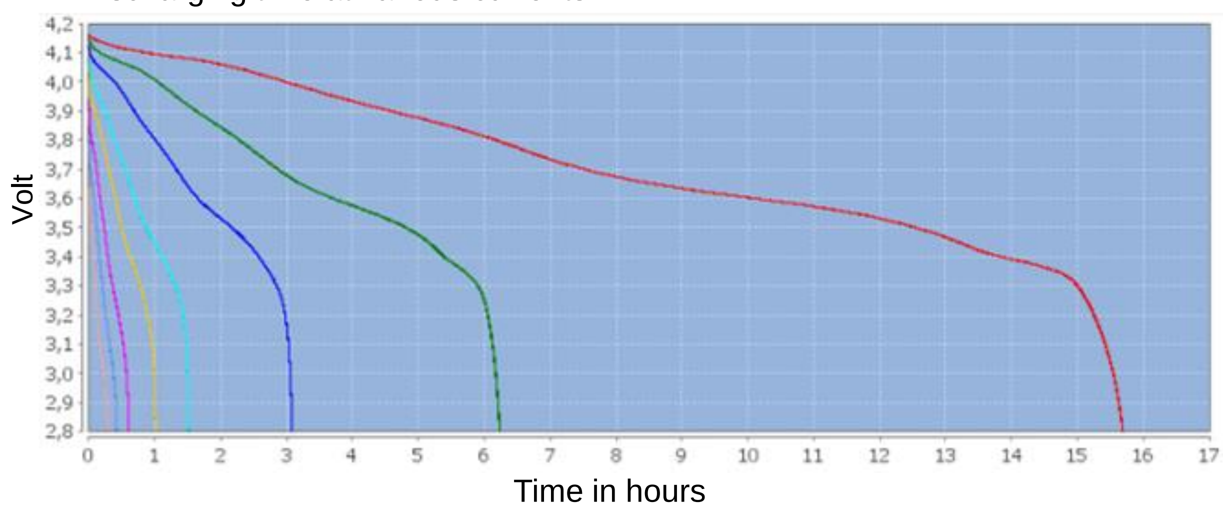


- The batteries are fixed in the electronics bay without any spring contacts.
- More than sufficient for the power requirements of the CanSat.
- High power density
- Lightweight and small size
- Appropriate power/weight ratio
- High performance and capacity
- Wide operating temperature range.

Container Power Source (2/2)

1. A LG MH1 Li-ion Battery supplies 3.7V. Two batteries are connected in series to get 7.4V.
2. On account of their performance and safety, LG MH1 Li-ion batteries are used.
3. High current requirements of Nichrome wire mechanisms(burning of fishing line) are fulfilled with the selected battery configuration.
4. Battery is connected to the whole system via power switch and power LED (power indicator)

Discharging time at various currents



Container Power Budget (1/2)

Component	Voltage (V)	Current (mA)	Power Consumption(Wh) (V x A x 1h)	Duty Cycle (HH:MM:SS)	Source
Teensy 3.6	5	45	0.225	02:00:00	Datasheet
BMP280	3.3	0.0027	0.00000891	02:00:00	Datasheet
Adafruit Ultimate GPS	5	25	0.125	02:00:00	Datasheet
Adafruit Mini Spy Camera	5	110	0.55	00:02:00	Datasheet
XBee S2C Pro X 2	3.3	2 X 120	0.792	02:00:00	Datasheet
Servo	5	300	1.5	00:02:00	Datasheet
Nichrome Wire X 2	5	2 X 1500	3	00:00:01	Measured
Buzzer	5	80	0.4	00:15:00	Datasheet
*Misc.	-	-	1	-	Estimate

***Uncertainties in some components have been included in the Misc. section**

Total Power = 7.59Wh

Container Power Budget (2/2)

Available Power	23.48Wh
Total Power Consumption	7.59Wh
Power Margin	15.89Wh

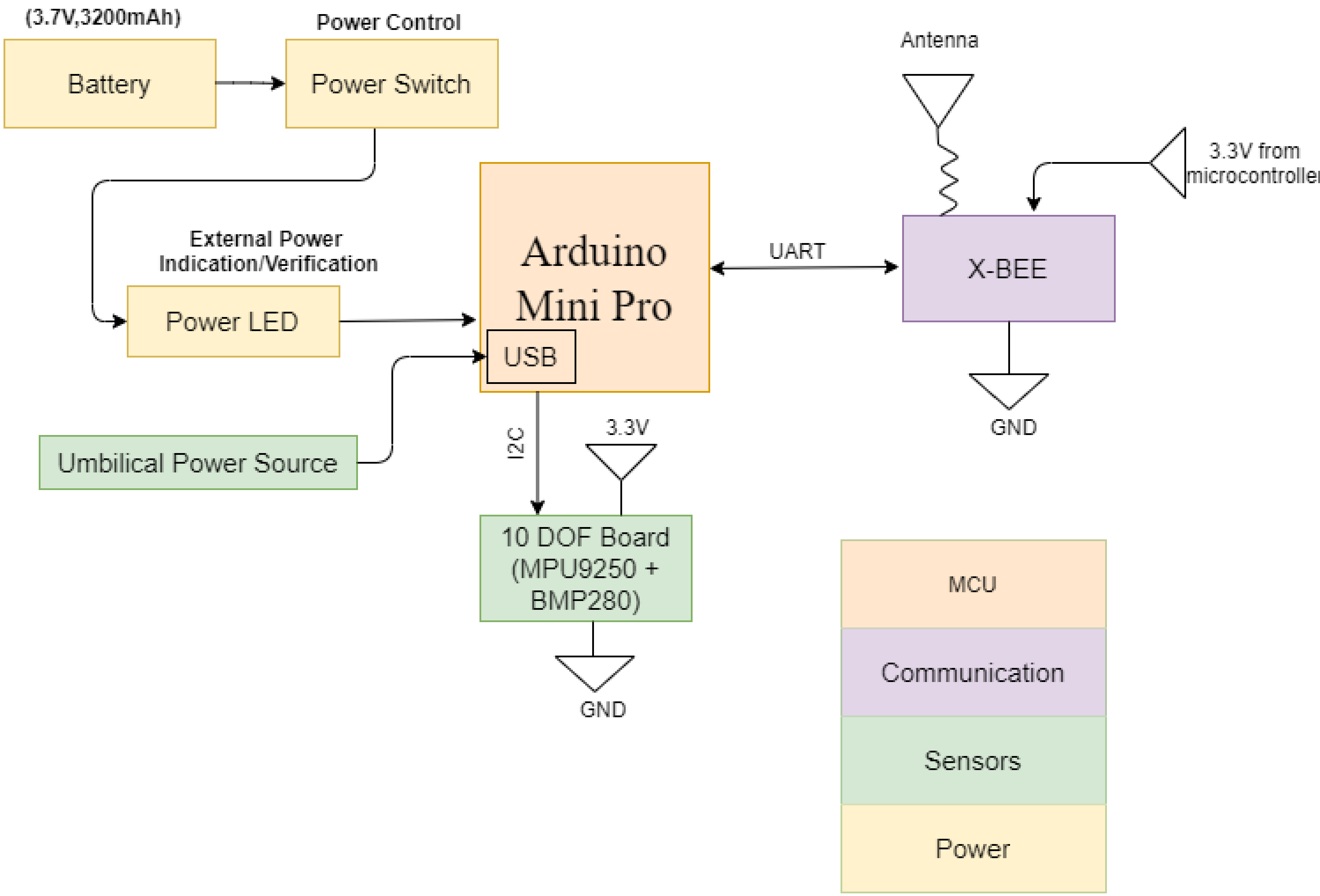
Available Power - Total Power Consumption = Power Margin

$$\text{Battery life(h)} = \frac{\text{Available power(Wh)}}{\text{Total power consumption(Wh)}} = 23.48/7.59$$

$$= 3.09\ hours (3\ hours\ 5\ mins)$$

- The whole system will be powered by two LG MH1 Li-ion batteries (in series) controlled by a power switch
- The Power Margin is kept sufficiently large to avoid any system failures
- Camera and servo start operating just before the 1st payload is released
- The system will work for more than two hours as per the mission requirement

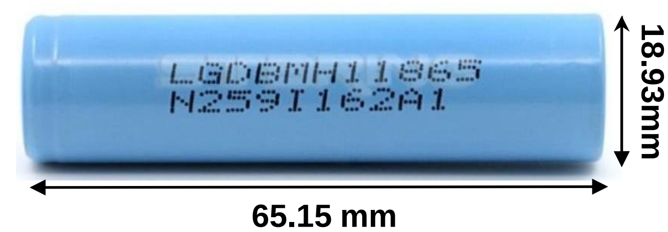
Payload Electrical Block Diagram



Payload Power Source (1/2)

Selected Battery : LG MH1 Li-ion Battery

Battery Chemistry	Lithium-ion
Weight	40gm
Voltage	3.7V
Current Capacity	3200mAh
Discharge Current	10A
No of Cells	1
Power	11.74 Wh
Operating Temperature	-20℃ to 60℃
Cost	₹490.00

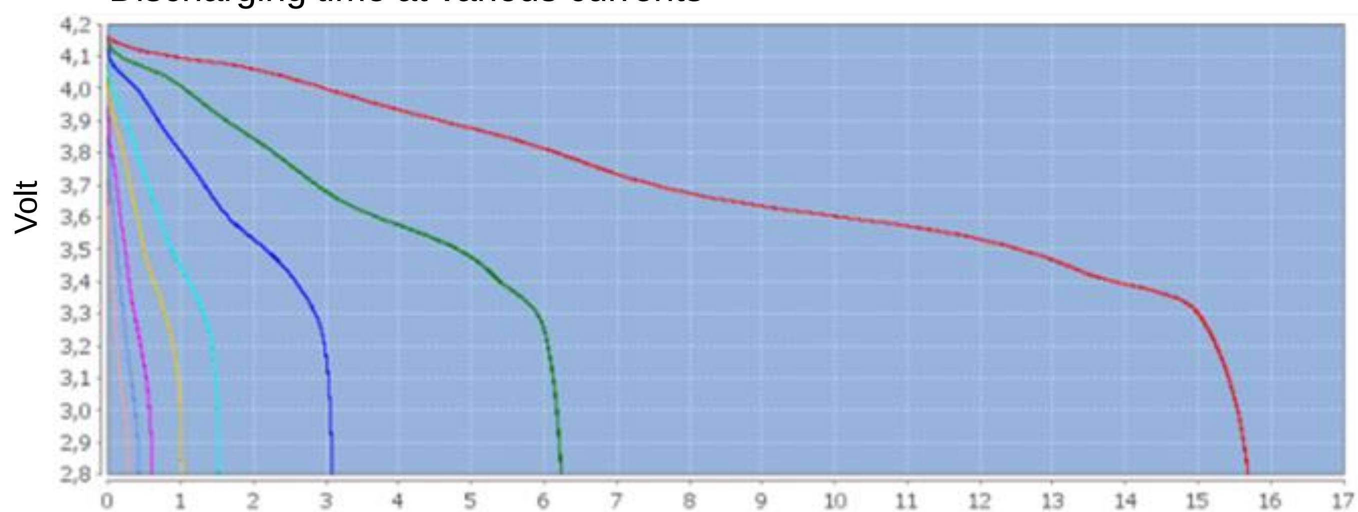


- Since a single battery is used in each of the payloads, **no** (series/parallel) **configuration** is used.
- The battery is fixed in the payload (seed) without any spring contacts.
- Lightweight and small size
- Discharge current up to 10A
- Appropriate power/weight ratio
- High power density

Payload Power Source (2/2)

1. A LG MH1 Li-ion Battery supplies 3.7V. A single battery is used in both of the payloads.
2. On account of their performance and safety, LG MH1 Li-ion batteries are used.
3. Single battery is used because it is sufficient according to our mission requirements.

Discharging time at various currents



Payload Power Budget (1/2)

Component	Voltage (V)	Current (mA)	Power Consumption(Wh) (V x A x 1h)	Duty Cycle (HH:MM:SS)	Source
Arduino Pro Mini	3.3	40	0.132	02:00:00	Datasheet
10 DOF Sensor (BMP280+ MPU9250)	3.3	4.42	0.014586	02:00:00	Datasheet
XBee S2C Pro	3.3	120	0.396	02:00:00	Datasheet
*Misc.	-	-	1		Estimate

Total Power = 1.542Wh

The Power budget is identical for both the payloads

***Uncertainties in some components have been included in the Misc. section**

Payload Power Budget (2/2)

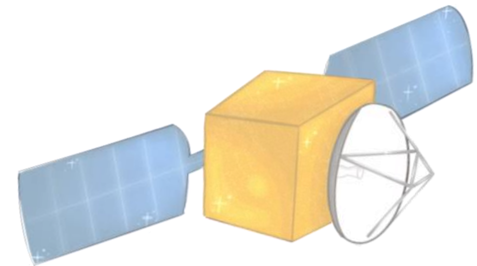
Available Power	**11.74Wh**
Total Power Consumption	**1.54Wh**
Power Margin	**10.2Wh**

Available Power - Total Power Consumption = Power Margin

$$\textbf{Battery life(h)} = \frac{\textbf{Available power(Wh)}}{\textbf{Total power consumption(Wh)}} = \mathbf{11.74/1.54}$$

$$= \mathbf{7.6\ hours}$$

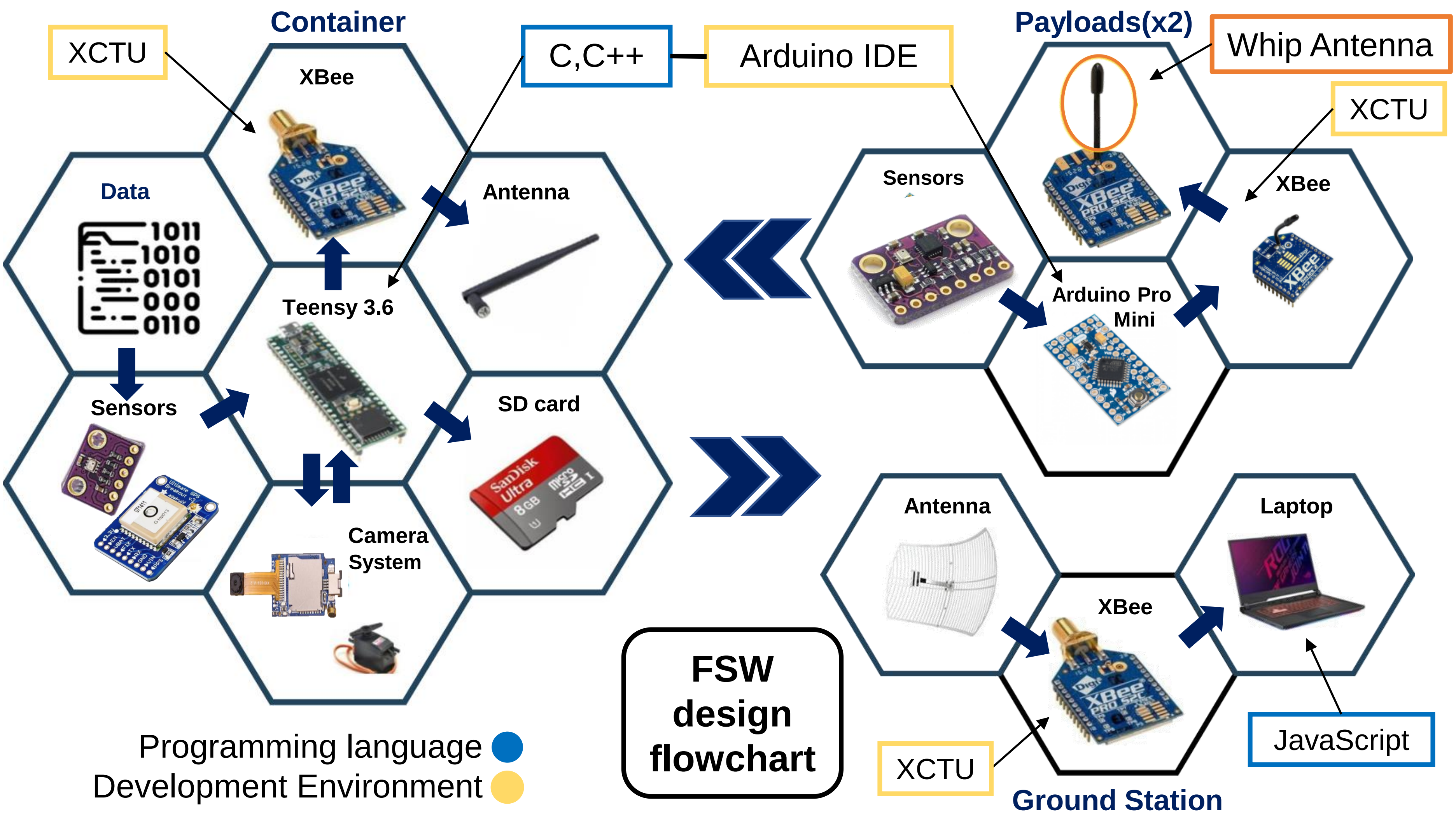
- The whole system will be powered by a LG MH1 Li-ion battery controlled by a power switch.
- According to the requirements of the mission guide, the payload must be powered for at least 2 hours, which was complied with.
- The Power Margin is kept sufficiently large to avoid any system failures.



Flight Software (FSW) Design

Presenter’s Name: Khyati Morparia

FSW Overview (1/2)



FSW Overview (2/2)

➢ Overview of the CanSat FSW design

- The sensor data for both the payloads will be collected by their respective MCU and transmitted by their XBee to the container
- One of the XBees in the container will receive the transmitted payload data and relay it with the container MCU
- The data from the payloads and the container will be stored on the SD card and transmitted to the ground station via the other XBee

➢ Programming languages

- C/C++ programming languages, JavaScript

➢ Development environments

- XCTU
- Arduino IDE

➢ Tasks

- The sensor data is read, calibrated and stored in SD card present in the container.
- The flight software of the container and payload controls the wireless transmission and relay communication of sensor data using XBee.
- The flight software of container configures the initiation of release mechanism of science payloads.
- In order to ensure safety of data in case of power or system failure, data is also saved in internal EEPROM memory.

FSW Changes since PDR

No changes have been made in the Flight Software Design (FSW) since the PDR.

FSW Requirements (1/5)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR25	The science payload shall measure altitude using an air pressure sensor.	Req	Very High	√		√	√
#CR26	The science payload shall measure air temperature.	Req	Very High	√		√	√
#CR27	The science payload shall measure rotation rate as it descends.	Req	Very High	√		√	√
#CR28	The science payload shall transmit all sensor data once per second.	Req	Very High	√		√	√
#CR29	The science payload telemetry shall be transmitted to the container only.	Req	Very High		√	√	√
#CR31	The container shall include electronics to receive sensor payload telemetry.	Req	Very High	√		√	√

FSW Requirements (2/5)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR33	The container shall include a GPS sensor to track its position.	Req	Very High	✓		✓	✓
#CR34	The container shall include a pressure sensor to measure altitude.	Req	Very High	✓		✓	✓
#CR35	The container shall measure its battery voltage.	Req	Very High	✓		✓	✓
#CR36	The container shall transmit its telemetry and the payload telemetry received once per second in the format described in the Telemetry Requirements section.	Req	Very High	✓	✓	✓	
#CR37	The container shall stop transmitting telemetry when it lands.	Req	Very High		✓	✓	

FSW Requirements (3/5)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR51	The container 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.	Req	Very High			√	√
#CR52	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the container altitude.	Req	Very High	√		√	√
#CR53	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Req	Very High			√	√
#CR59	All telemetry shall be displayed in real time during descent on the ground station.	Req	Very High	√		√	√

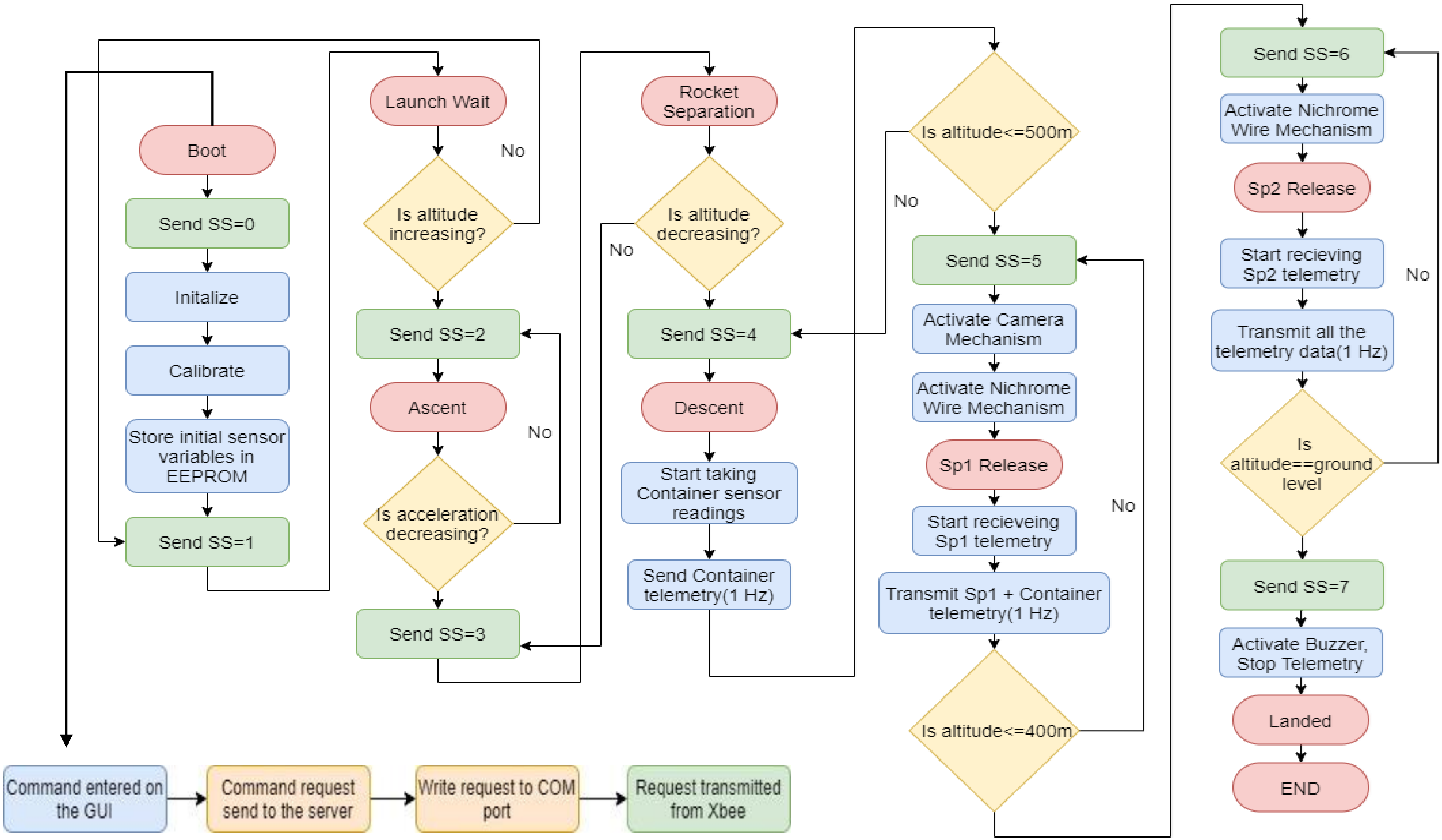
FSW Requirements (4/5)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR64	The ground station software shall be able to command the container to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	Req	Very High			√	√
#CR65	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 container.	Req	Very High	√		√	√
#CR66	The science payloads shall not transmit telemetry during the launch, and the container shall command the science payloads to begin telemetry transmission upon release from the container.	Req	Very High		√		√

FSW Requirements (5/5)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#BNS1	A video camera shall be integrated into the container and point toward the ground. The camera shall capture the release of both science payloads and capture the descent of the science payloads. The video shall be spin stabilized with the view not rotating more than +/- 30 degrees. Video shall be in colour with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the container is retrieved.	Bonus Requirement	Medium	✓		✓	✓

Container CanSat FSW State Diagram (1/3)



Container CanSat FSW State Diagram (2/3)

SOFTWARE STATE	Activation Mechanism	Description
SS = 0	Power switch	**CanSat boots**. Subsystem **initializes** and **calibration** is done. Sensor variables are stored in EEPROM.
SS = 1	-	Container sets its time to UTC time (1s before launch) and CanSat enters **idle state** waiting for launch.
SS = 2	Sensor(altitude) based activation	The Rocket is **launched**. The altitude starts increasing.
SS = 3	Sensor(altitude) based activation	The **Rocket reaches apogee,** acceleration decreases and **releases the CanSat.** CanSat descends at a rate of 15m/s (±5m/s).
SS = 4	Air Flow	The **container parachute is released,** the altitude starts decreasing. **It takes sensor readings** and starts telemetry (1Hz).
SS = 5	Nichrome wire	The container reaches 500m, **activates the camera** mechanism, **releases the payload 1** with the help of nichrome wire mechanism and starts relaying telemetry (1Hz).
SS = 6	Nichrome wire	The container reaches an altitude of 400m, **releases the payload 2** with the help of nichrome wire mechanism and relays all the telemetry data to the ground station (1Hz).
SS = 7	Sensor(altitude) based activation	The **container reaches ground level** it stops telemetry and activates the buzzer.

Container CanSat FSW State Diagram (3/3)

FSW recovery to correct state after processor RESET (common for payload and container)

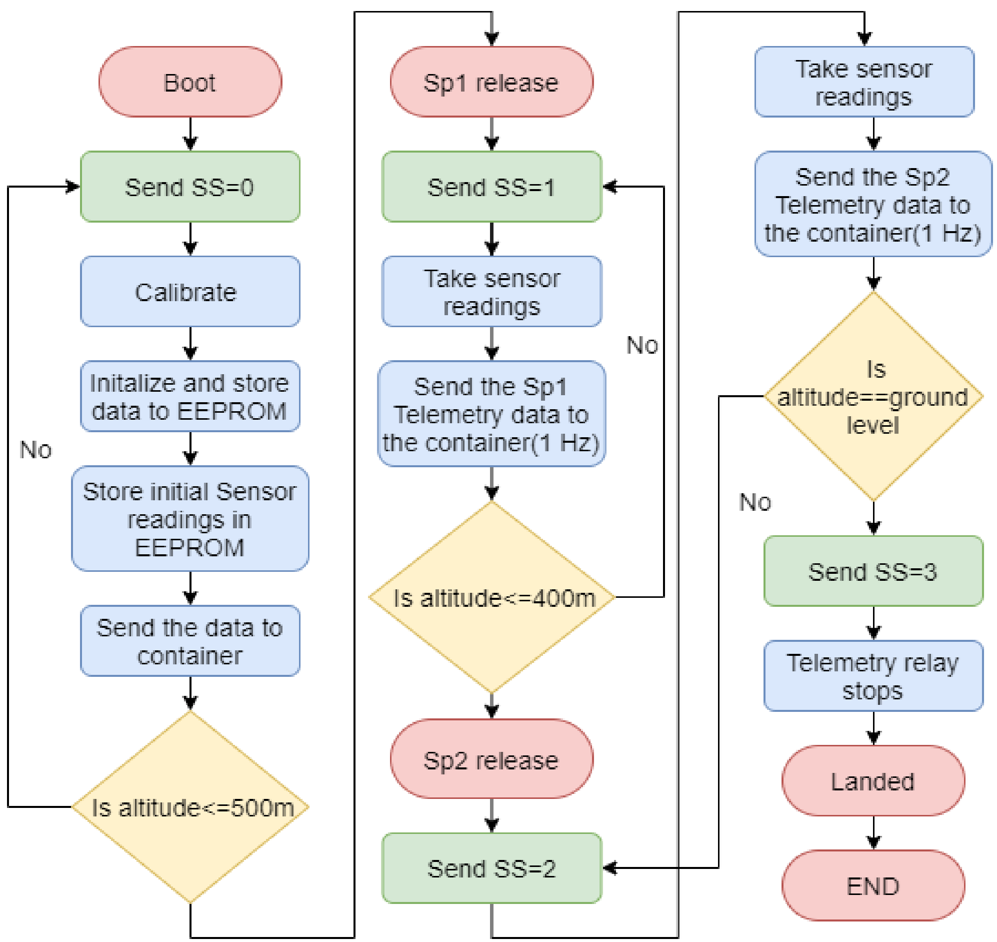
➢ **EEPROM variables (Remain unchanged after RESET)**

Variable Name	Variable description	Mission requirements
Mission time	The time passed since boot	Should not alter even after the processor has been reset
Packet Count	The number of successful Telemetry packets transmitted from the payload	Should not alter even after the processor has been reset
Software State	State of configuration and phase of mission	Should not alter even after the processor has been reset
Boot time	Time instant in seconds when CanSat is launched	Used to calculate the time of the mission. Remains the same for the entire mission
Reference Altitude	Altitude from sea level when CanSat is launched	Will remain the same throughout the mission and will be used to calculate the height relative to the ground level from which CanSat departs

➢ **Possible reasons for RESET and Methods of Recovery**

- Although, all care has been taken to firmly secure all the electronics and interconnections, due to unexpected shocks and instability induced when the CanSat is released from the rocket the processor might reset.
- In such cases, precaution has been taken to recover all the above variables from the EEPROM memory when the setup function in the code is executed after reset.
- Configuration state is also stored in EEPROM

Payload CanSat FSW State Diagram



- The FSW Diagram is same for both the payloads.
- The source of power is LG MH1 Li-ion battery(3.7V).
- The initial reference altitude and packet count variables are stored in the EEPROM.
- 3D printed slots are used to hold the PCB steadily.
- Care has been taken to firmly secure all the electronics and interconnections.
- In case of unexpected reset, precaution has been taken to recover the EEPROM variables from EEPROM memory when the setup function in the code is executed.
- The payload boot is controlled by an external power switch.

Simulation Mode Software

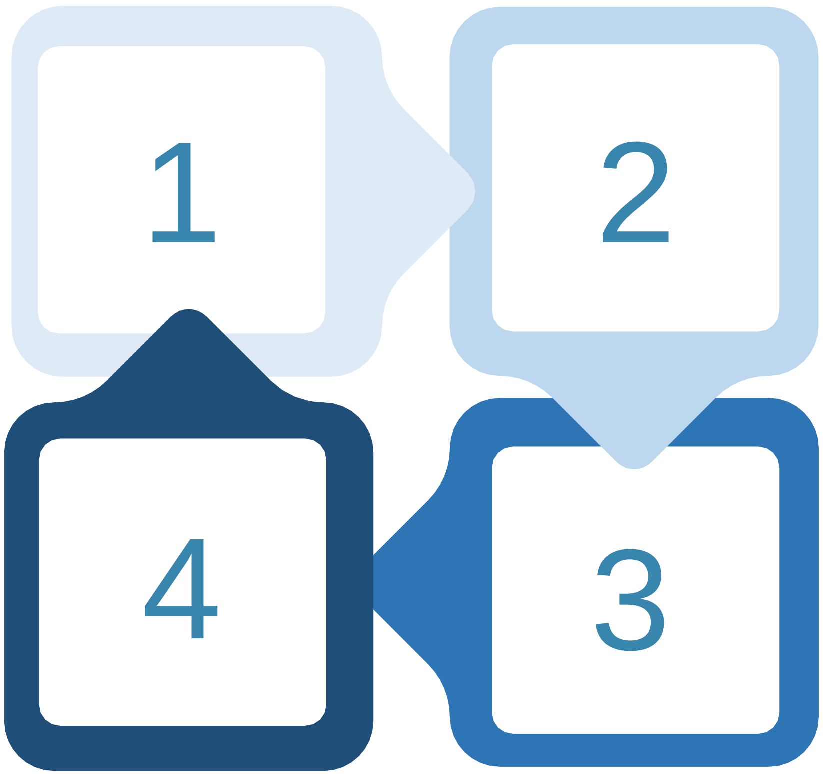
The commands which are required to begin Simulation Mode	`CMD,1567,SIM,ENABLE` `CMD,1567,SIM,ACTIVATE`
The command which provides simulation mode pressure data	`CMD,1567,SIMP,101325`
Simulation mode activation in Ground station GUI	

- The Ground station software reads the simulated csv file of the pressure sensor data and transmits the pressure data at a rate of 1 Hz to container.
- For this purpose the ground station XBee will be set as **COORDINATOR.**
- If the CanSat container operates in the flight mode, the container operates normally, using actual sensor data. If simulation mode is enabled and activated, the simulated barometric pressure values and the calculated altitude values are used to replace the corresponding real sensor data. No change in the data from the other sensors.
- Thus the Flight Software uses this data in software logic and performs the mission.
- Hence, all the mission requirements for the simulation mode are fulfilled.

Software Development Plan (1/4)

Test Methodology

Testing of each sensor module with different algorithms. Algorithm finalization and subsystem code compilation.



By inserting and checking codes, meeting mission requirement.

Code debugging and finalization of acceptable telemetry format compatible code.

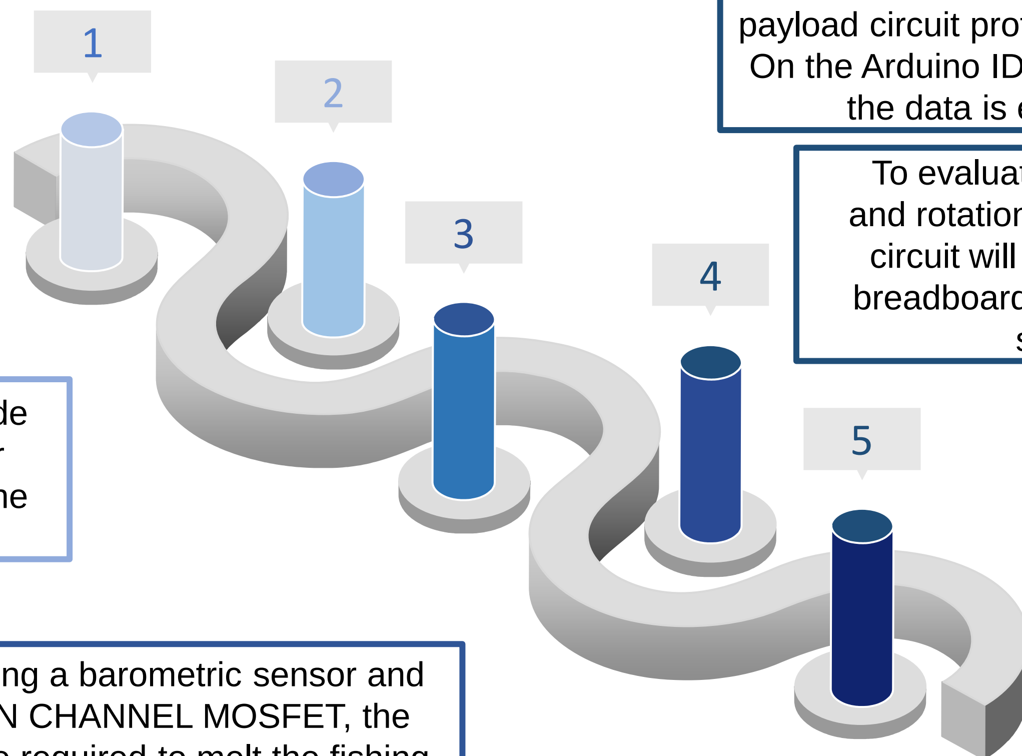
Testing of the entire CanSat system.

Software Development Plan (2/4)

Prototyping and Prototyping Environments

Individual testing of sensors on the breadboard and evaluation on the Arduino IDE serial monitor.

Uploading the blink code to the microprocessor tests the boot time of the microprocessor.



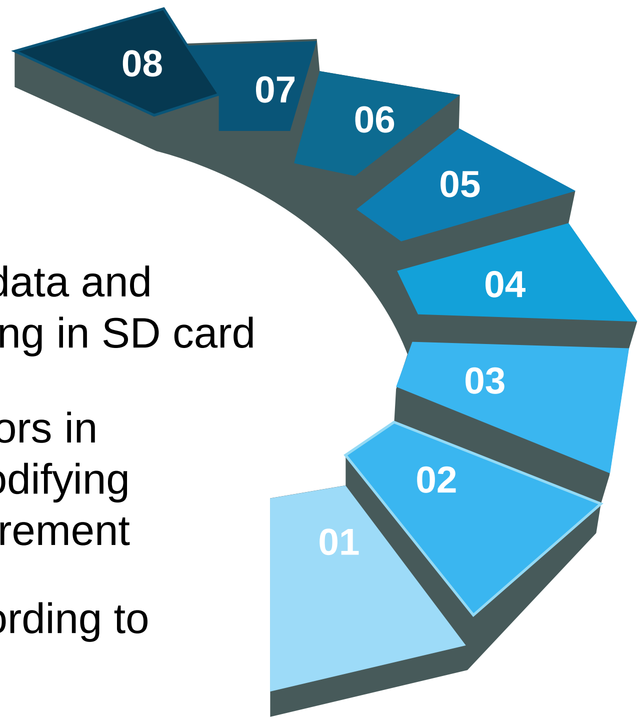
Using a barometric sensor and a N CHANNEL MOSFET, the time required to melt the fishing line with the Nichrome wire is determined.

By supplying the necessary power and voltage, all sensors are mounted on the breadboard and the payload circuit prototype is created. On the Arduino IDE serial monitor, the data is evaluated.

To evaluate the reaction time and rotation speed, a prototype circuit will be installed on the breadboard for an axis camera stabilizer.

Software Development Plan (3/4)

Software Subsystem Development Sequence



07 Assembling the components of the whole subsystem

05 Storage of telemetry data and Camera video recording in SD card

03 Integration of all sensors in a unified code and modifying according to the requirement

01 Sensor selection according to mission requirements

08 Testing wireless communication with the ground station

06 Designing and testing PCB and checking the software compatibility

04 Using EEPROM for mission time recovery, packet count and FSW data (SS)

02 Library research, code modification and testing of each sensor

Software Development Team:

- Nisarg Shah
- Khyati Morparia

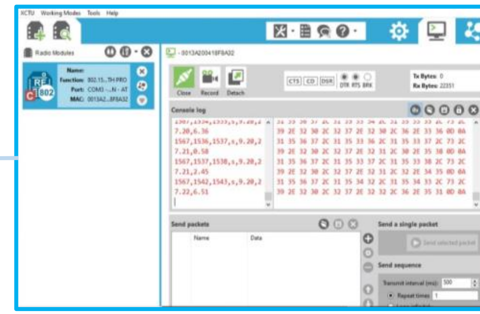
Software Development Plan (4/4)

- Altitude calibration for both nichrome wire release mechanisms
- Testing of communications and relaying algorithm.
- Logging of sensor data to the SD card.
- Integration of the PCB and flight software of the container and payloads.

The FSW is developed successfully

- Timely completion of the algorithm which is designed to capture the release of payloads and store it on an SD card.

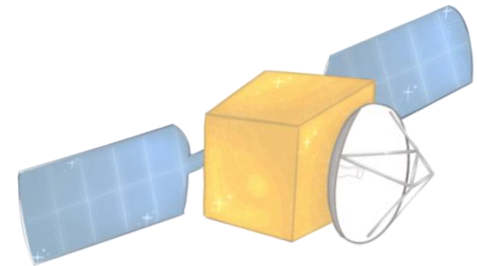
Testing of Communication with ground station



The aforementioned tasks were successfully completed

Sensors were calibrated

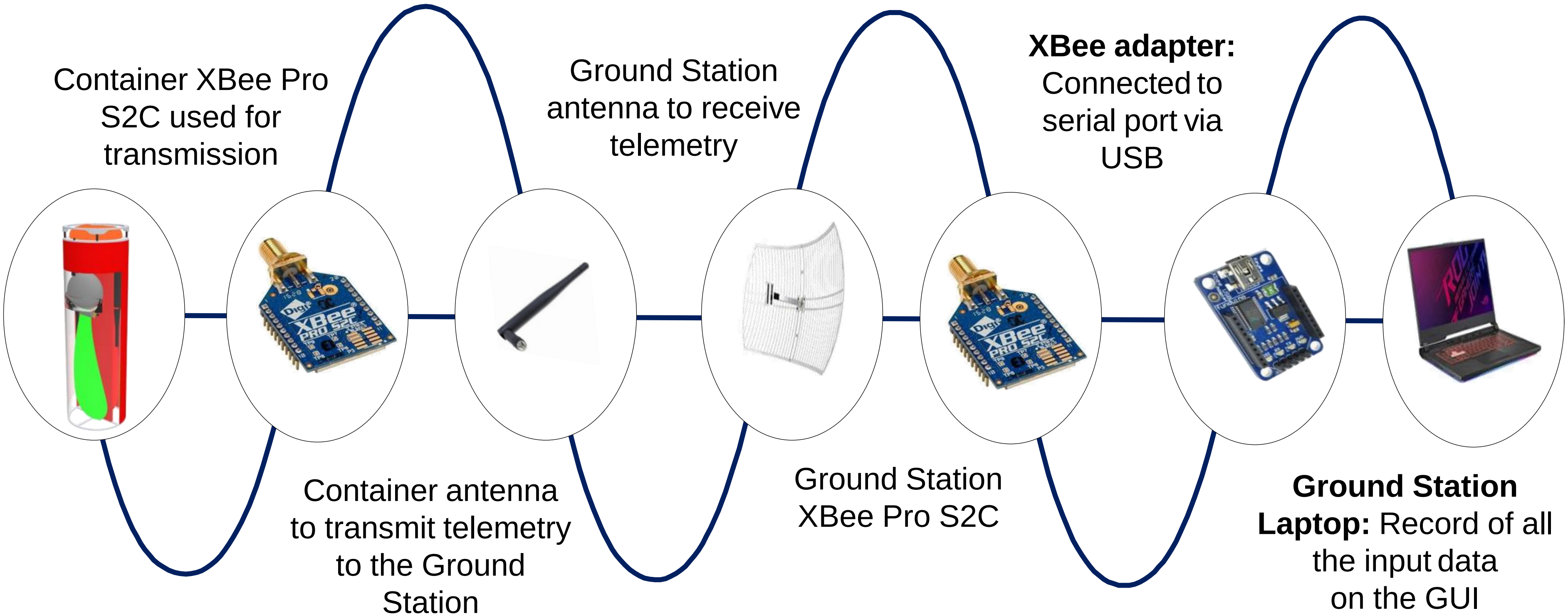
Progress Since PDR



Ground Control System (GCS) Design

Presenter's Name:
Khyati Morparia

GCS Overview



GCS Changes Since PDR

No changes have been made in the Ground Control System (GCS) since the PDR.

GCS Requirements (1/2)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR19	XBee radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBee radios are also allowed.	Req	Very High		√		
#CR20	XBee radios shall have their NETID/PANID set to their team number.	Req	Very High		√		
#CR21	XBee radios shall not use broadcast mode.	Req	Very High		√		
#CR54	The ground station shall command the Cansat to start transmitting telemetry prior to launch.	Req	Very High		√		√
#CR55	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Req	Very High			√	√

GCS Requirements (2/2)

Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR59	All telemetry shall be displayed in real time during descent on the ground station.	Req	Very High	✓		✓	✓
#CR62	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBee radio and a hand-held antenna.	Req	Very High		✓		
#CR63	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.	Req	High		✓		

GCS Design

Ground Station Diagram

Hand held antenna

Antenna connected to XBee with N type to RPSMA connector

XBee Module

XBee module will be connected to XBee adapter with 2.54mm headers

XBee Adapter

Adapter will be connected to Laptop via USB cable and communicate via serial connection

Ground Station Laptop

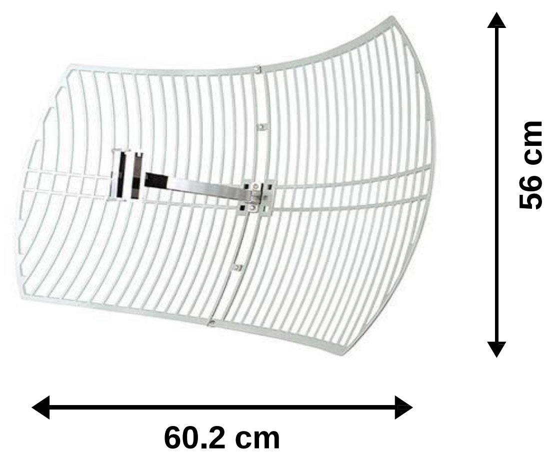
Specifications	
Battery Life of laptop	4 hours of battery life
Overheating Mitigation	External cooler under the laptop Sun shielding umbrella
Auto Update Mitigation	Auto update will be disabled, internet connection will be disabled
Portability	The Entire GCS is completely portable

GCS Antenna (1/5)

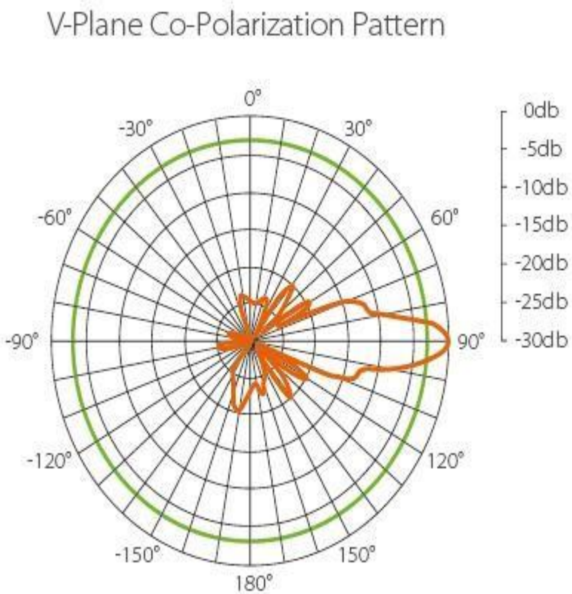
Antenna Name	Type	Frequency Range (GHz)	Gain (dBi)	VSWR	Polarisation	Connector	Cost (₹)
TLANT2424 B	Parabolic Grid-directional	2.4	24	≤ 1.5	Vertical, horizontal	N Female	3200.00

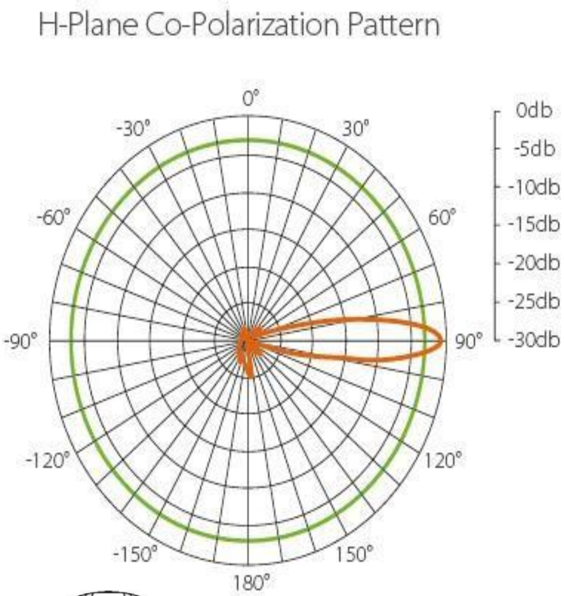
Selected Antenna : TLANT2424 B

- Since it is hand-held, we can direct it easily
- 24dBi directional operation and covers long range (56km)
- Weatherproof design, suitable for all weather conditions
- Simple installation and implementation with XBee

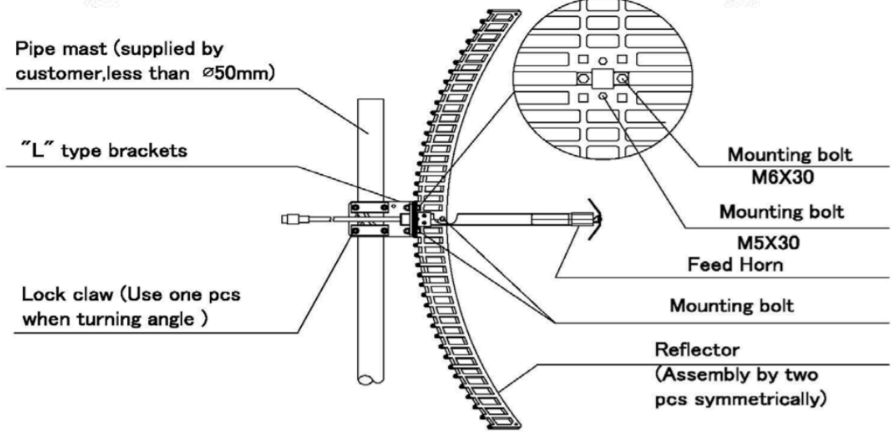


GCS Antenna (2/5)





Radiation pattern of TP-LINK TLANT2424 B



Antenna Construction

GCS Antenna (3/5)

Selected Design : Handheld

- On account of it’s beam like wave pattern, the orientation can be adjusted for optimum signal reception.
- The antenna is highly directional, so portability is necessary to target payload.
- It is cost effective and very easy to use.

GCS Antenna (4/5)

Radio link budget formula:

$$P_{RX} = P_{TX} + G_{TX} + G_{RX} - L_{TX} - L_{FS} - L_P - L_{RX}$$

P_{RX}=Received Power (dBm)

P_{TX}=Transmitter Output Power (dBm)

G_{TX}=Transmitter Antenna Gain (dBi)

G_{RX}=Receiver Antenna Gain (dBi)

L_{TX}=Losses Associated with Transmitter(cable, connectors, etc) (dB)

L_{FS}=Free Space Losses (dB)

L_P=Miscellaneous Signal Propagation Losses (polarization misalignment, etc) (dB)

L_{RX}=Losses Associated with Receiver(cable, connectors, etc) (dB)

$$L_{FS} = 20log_{10}\left(\frac{4\pi f d}{c}\right)$$

f =frequency in MHz
d =distance in km
c =speed of light

P_{TX} = 18dBm G_{TX} = 5dBi G_{RX} = 24dBi
L_{RX} = 1dBm L_{FS} = 103.56dB L_P = 5dBm
L_{TX} = 1dBm

GCS Antenna (5/5)

XBee receiver Sensitivity: -101dBm

- The Free space loss(L_{FS}) is calculated for a frequency of **2.4GHz** and distance of **1.5Km**
- Losses associated with transmitter and receiver cable(L_{TX},L_{RX}) are assumed to be 1dBm
- Miscellaneous losses(L_P) is assumed to be 5dBm
- The **Fade margin** is taken to be -10dBm

P_{RX} + Fade margin = -73.56dBm > -101dBm

- The Safe margin is approximately **28dBm** which is sufficient and reliable

GCS Software (1/11)

Telemetry Display Prototypes (Container) :

<TEAM_ID>,<MISSION_TIME>,<PACKET_COUNT>,<PACKET_TYPE>,<MODE>, <SP1_RELEASED>,<SP2_RELEASED>, <ALTITUDE>,<TEMP>, <VOLTAGE>,<GPS_TIME>,<GPS_LATITUDE>,<GPS_LONGITUDE>, <GPS_ALTITUDE>,<GPS_SATS>,<SOFTWARE_STATE>, <SP1_PACKET_COUNT>,<SP2_PACKET_COUNT>,<CMD_ECHO>,<BONUS_DIRECTION>

Telemetry Display Prototypes (Payloads) :

<TEAM_ID>,<MISSION_TIME>,<PACKET_COUNT>,<PACKET_TYPE>, <SP_ALTITUDE>,<SP_TEMP>,<SP_ROTATION_RATE>

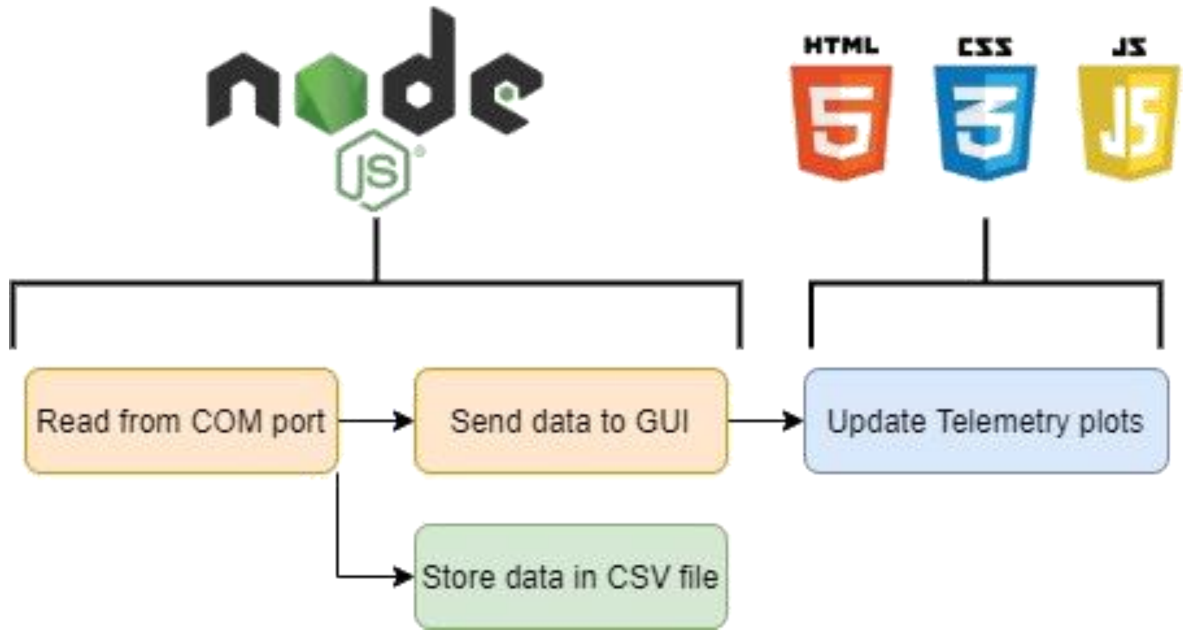
Real Time Plotting Software Design:

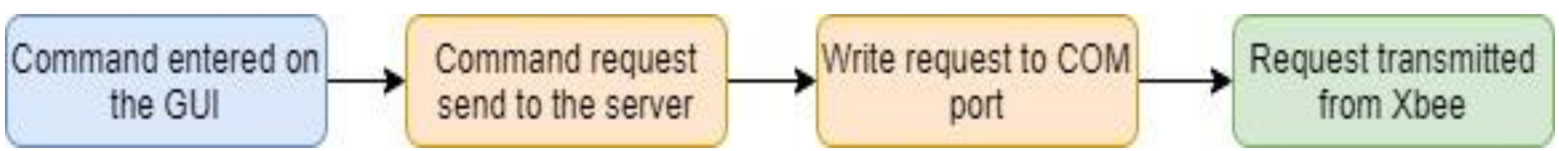
- Code for the ground station is built with visual studio code using JavaScript
- Telemetry data received will be registered right after being read in the ground station XBee Module in a .csv format
- The data received would then be presented on real time plots displayed in engineering units
- Telemetry will be checked by comparing data stored on the SD card with data stored on the device in .csv format
- The ground station software will display all the real time telemetry data

GCS Software (2/11)

Commercial off the shelf (COTS) software packages:
- XCTU (XBee Program Software)
- Visual studio code
- Arduino IDE

Server side:
- Node.js
- Socket.io



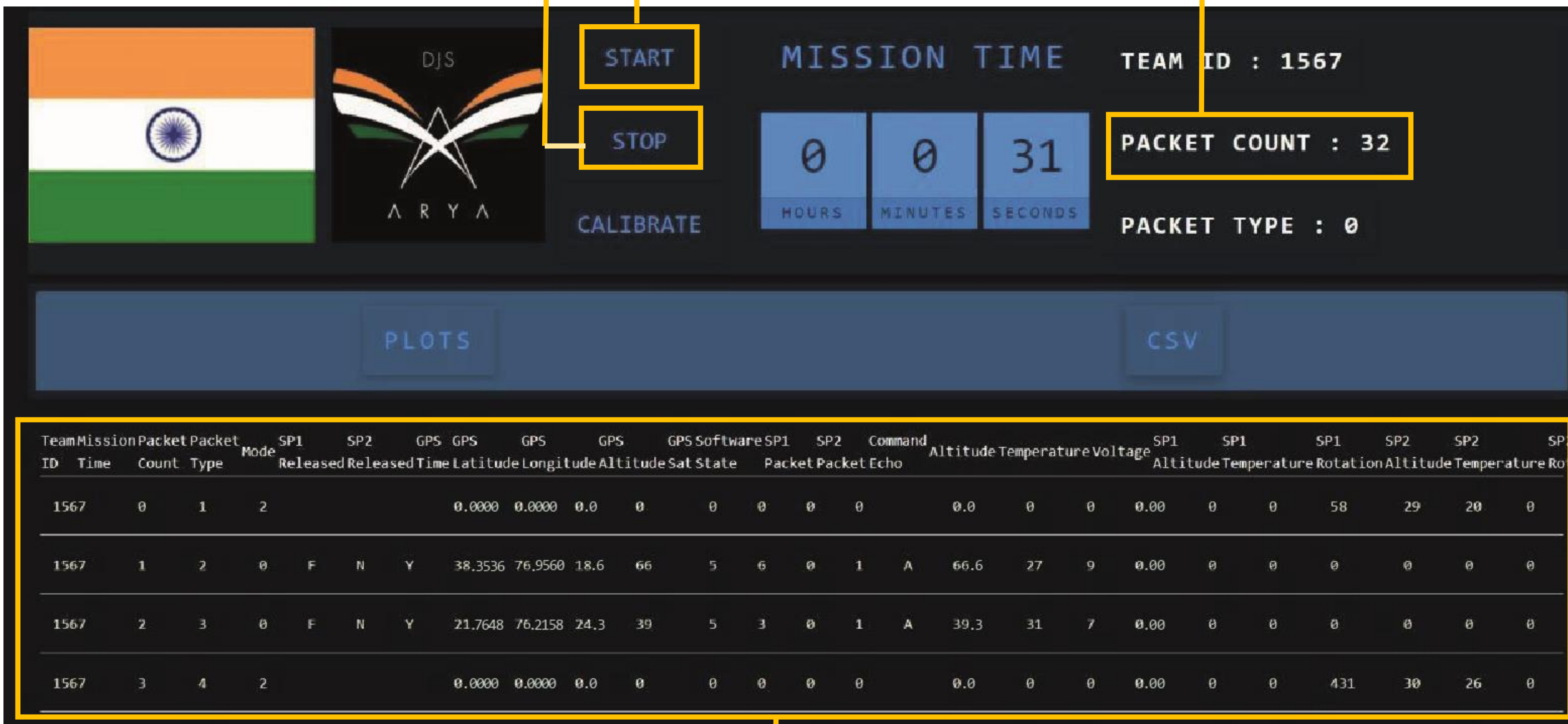


GCS Software (3/11)

Stop Telemetry

Start Telemetry

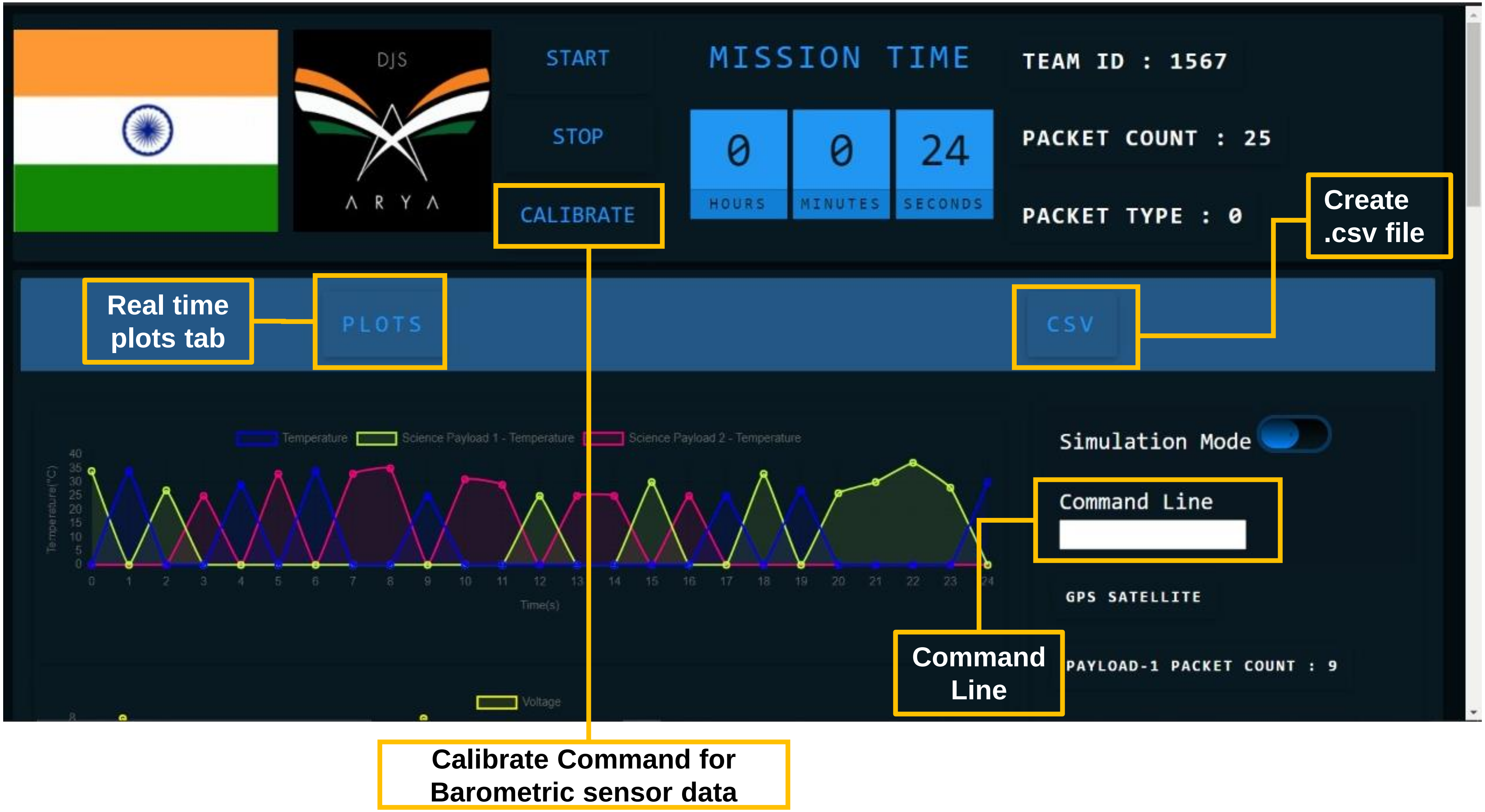
Packet Count



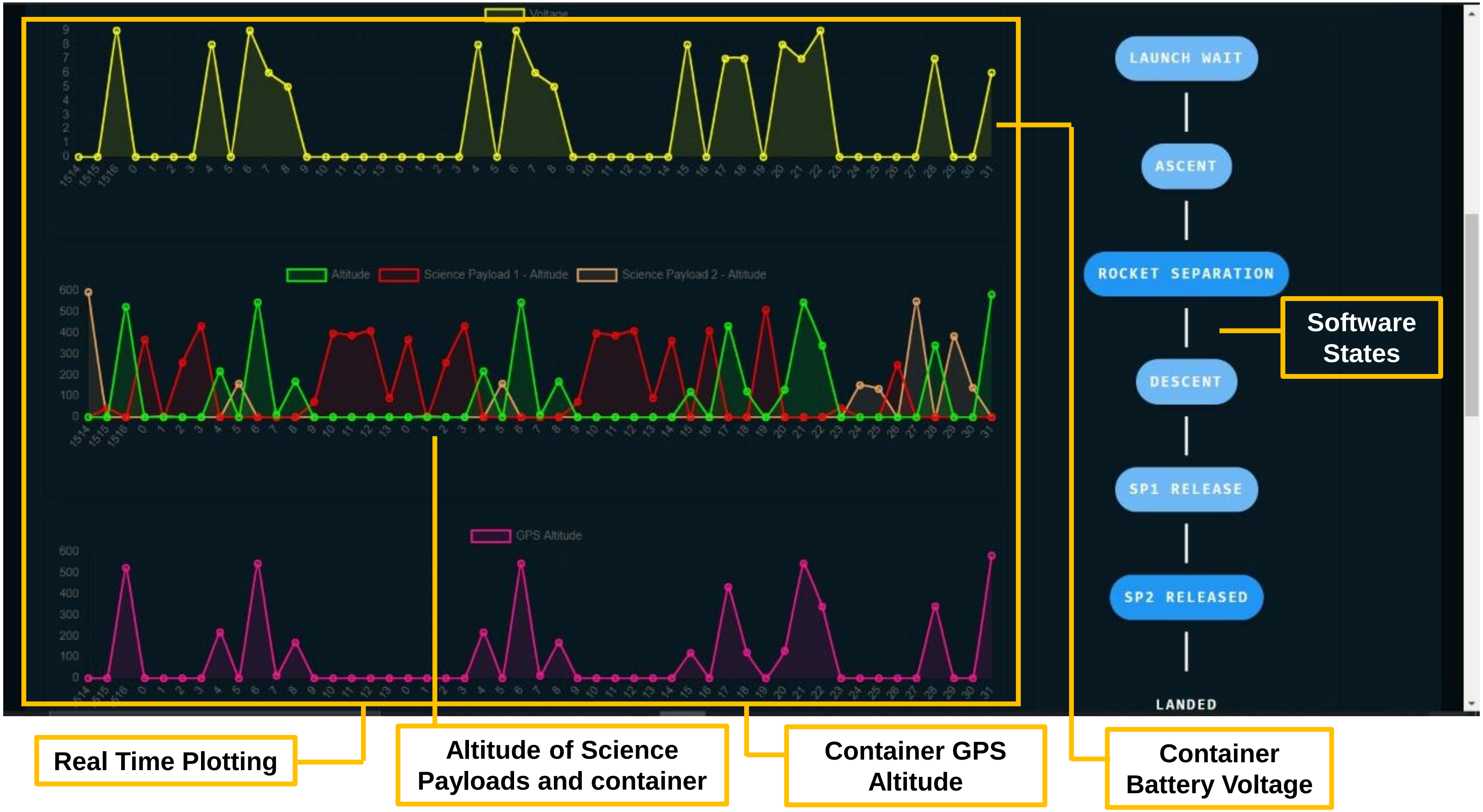
Team ID	Mission Time	Packet Count	Packet Type	Mode	SP1 Released	SP2 Released	GPS Time	GPS Latitude	GPS Longitude	GPS Altitude	GPS Sat	Software State	SP1 Packet	SP2 Packet	Command Echo	Altitude	Temperature	Voltage	SP1 Altitude	SP1 Temperature	SP1 Rotation	SP2 Altitude	SP2 Temperature	SP Ro	
1567	0	1	2				0.0000	0.0000	0.0	0	0	0	0	0		0.0	0	0	0.00	0	0	58	29	20	0
1567	1	2	0	F	N	Y	38.3536	76.9560	18.6	66	5	6	0	1	A	66.6	27	9	0.00	0	0	0	0	0	0
1567	2	3	0	F	N	Y	21.7648	76.2158	24.3	39	5	3	0	1	A	39.3	31	7	0.00	0	0	0	0	0	0
1567	3	4	2				0.0000	0.0000	0.0	0	0	0	0	0		0.0	0	0	0.00	0	0	431	30	26	0

Telemetry Data Recording

GCS Software (4/11)



GCS Software (5/11)



GCS Software (6/11)

Container GPS Latitude

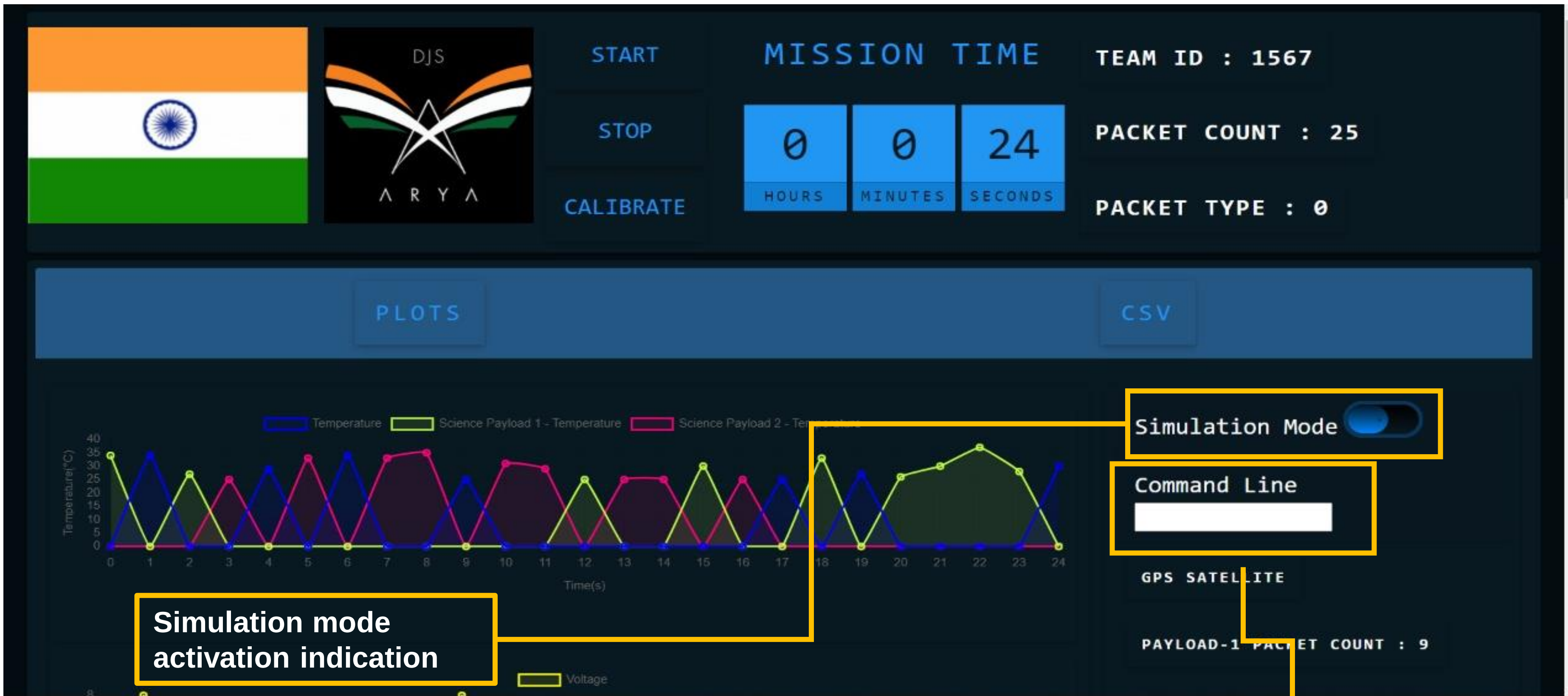
Container GPS Longitude

Science payload rotation

All Telemetry data displayed in engineering units

Real Time Plotting

Simulation Mode



CMD,1567,SIM,ENABLE
CMD,1567,SIM,ACTIVATE

Simulation mode activation commands sent through command line

Command line to activate simulation mode and send simulated sensor profile to container

On turning the simulation mode on, the .csv file is read on the server side and the pressure values are sent to the container at rate of 1Hz, which calculates the corresponding values of altitude and thus overwrites the real sensor data. When the ground station receives this data, it is plotted.

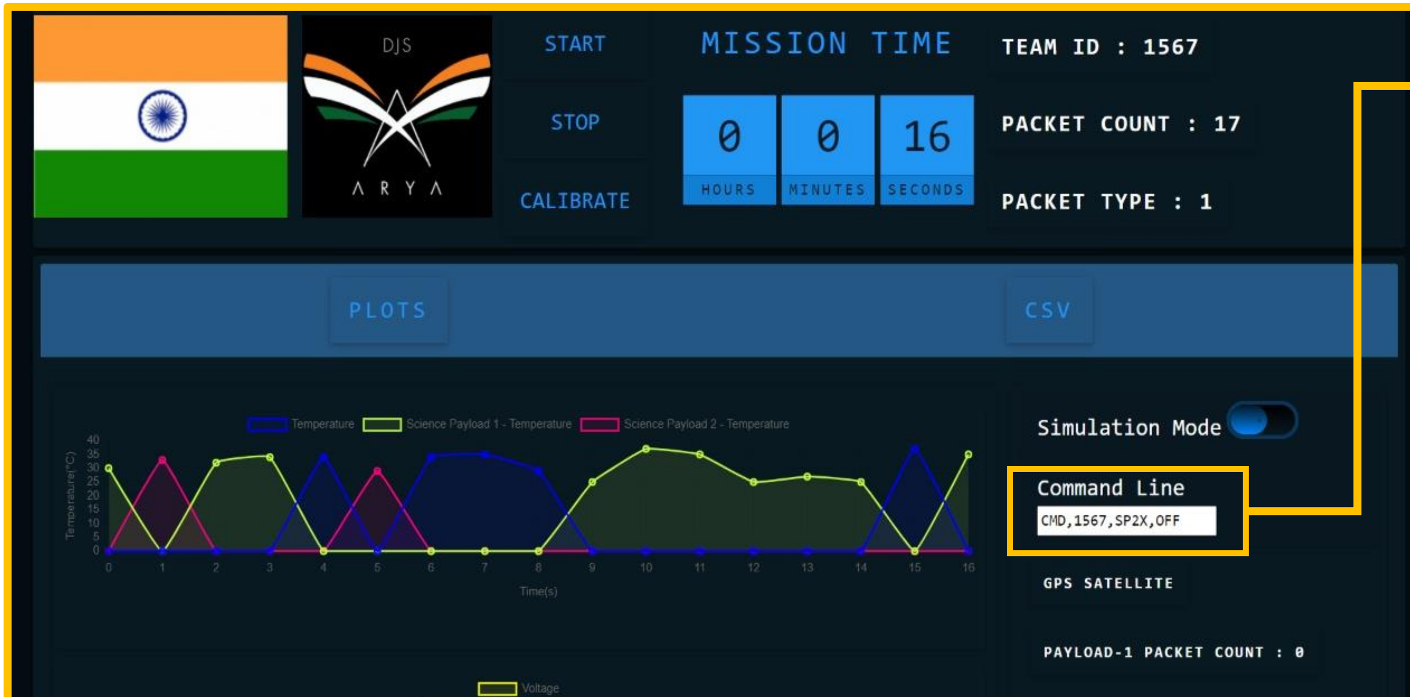
Container GPS Longitude

SP1 Rotation and SP2 Rotation

Simulated Pressure

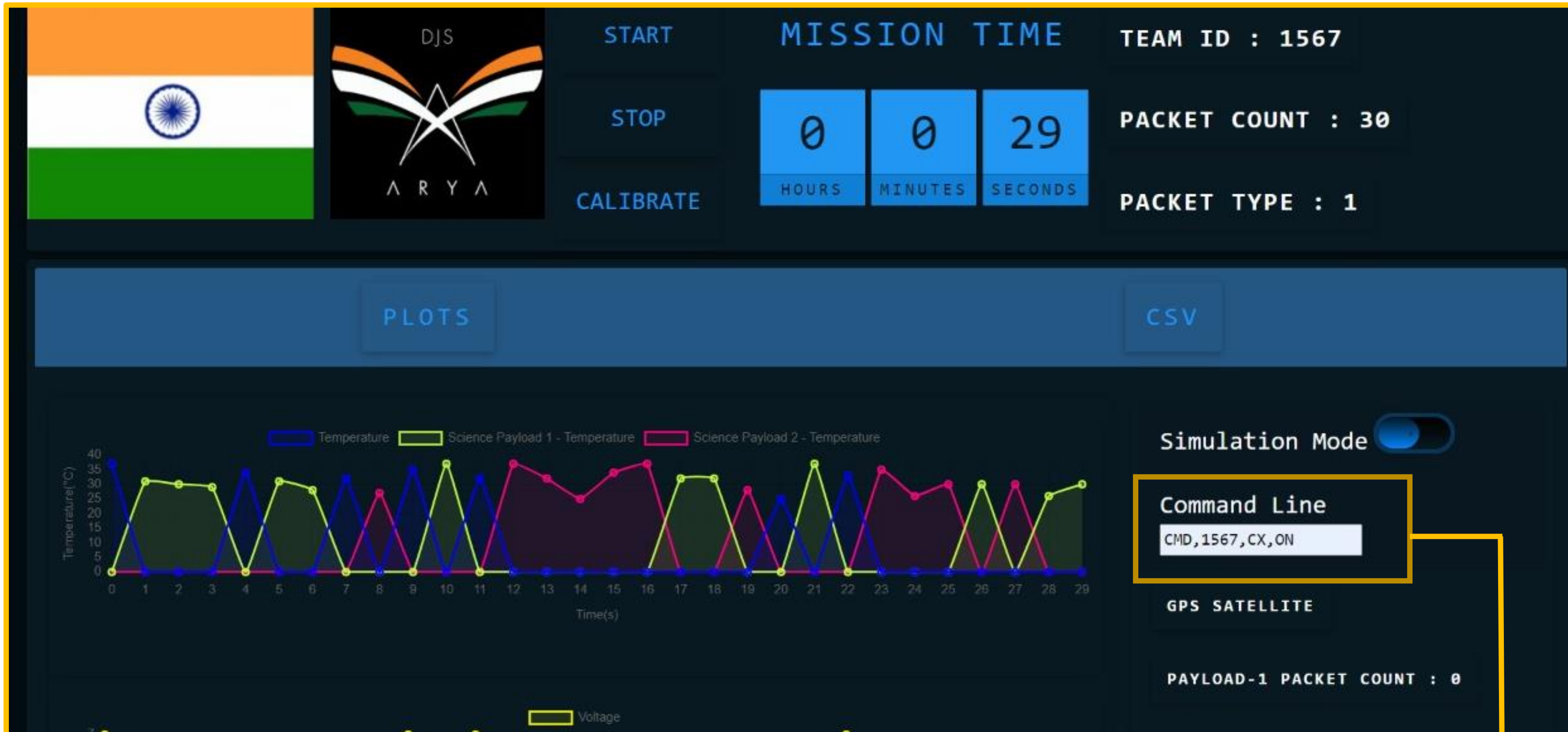
GCS Software (9/11)

- **Commanding:** A text input field is provided in the GUI where the commands can be entered by the operator which are read and processed by the server thus writing the corresponding request on the serial port. The XBee module reads the written request and sends it to the container XBee, then the container microcontroller processes it and performs the appropriate function.



Command instance: CMD,1567,SP2X,OFF is a command written in the GUI. The telemetry transmissions are deactivated on receiving the command mentioned above from the ground station. Thus, second payload's telemetry is switched off.

GCS Software (10/11)

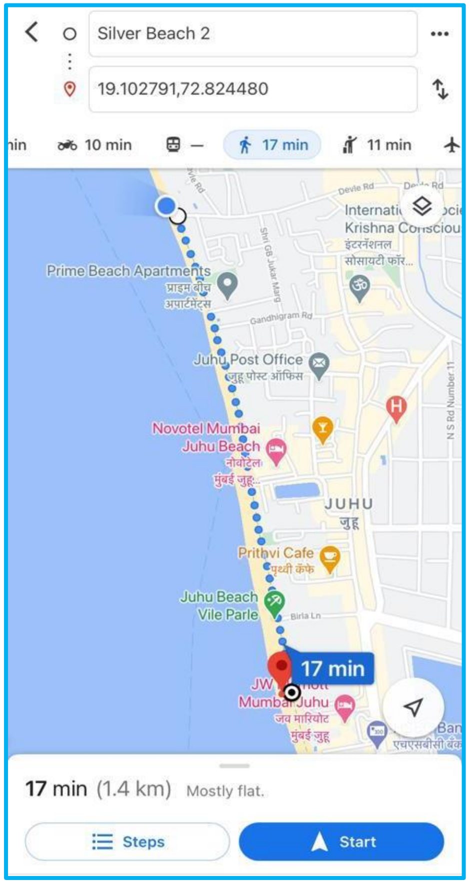


When the container receives the shown command from the ground station, its telemetry transmissions get activated, thus plotting the telemetry data of the Container.

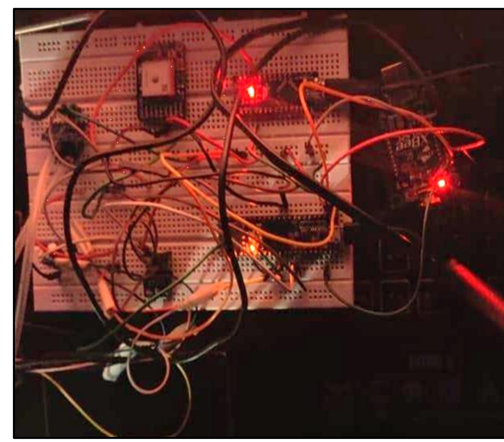
Container Command ON

GCS Software (11/11)

Progress since PDR



- GUI was successfully tested with the ground station antenna
- Test was performed at a local beach
- The range of the antenna turned out to be 1.4km



MQTT Integration

➢ MQTT Integration

- MQTT is a publishing and subscription-based messaging system that has been used for remote viewing of the telemetry data and for which we use **MQTT.js package**.
- For this method, the languages we use are **JavaScript, mqtt.js and Node.JS framework.**

➢ GCS Design

- On receiving the telemetry data from the XBee, the data is sorted and put into an object which is used to plot and write it in .csv format which is sent as telemetry data to MQTT server.
- The **ON** and **OFF buttons** on the dashboard regulate the transmission of all the telemetry (Container + SP1 + SP2) as well as the MQTT server submission of telemetry.

➢ MQTT Test Plans

- We have used https://test.mosquitto.org/ as our client to create the instance.
- The CSV data is published by subscribing to a topic 'teams/1567' which we create and using the client to publish the data which is also displayed on the terminal.

CanSat Integration and Test

Presenter's Name: Khyati Morparia

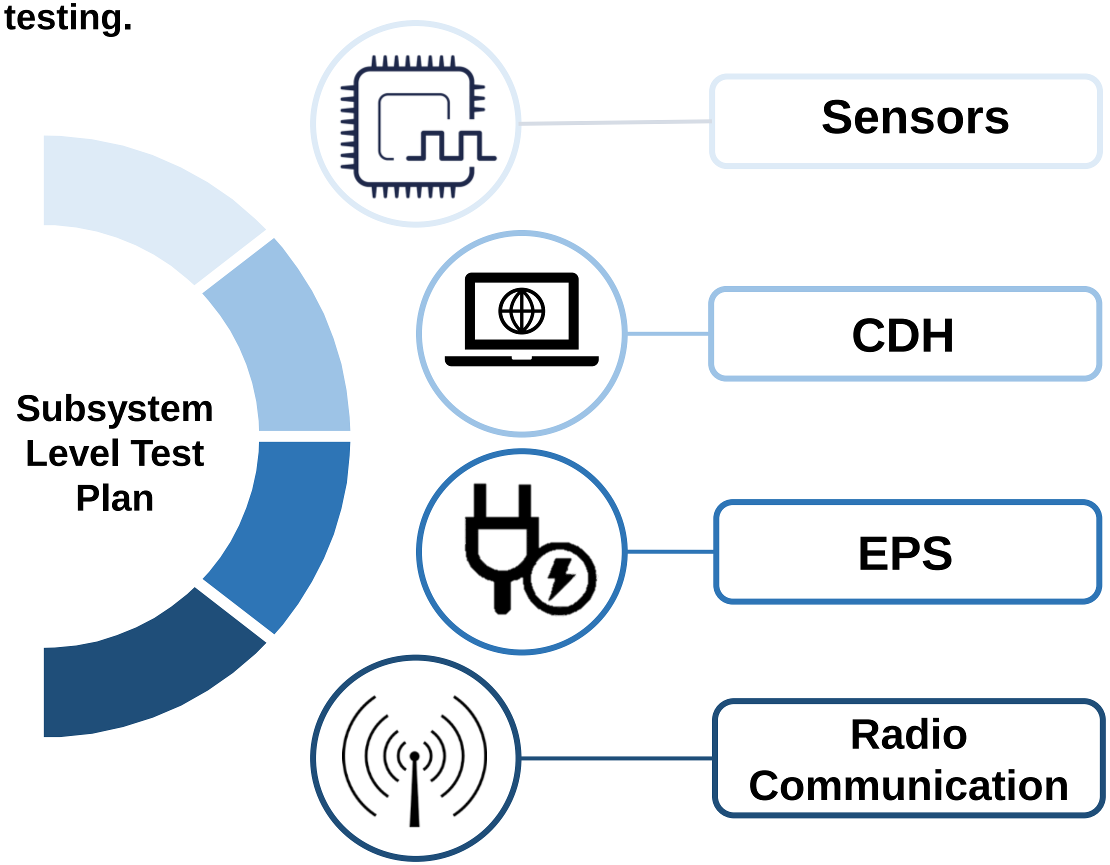
CanSat Integration and Test Overview (1/5)

CanSat Integration and test

- **Subsystem Level testing plan**
  - Sensors
  - CDH
  - EPS
  - Radio communication
  - FSW
  - Mechanical
  - Descent Control
- **Integrated Level Functional Test Plan**
  - Descent Testing
  - Communication
  - Mechanisms
  - Deployment
- **Environmental Test Plan**
  - Drop Test
  - Fit check
  - Thermal Test
  - Vibration Test
  - Vacuum Test
- **Simulation Test Plan**
  - Software State Test
  - Telemetry Test
  - Release Mechanism Test

CanSat Integration and Test Overview (2/5)

All the tests were performed at an individual level.
Positive results led to subsystem level and integrated level testing.



All sensors are individually tested and calibrated on a breadboard. Later, they are integrated together with the microcontroller and a unified code is produced.

Communication between XBees via antennas is tested by sending and receiving sample data which is in accordance with the telemetry format.

On basis of power sufficiency calculations, the whole system along with the release mechanism has been tested with batteries to validate the power consumption and battery efficiency.

XBees are setup in a star topology with PANID set according to the mission requirements. Range test is performed with sample data to validate the radio modules and antennas.

CanSat Integration and Test Overview (3/5)

Subsystem Level Test Plan

FSW

Entire Flight Software, GUI and flow of software states was tested by varying the altitude levels of the whole system using an elevator.

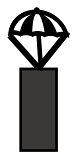
Mechanical

Dimension tests were performed on all parts. Simulations were performed on the container and the payload to check the survivability under 30Gs of shock.

Descent Control

Different angle of attacks for the payload wing were tested for sufficient lift generation using SolidWorks flow simulation and XFLR5 software. Drop test of payload was carried out to verify the same. Container parachute was tested to validate sufficient drag generation along with spill hole area iteration.

INTEGRATED LEVEL FUNCTIONAL TEST PLAN

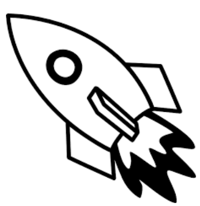


Descent Testing

Descent testing of the container and the payloads is performed and various subsystem mechanisms are verified.

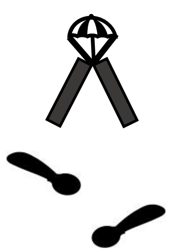
Communication

Communication test is carried out to verify, identify and eliminate any loss of data between payload-to-container and container-to-ground station.



Deployment

The container parachute deployment was tested. The seed-wing attachment point was tested for durability and survivability.



Mechanism

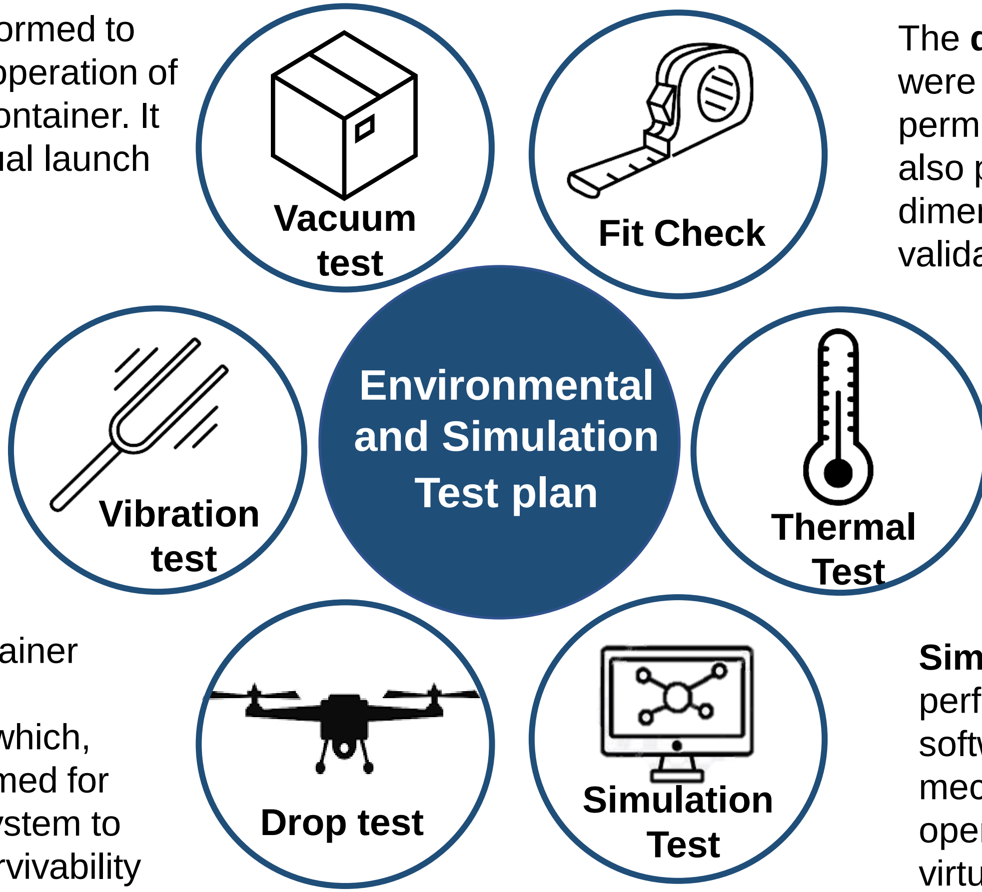
Payload release mechanism using nichrome wire and fishing line was tested. The burning of wire via a digital trigger and IRL 540N MOSFET at different altitudes was also tested.

CanSat Integration and Test Overview (5/5)

Vacuum test was performed to verify the deployment operation of the payload from the container. It helps in creating a virtual launch environment.

The **dimensions** of the CanSat were checked to be within the permissible range. The CanSat also passed through a go/no-go dimension inspection thus validating its dimensions

The CanSat will be tested using orbit sander to check its **endurance and durability** to withhold 30Gs of shock.



Temperature tolerance and sustainability of CanSat will be tested in a heat chamber with the help of hair dryers.

The payloads and container underwent **drop tests** individually. Following which, drop test will be performed for the whole integrated system to check the structural survivability and efficient functioning of release mechanisms.

Simulation test will be performed to verify the software state logic, release mechanisms and telemetry operation. It is useful for a virtual launch environment.

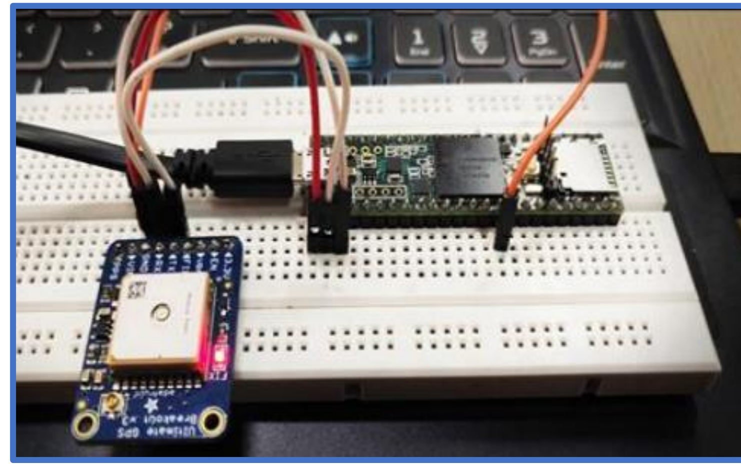
Subsystem Level Testing Plan (1/15)

Electronics Integration and Testing Description

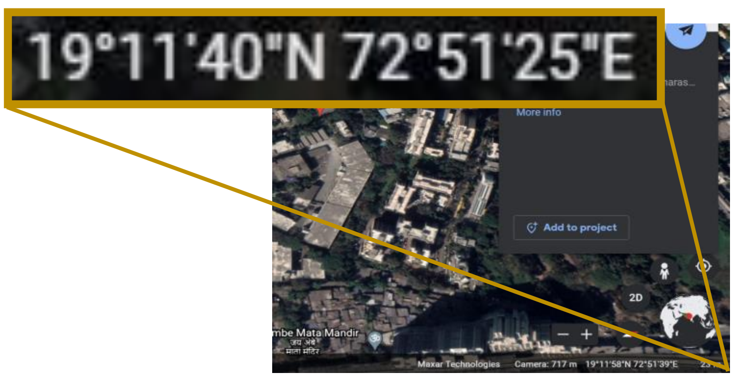
- Sensor selection is carried out by the whole team under the supervision of the faculty advisor.
- Each sensor is tested individually, and the obtained sensor values are stored and verified with expected readings and are later calibrated if required by adding an offset.
- All the calibrated sensors are integrated together, and a unified code is written in Arduino IDE using C/C++ according to the requirements of the mission statement.
- This set up is powered using external battery to satisfy the power requirements of the whole system.
- Once the power requirements are satisfied, the whole electrical subsystem is then miniaturized to fulfil the space constraints by designing PCB and the fabrication is carried out.

Sensors: GPS (Adafruit Ultimate GPS)

- The locking of GPS module with the Geo-stationary satellites was tested in the university premises.
- The coordinates are validated with the help of Google Earth.



GPS Testing



Google Earth coordinates

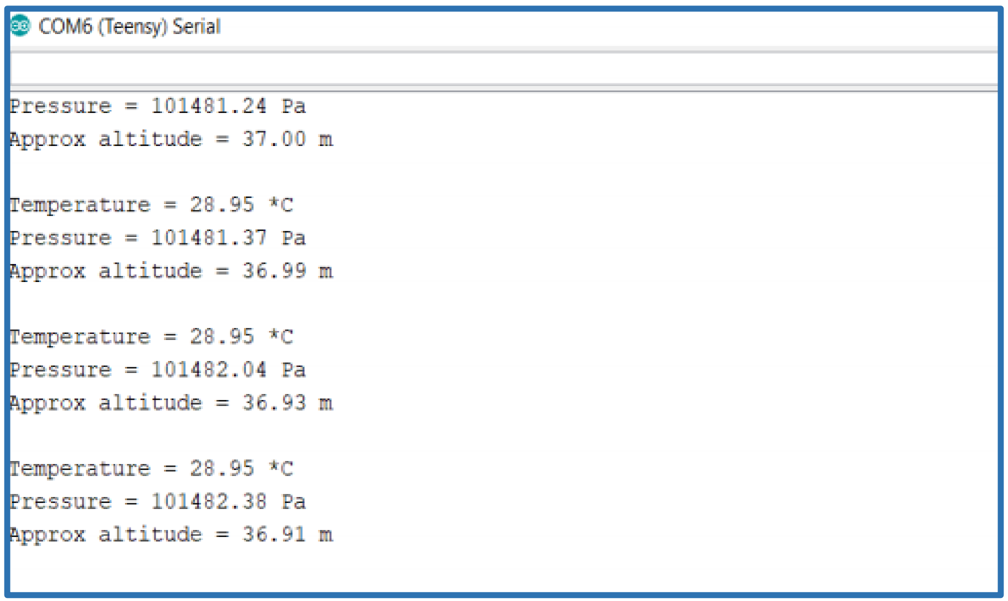
```
Time: 08:52:36.39200
Location: 1912.0175N, 7251.4263E
Altitude: 79.10
Satellites: 5
$GPGGA,085237.000,1912.0174,N,07251.4264,E,2,05,1.11,79.1,M,-62.7,M,0000,0000*7D

$GPRMC,085237.000,A,1912.0174,N,07251.4264,E,0.29,207.38,251020,,,D*6D
```

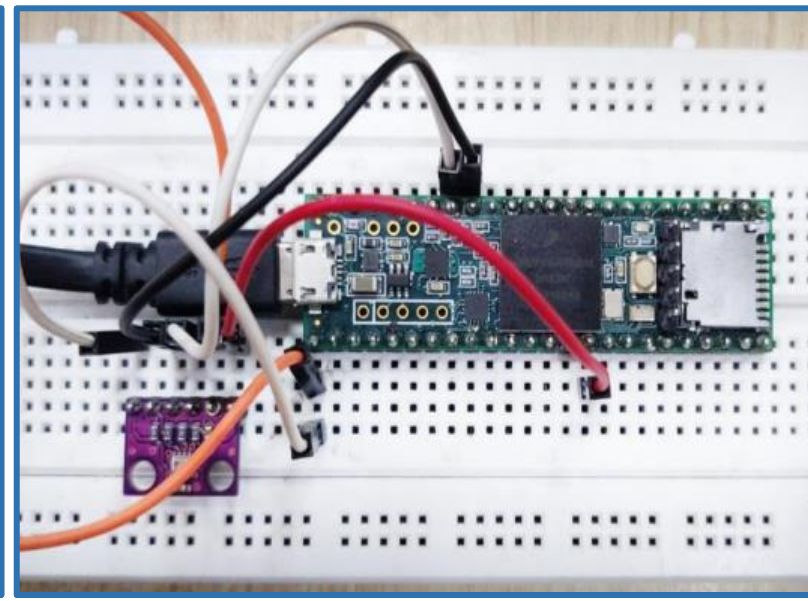
GPS after lock readings

Sensors: Air Pressure and Temperature (BMP280)

- The data received by BMP280 after uploading the code, is verified with the local weather and pressure data online.
- Altitude is verified by testing the sensor from a known elevation.



BMP 280 Readings

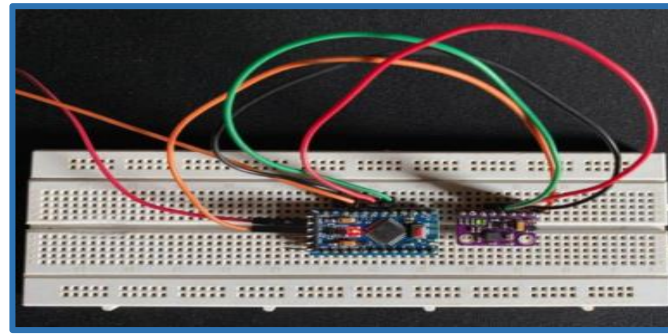


BMP 280 Testing

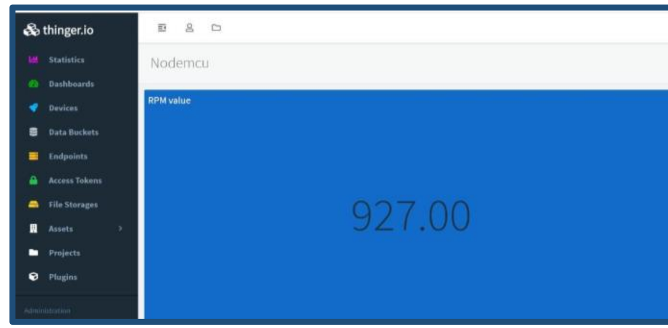
Sensors: RPM (10 DoF Sensor Module)

The sensors on the 10DoF are tested.

- The data obtained from BMP280, was verified with local weather and pressure data online.
- Altitude is verified by testing the sensor at a known elevation.
- The readings of the MPU9250 were validated by rotating the breadboard containing MPU9250 connected with a Wi-Fi Module, with the help of a DC motor having an RPM of 1000. The Wi-Fi module helped read and track real time data via Thinger.io cloud platform.



Real time rpm value

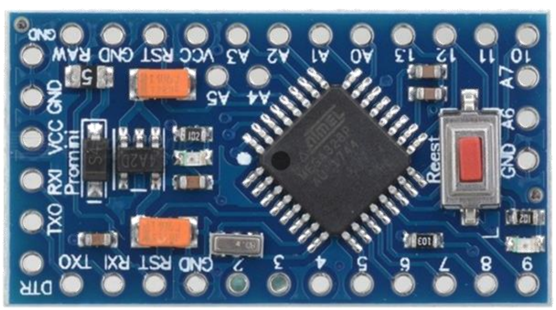



```
Temperature = 28.44 *C
Pressure = 1009.69 hPa
Approx altitude = 13 m
RPM:11.98
```

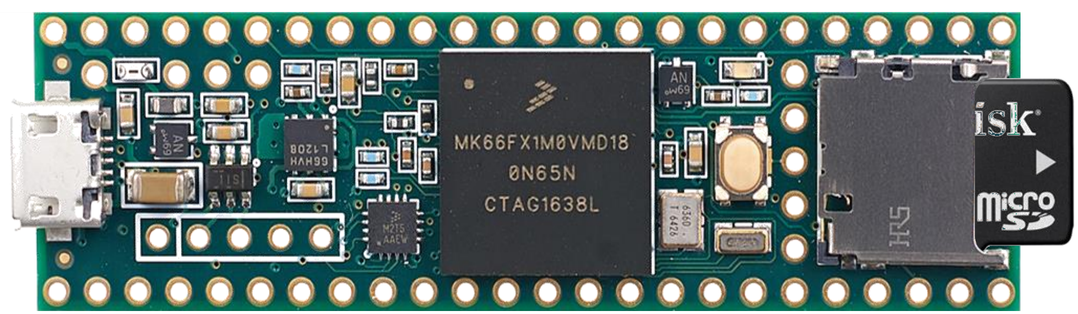
Initial Temperature, pressure and rpm readings

Communication and Data Handling (CDH)

- Efficient handling of data between all communications and sensor subsystem takes place due to the microcontrollers
  - Payload: Arduino Pro Mini
  - Container: Teensy 3.6
- The testing of EEPROM data variables and Teensy RTC are also validated.
- The data is stored with the help of SD card which is installed in the in-built SD Card slot of Teensy 3.6



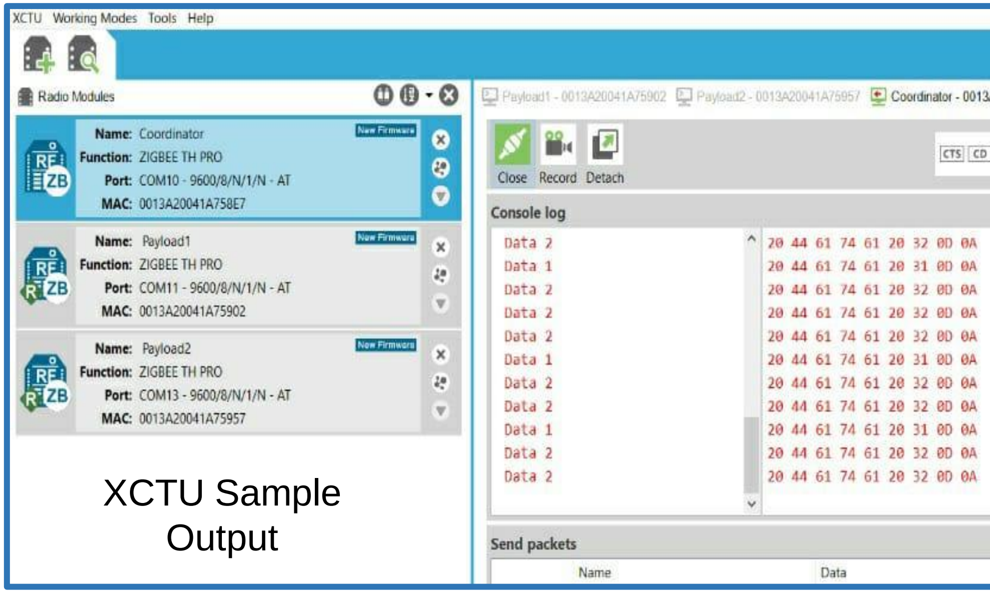
Arduino Pro Mini



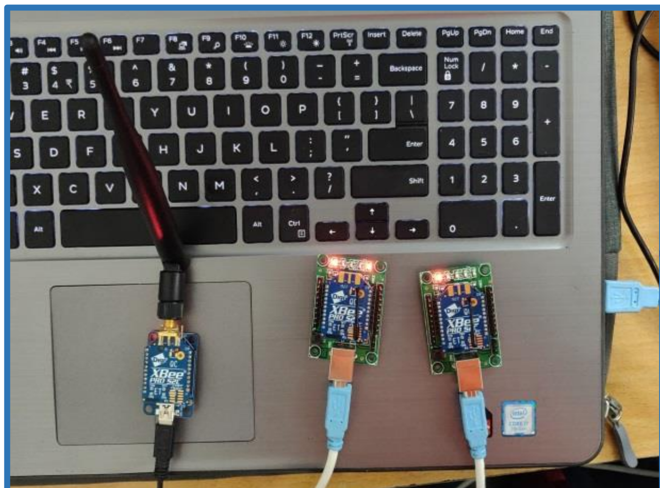
Teensy 3.6

Radio Communications

The sensors are integrated together to verify code efficiency and compliance with the mission telemetry format. Analysis of noise in the data with 1Hz sampling rate is also done.



XCTU Sample Output



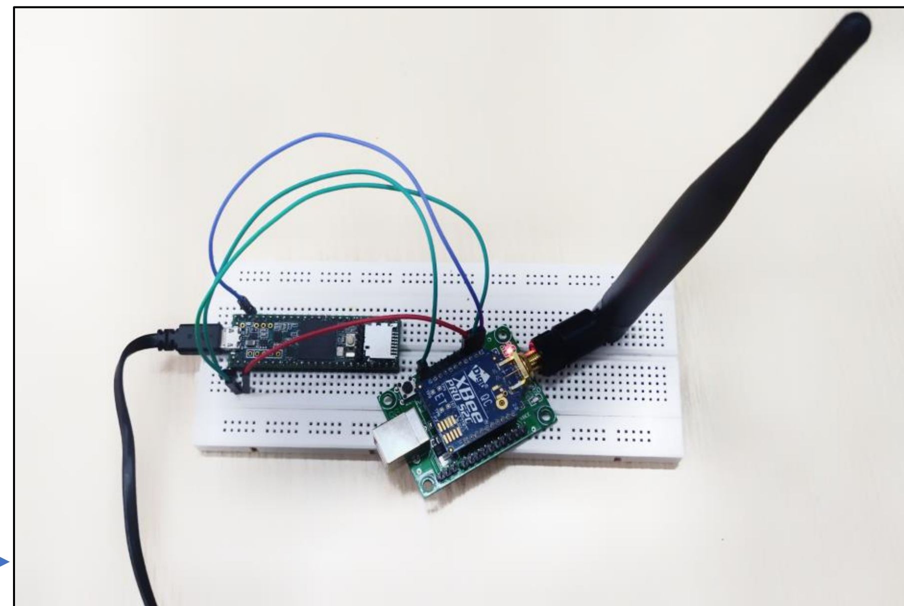
The star network topology between container XBee and payload XBees

- The relay communication with the help of Teensy 3.6 and the two container XBees,
- End to end communication between the Container XBee and Ground Station XBee

Subsystem Level Testing Plan (7/15)

Radio Communications

All the telemetry (container + payloads) is relayed to the ground station with the help of the omni-directional antenna in the container. The communication between container and ground station was tested.



Ground Station Antenna

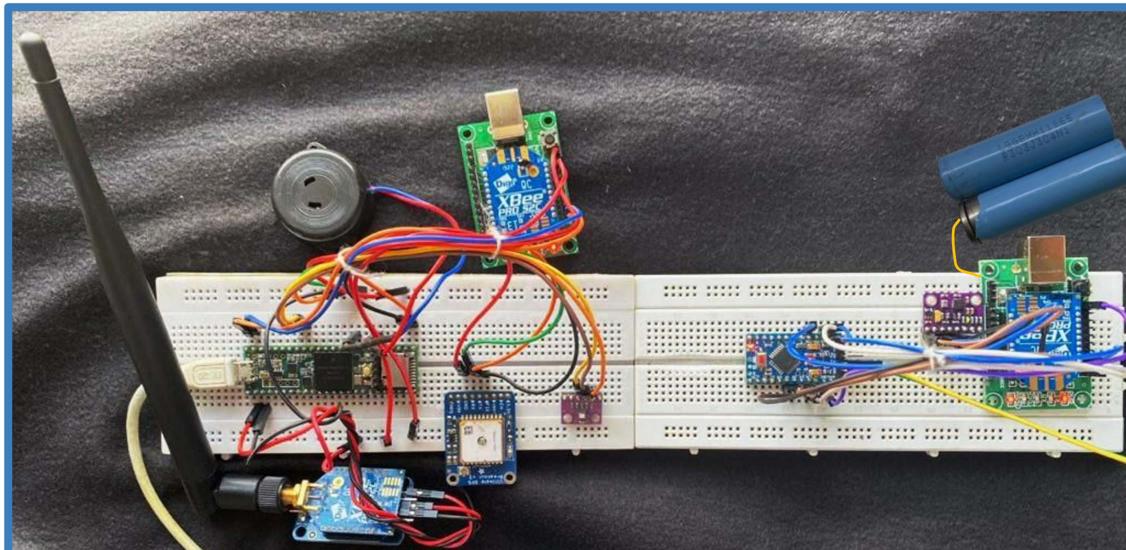
Container Antenna

Subsystem Level Testing Plan (8/15)

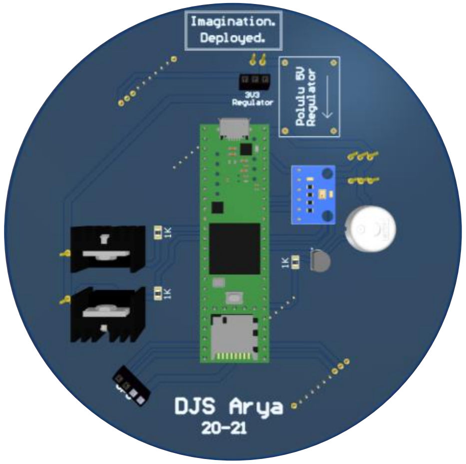
Electrical Power Subsystem

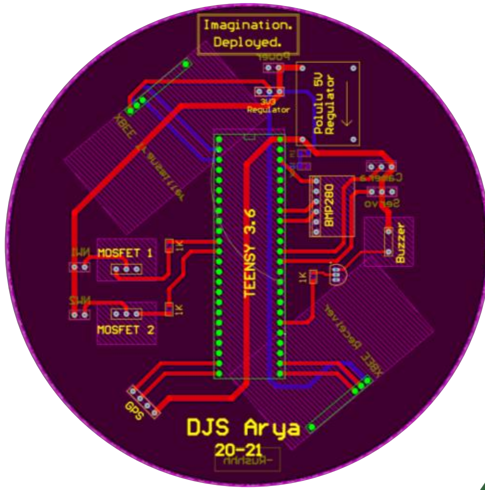
- All electronics of Payload and Container are connected on a breadboard and powered by their respective battery configurations.
- The system is powered on and readings are displayed.
- The batteries of container and payload will operate for more than 2 hours which suffices our mission requirements.
- The entire test has been carried out without any power issues.

Electronics subsystem testing on Breadboard



Subsystem Level Testing Plan (9/15)

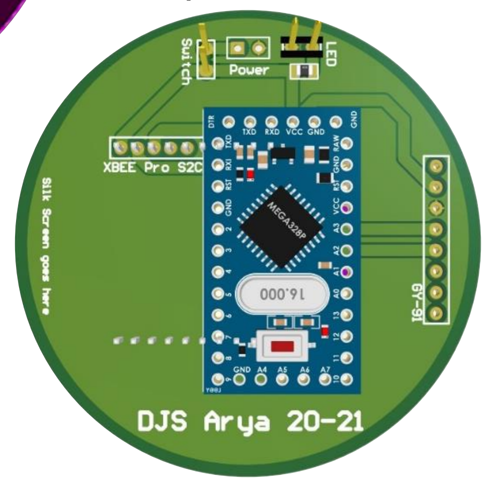


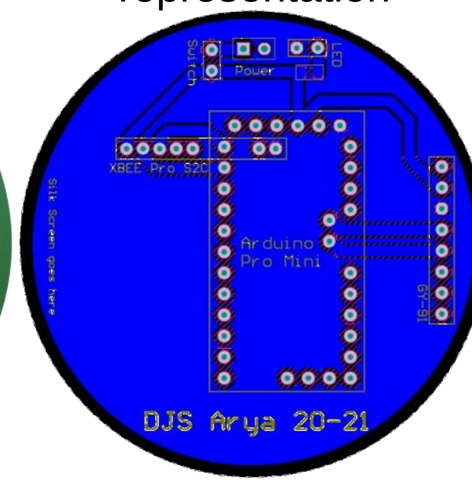


Payload PCB Design

3D representation

2D schematic representation





3D representation

2D schematic representation

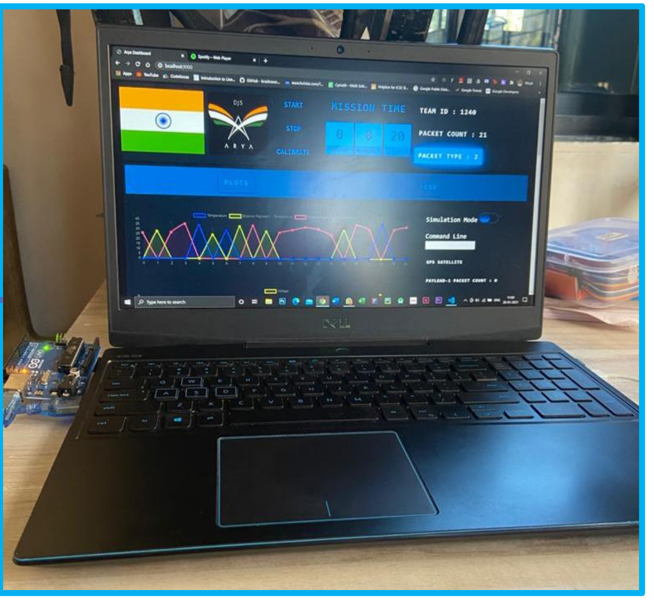
Container PCB Design

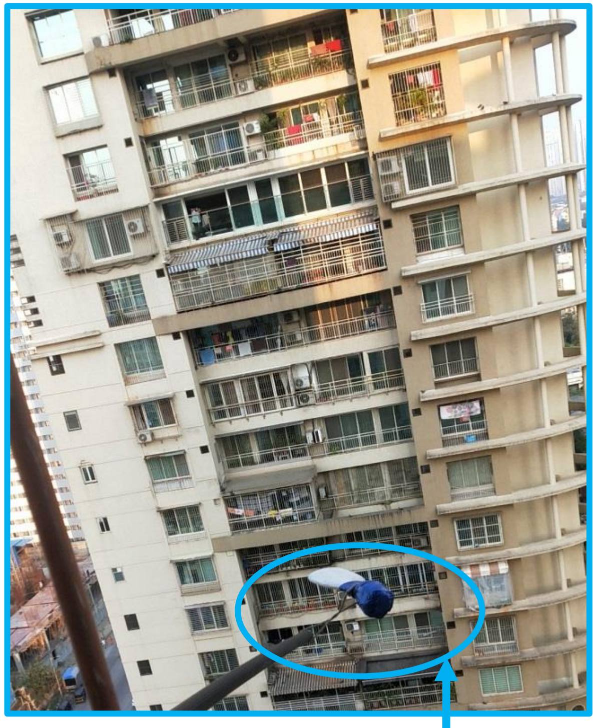
After testing all electronic subsystems and power requirement, the whole system is condensed into a PCB which fits perfectly in the payload and container.
The PCB is also tested out with the FSW.

Flight Software Subsystem

- The entire Flight SW and state flow was tested using building elevator.
- As altitude changes occurred, different software states were triggered and switched.

All telemetry and FSW data successfully displayed on the GUI





Payload

Mechanical Subsystem

- The entire mechanical assembly was designed using CAD software and XFLR5 Analysis. Manufacturing of various parts was done with industrial grade machines.
- The angle of attack of the wing of the science payload was tested for various iterations.
- A prototype of the autorotating maple seed science payload was manufactured for rigorous testing.

The following materials were used:

- The wing: Balsa with a covering of Monokote
- The seed: 3D printed with PETG

All structures have been built to survive 15Gs of launch acceleration and 30Gs of shock. All these structures and components have been designed and validated with SolidWorks simulations.

Subsystem Level Testing Plan (12/15)

Mechanisms

All release mechanisms are purely mechanical, and heat based. Keeping safety in mind; **NO** pyro, chemical, laser etc. based mechanisms have been used.

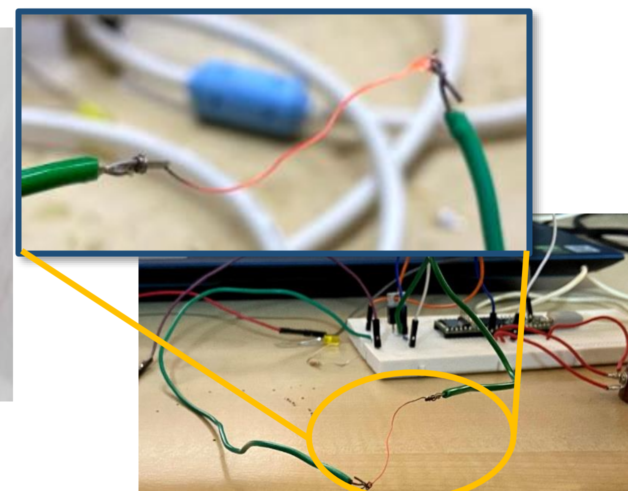
CONTAINER

- 3D printed hinges are used to connect the electronics bay with the container doors.
- The nichrome wire is housed inside a 3D printed box which ensures that the surroundings are protected.
- Elastic bands along with nichrome wire mechanism are used to open the container doors for the release of the science payloads at required heights.

Elastic Band

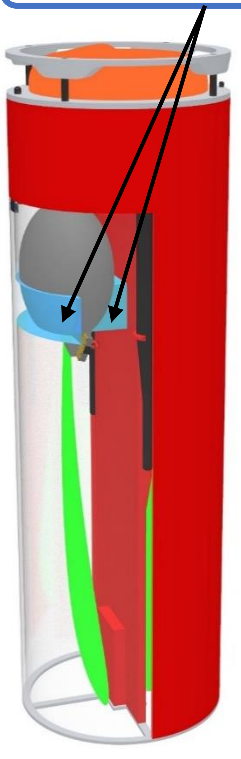
3D printed nichrome wire Box

3D printed Hinges

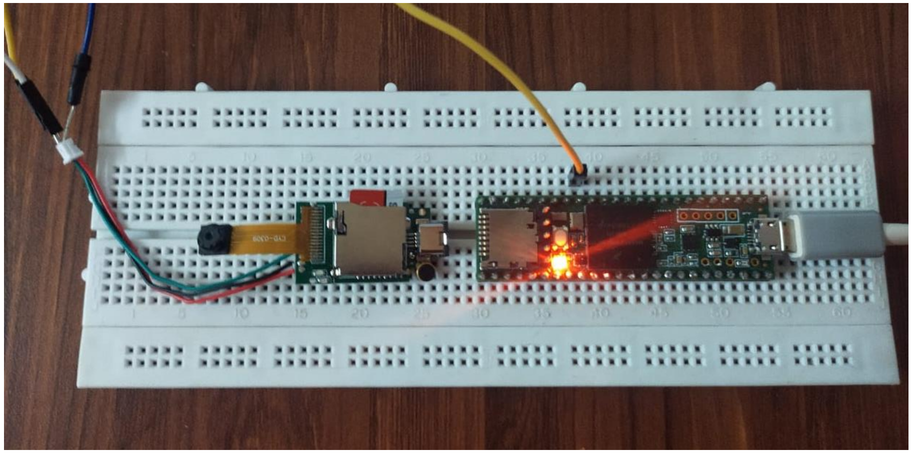


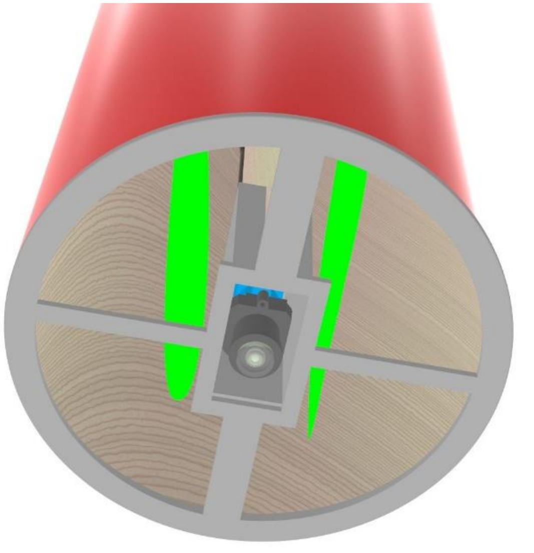
Mechanisms

3D extrusions



The dimensions of 3D extrusions made in the container, were verified for perfect fitting of the payloads





The rotation of Camera via servo motor was also tested

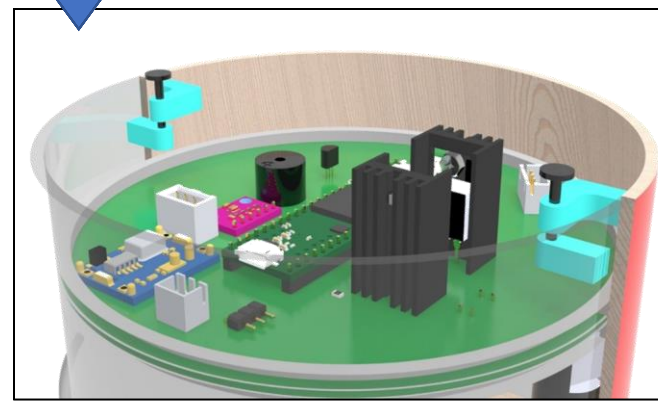
Subsystem Level Testing Plan (14/15)

Mechanisms

PAYLOAD

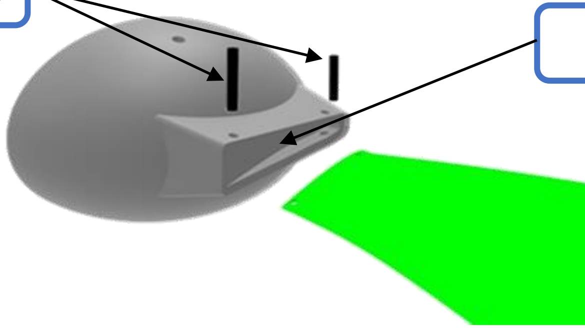
- The pin door mechanism secures the two halves of the electronics compartment by aligning the holes of the 3D extrusion and passing a pin through them.
- The wings of the science payloads are aligned at a fixed calculated angle using seed-wing attachment point and secured with carbon fiber support pins.
- Wing slot of each payload is made to perfectly accommodate the root of the wing with CF support pins passing through the wing and seed

Pin Door Mechanism



Support Pins

Wing slot



Test payload

Subsystem Level Testing Plan (15/15)

Descent Control

PAYLOAD

- A smooth and controlled descent was observed after the autorotating science payload underwent number of iterations in the
    1. Centre of gravity of the seed and
    2. Angle of attack of the wing

CONTAINER

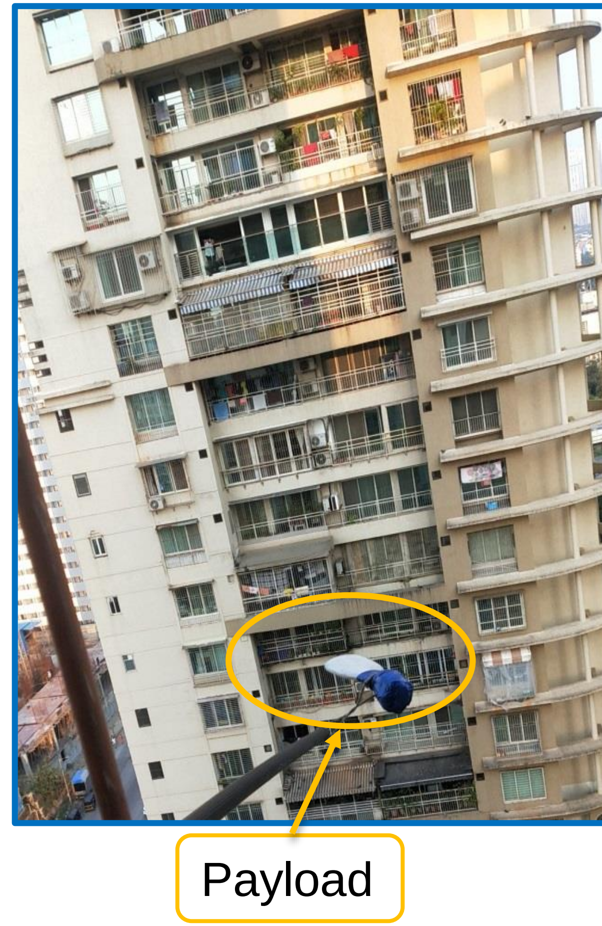
- The calculations for the total surface area and required radius of the parachute are done.
- Two mass equivalents: CanSat (600 gm) and Container (300 gm) are used for testing of parachute before and after the release of the science payloads

The container and science payloads were tested for their respective descent rate velocities and are validated to be within the restrictions mentioned in the mission guide.

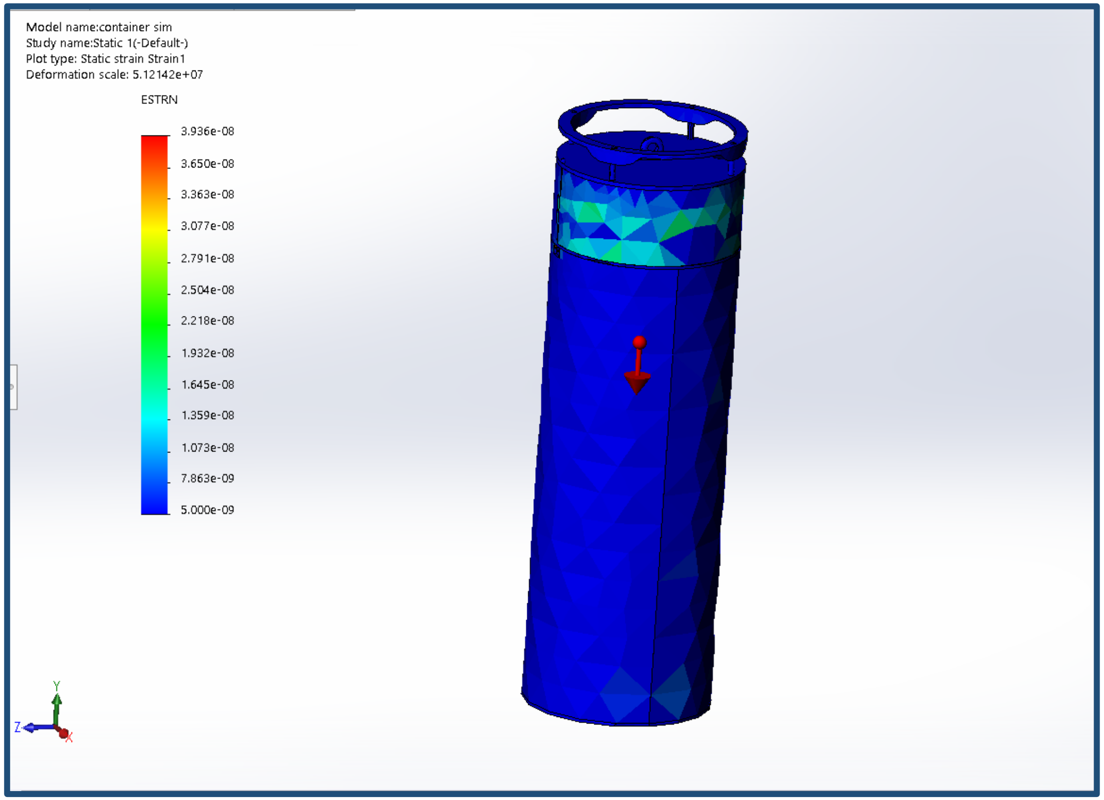
Integrated Level Functional Test Plan (1/8)

Descent Testing and Parachute release

- Initially the container and the payload were individually dropped from a height of approximately 100 meters and 60 meters respectively to verify their robustness and strength.
- Deployment of the parachute was observed as soon as the container was dropped.
- The autorotation of the maple seed payload was achieved after 15 meters of freefall.
- Parachute was drop tested with a weight equivalent to 600gm from a height of approximately 100m.
- After deployment, a smooth descent was observed.
- Parachute attachment point successfully survived the drop test.
- The descent time was approximately 7 seconds.



Mechanisms: Container stress analysis



- The stress analysis is carried under shock load of 30Gs for the container.
- The colors indicate the stress on the container - deep blue indicating the least shock.

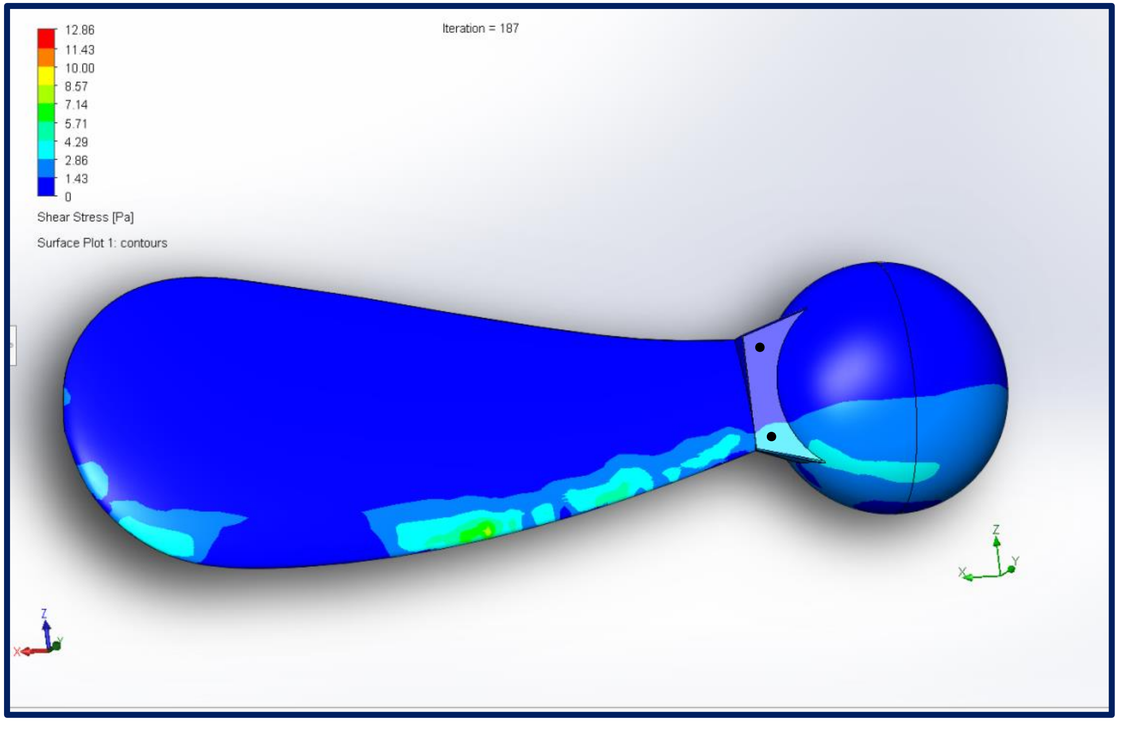
Test output:

Stress on all structural parts is studied with the help of SolidWorks.

The characteristics of various parts of the container such as

- Thickness of balsa fiberglass composite and
- Infill percentage of 3D printed container parts have been selected accordingly.

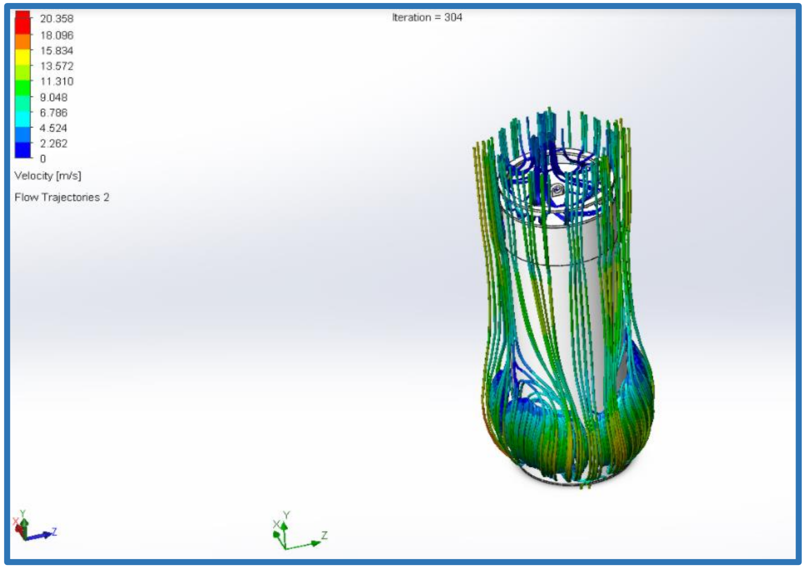
Mechanisms: Payload stress analysis



Test output

- Stress simulation was conducted on SolidWorks.
- The colors indicate various stress regions on the payload.
- Upon receiving the results, we verified that the payload survives 30Gs of shock.

Mechanisms: Flow simulation

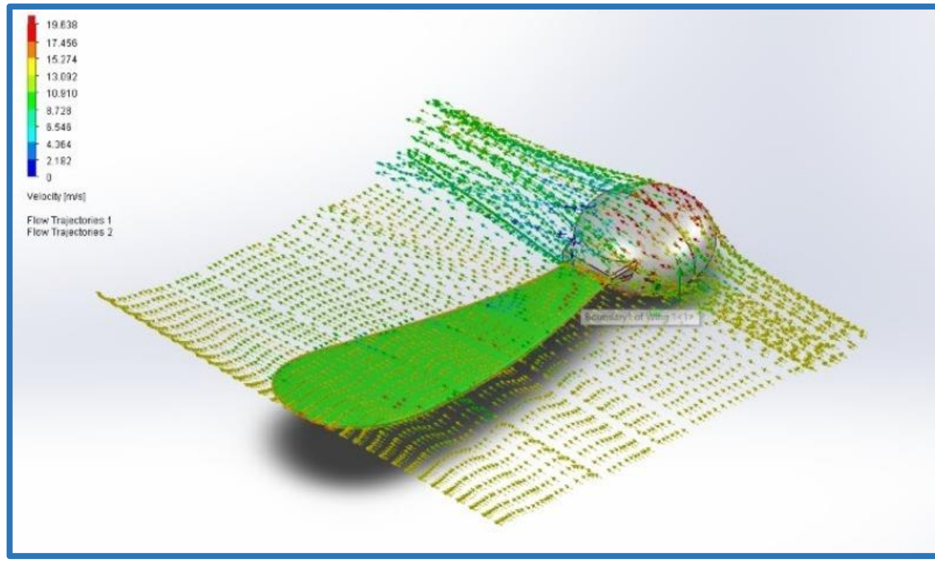


Test output (Payload):

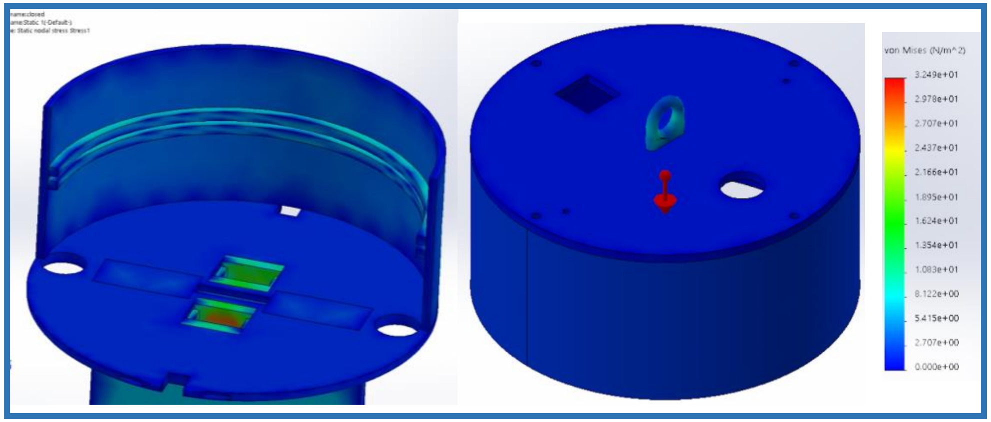
- The Flow Simulation shows how the wind interacts with various sections of the payload.
- After various iterations, the angle of attack was chosen to be 11°

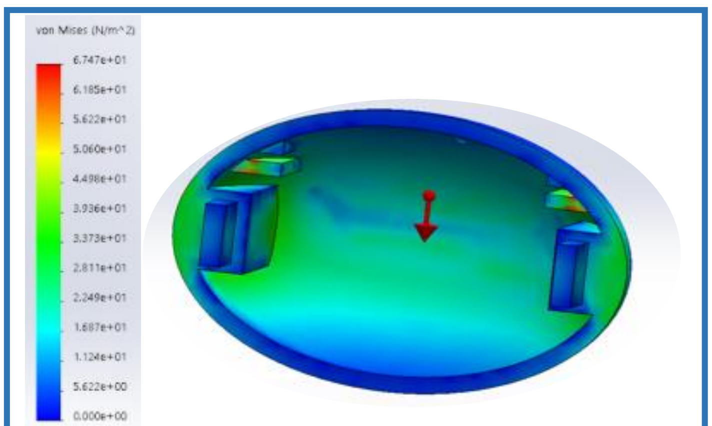
Test output (Container):

- Flow simulation done on the container projects a stable descent.



Mechanisms: Stress analysis of PCB slots





Test output (Container):

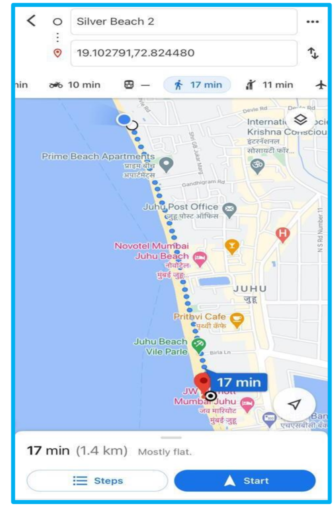
- Stress analysis on the PCB slot shows that it can withstand 30Gs of shock.
- The position of the slot provides the required strength and space for holding all the electronic components.

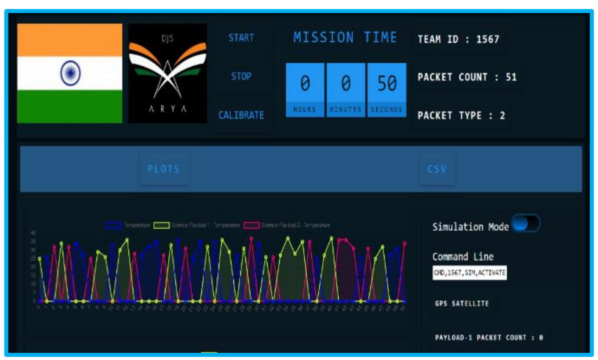
Test output (Payload):

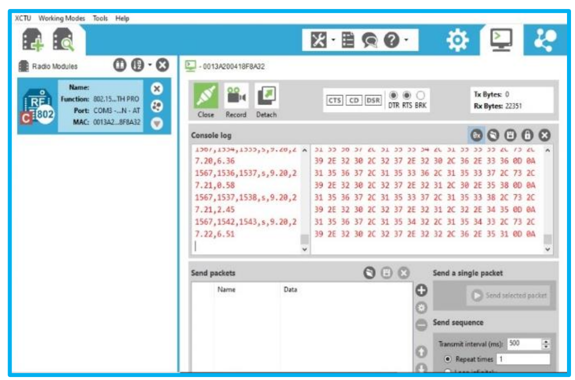
- Stress analysis on the payload proved it is durable enough to withstand 30Gs of shock.
- It holds the PCB and its components firmly in place during descent

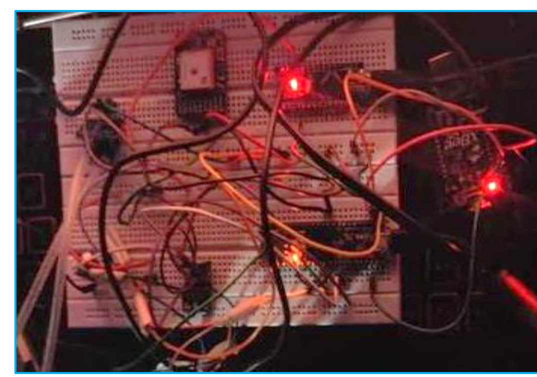
Communications

- Communication between payload-to-container and container-to-ground station with the help of XBees was tested successfully without any loss of any packet/ telemetry.
- Transmission with XBee was tested by keeping the handheld antenna fixed at one place and moving the XBee from antenna as far as possible and tested how far the connection was stable
- Despite several people along the way acting as obstacles, no packet loss was observed until 1.4 km. XCTU software was used to verify telemetry data on the GUI.





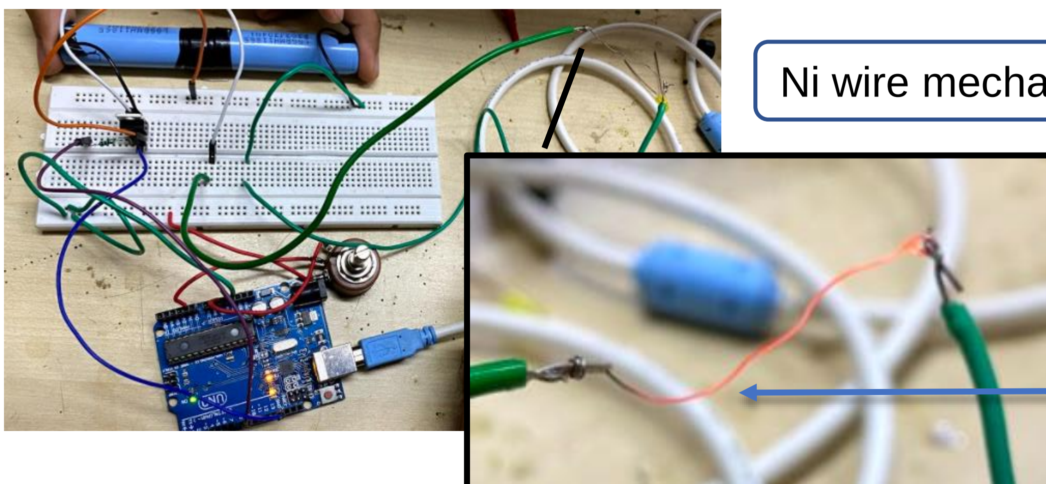




Integrated Level Functional Test Plan (8/8)

Deployment and Release Trigger

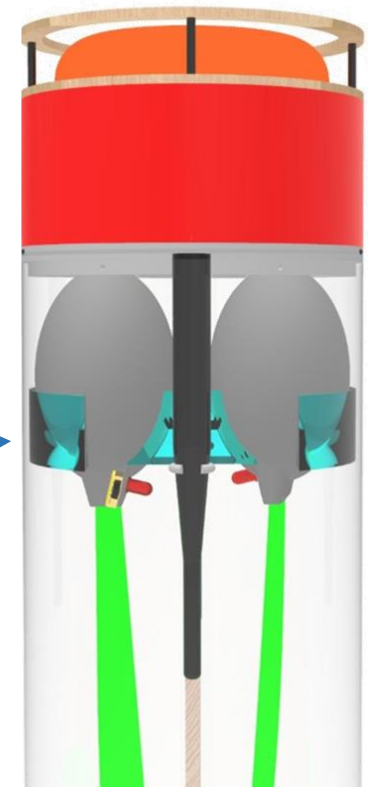
- Nichrome wires of different gauges were tested.
- Based on which, the current to be supplied and time required to burn the fishing line were taken into account.
- Placement of maple seed science payloads in the container were tested to be perfectly aligned with the 3D printed extrusions.
- Deployment of the two payloads was tested using nichrome wire release mechanism at simulated 500m and 400m respectively using BMP 280.



Ni wire mechanism circuit

Red hot Nichrome wire

3D printed extrusions



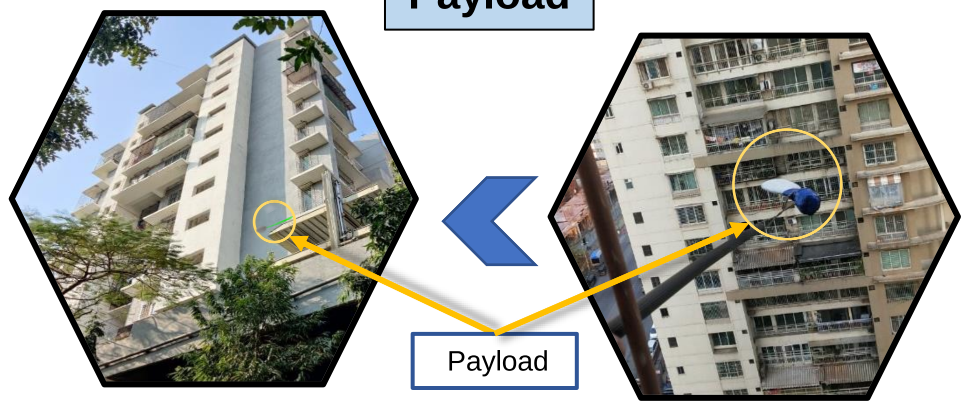
Environmental Test Plan (1/3)

DROP TEST

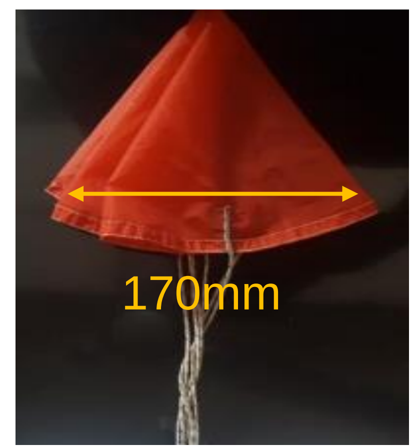
- In order to verify the survivability of the wing attachment and strength of the seed, Payload was dropped from a height of approximately 60m.
- Electronic components were integrated in the payload while testing
- Due to its structure and low CG, payload achieved autorotation
- Descent time for the payload was approximately 3s
- The camera was also tested during the drop test

- To ensure smooth deployment, container parachute was tested
- Container has been manufactured and drop test was performed successfully.

Payload



Container



Environmental Test Plan (2/3)

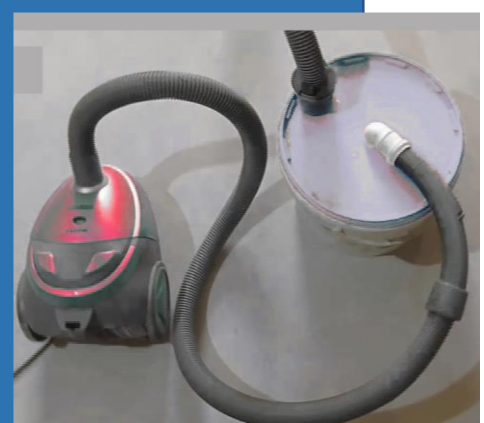
- Stowed CanSat dimensions were checked with a measuring tape.
- The length of the container was measured and found to be within 392 mm and diameter within 122 mm

FIT CHECK

- Payload is such that it fits inside the container without any hindrance.
- To check the clearance of the CanSat, a compartment like the rocket CanSat section was prepared

- CanSat will be kept in a bucket and covered using a polycarbonate sheet.
- A vacuum cleaner will be used to pull a vacuum.

VACUUM TEST



When the peak value is reached, the telemetry is tracked, and the vacuum is shut off.
Air enters the vacuum chamber slowly and the operation of CanSat is monitored.

Environmental Test Plan (3/3)

- An Orbit sander will operate at a fixed orbits per minute ranging from 12000 to 14000 orbits per minute.
- The CanSat will be placed on the orbit sander.

VIBRATION TEST

- The sander will be at full speed for 5 seconds.
- The amount of shaking generated by this sander is around 20 to 29 Gs.

- CanSat will be placed in a thermal chamber with inner temperature displayed on the screen.
- The chamber will be on till the inner temperature reaches 60ºC.

THERMAL TEST

- The test will go on for 2 hours and the temperature will be monitored.
- Damage inspection shall be done after removing the CanSat from the chamber.

Test Procedures Descriptions (1/5)

	Test Procedures	Test Description	CR No.	Pass/Fail Criteria	Status
SENSORS	GPS Sensor Test	Accuracy test for location readings	33	The GPS data should correspond to our actual location	✓
	Air Pressure Sensor Test	Altitude is verified by testing the sensor at a known elevation.	25,34	The sensor values of altitude correspond to known elevation	✓
	Air Temperature Sensor Test	Precise measurement of the surrounding temperature	26	The measured values correspond to the actual temperature	✓
	Rotations per Minute Sensor Test	Accuracy test for the calculated number of rotations per minute	27	The readings from the sensor are equal to the actual motor RPM with which it was tested	✓
	Battery Voltage Test	Test for accurate measurement of battery's voltage	35	The measured value is equal to the predicted value	✓
	Bonus Camera Test	Testing the compliance of the camera with the mission guide requirements	#BNS1	The image produced by the camera is of 640x480 pixels and is stored in SD card	✓

Test Procedures Descriptions (2/5)

	Test Procedures	Test Description	CR No.	Pass/Fail Criteria	Status
C D H	XBee Communication Test	The star network topology (between container XBee and Payload XBee) and end to end communication is tested.	19,20,21,30	The data communication occurs without any loss of data	✓
	XBee Antenna Range Test	At different ranges, the transfer of telemetry between 2 different XBees and antenna were tested for various ranges.	31,36,62	GCS receives the entire telemetry data from the range up to 1.4 Km	✓
E P S	Testing of Power source	Verify power source provides required power level (current and voltage)	42,45,47	The measured and actual values should match	✓
F S W	Testing of subsystem	The entire Flight Software and state flow was tested	48,49	There is communication between the payload and the interface	✓
	Testing of Data Transmission in CSV format at 1 Hz	Transmission of data using XBees to check the rate of transmission in proper format	36,51,55,65	The data transmission happens at the required rate(1 Hz) and received data is in CSV format	✓

Test Procedures Descriptions (3/5)

	Test Procedures	Test Description	CR No.	Pass/Fail Criteria	Status
FSW	Testing of Data Recovery using EEPROM	Resetting the telemetry to check the data recovery using EEPROM memory	48,49,50,55,57	The transmission of data continues from where it was reset	✓
GCS	Testing of the GCS Interface	Checking the transmission between container XBee and Ground Station XBee by varying parameters. 3 XBees are set up for transmitting and receiving sample data in string format	54,58,59,60,61, 62,63,64	All received telemetry should be plotted in real time which shall be verified later by comparing the csv format and the values on the serial monitor.	✓
	Testing Accuracy of XBees Communication			The transmission of telemetry data occurs without any loss of data	✓
	Testing of Compliance of Data with Competition Guide Requirements	Compliance of the telemetry data format as per the competition guide and recording in .csv format	51,55,65	The received data is in compliance with the mission guide.	✓

Test Procedures Descriptions (4/5)

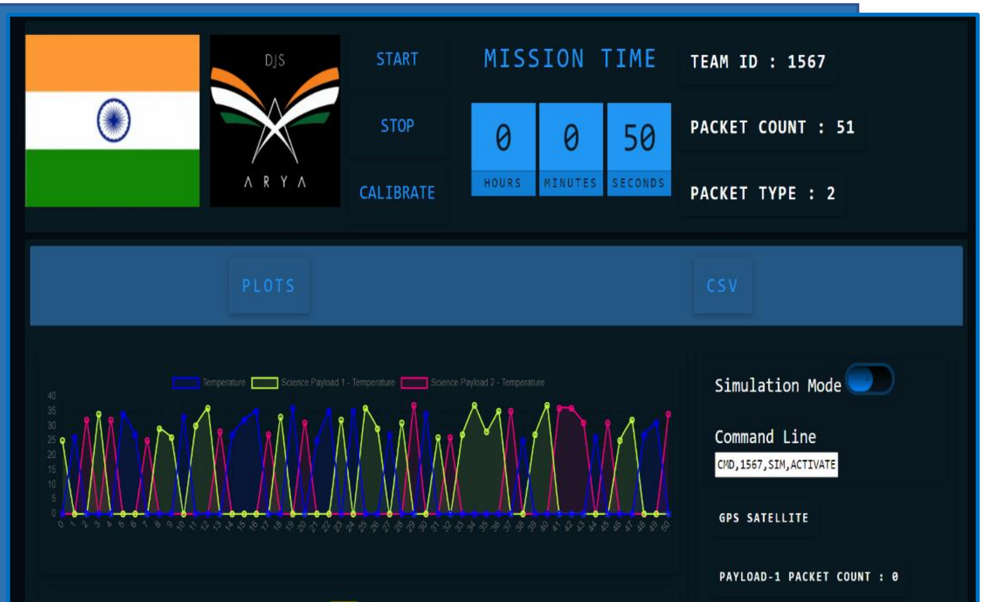
	Test Procedures	Test Description	CR No.	Pass/Fail Criteria	Status
GCS	Internal RTC Test	Internal RTC on Teensy 3.6 is connected to the coin-cell and its data is recorded. It will store the time even if the microcontroller is reset	50	The RTC must keep the time even after reset and real time plotting of data happens on GCS software	✓
ENVIRONMENTAL	Mass Test and Fit Test	The total mass of the CanSat is measured The dimensions of the whole CanSat are measured	1,2,3,5	Mass should be 600 $\pm$ 10 gm CanSat shall fit in a cylindrical envelope of 125mm x 400mm	✓
	Drop Test	The CanSat is released from a height of 61cm with the support of a kevlar chord to validate its survivability and shock absorbance.	12,13,14	No part of the CanSat should be detached. The structure must not flex during the drop test	✓
	Thermal Test	CanSat is placed in a thermal chamber and the temperature is set to 60°C using hair dryers to verify its survivability	-	No material should warp, weaken, change characteristics, or fail to function at temperatures up to 35°C	✓
	Vibration Test	Orbit sander is used to verify shock survivability of all major structures of the CanSat	-	CanSat is placed along the edges of the sander and is cycled regularly over a minute to survive vibrations up to 233 Hz and a shock up to 29 Gs	✓
	Vacuum Test	Deployment operation of payload(s) is verified using a bucket and polycarbonate sheet	-	The CanSat should transmit the telemetry even when peak altitude is reached	✓

Test Procedures Descriptions (5/5)

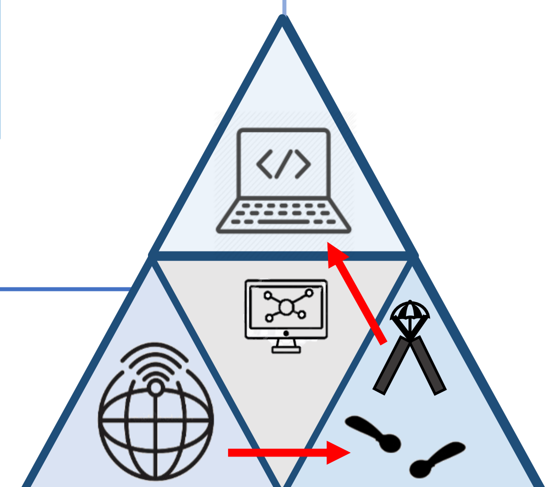
	Test Procedures	Test Description	CR No.	Pass/Fail Criteria	Status
MECHANICAL	CanSat release mechanism	Release of the CanSat from rocket, deployment of the parachute is tested	3,8	Parachute deploys passively as soon as the CanSat starts to free fall	✓
	Descent of CanSat	Descent of CanSat is observed at every stage	10	With the help of parachute, the CanSat should descend at a rate of 15 ± 5 m/s	✓
	Payload Release Mechanism Test	Release of both the payloads at different altitudes are tested	15,16,32	Nichrome wire should burn at specific altitude, cutting the fishing line and opening the container walls to release the payloads	✓
	Descent of payloads	Descent of payload after being deployed from the container is observed at every stage	22,23	The payload after separating from the CanSat should adjust to its nadir position so that it has a maximum descent rate of 20 m/s	✓
	Payload Autorotation Test	Autorotation of payload during its descent is observed	22	The payload should autorotate with a descent rate of less than 20 m/s	✓

Simulation Test Plan

Simulation mode activation command

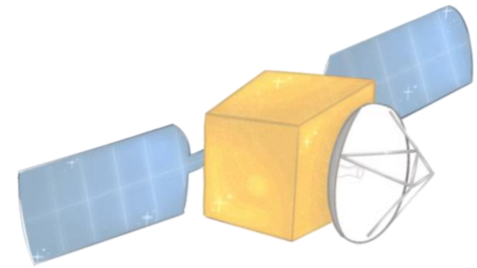


- Verification of software states was done.
- At 500 m and 400 m, the CanSat deploys both the payloads respectively.



- Dummy files containing csv of air pressure were created.
- Further, these values were fed to the Teensy 3.6

- As the Teensy 3.6 receives the pressure values from the ground station it calculates the appropriate altitude.
- Release mechanism for payload release has also been verified.



Mission Operations & Analysis

Presenter's Name: Anushka Kanabar

Overview of Mission Sequence of Events (1/5)

Arrival	Pre-launch	Launch

Arrival

- Team will arrive at the launch site.
- Integrity of CanSat shall be checked for any damage suffered during travel.
- Setup of Ground Station system.
- Drop test will be performed
- Mount antenna and connect with XBee.
- Set up umbrella and keep stock for water.

Pre-launch

- Checking size and weight of CanSat.
- Using fully charged batteries that will last at least 2 hours.
- Calibrate the camera to the magnetic north of the earth.
- Check communication by sending handshake request.
- Separation Mechanism will be connected to container with fishing line.
- Assembly will be completed
- Parachutes will be placed in parachute compartment of container.
- Payload will be placed in container.

Launch

- CanSat will be switched on.
- System will start sending software state data and begin FSW boot.
- Data transfer with GCS will be confirmed.
- The CanSat will perform the entire mission as stated in the Mission Guide, complying with all the restrictions posed on the speed and altitude of each state.

Overview of Mission Sequence of Events (2/5)

CanSat assembly and testing

Arrival

- CanSat integrity shall be checked for any damage suffered during travel
- Drop test will be performed

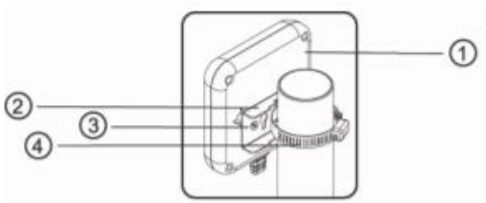
Pre-Launch

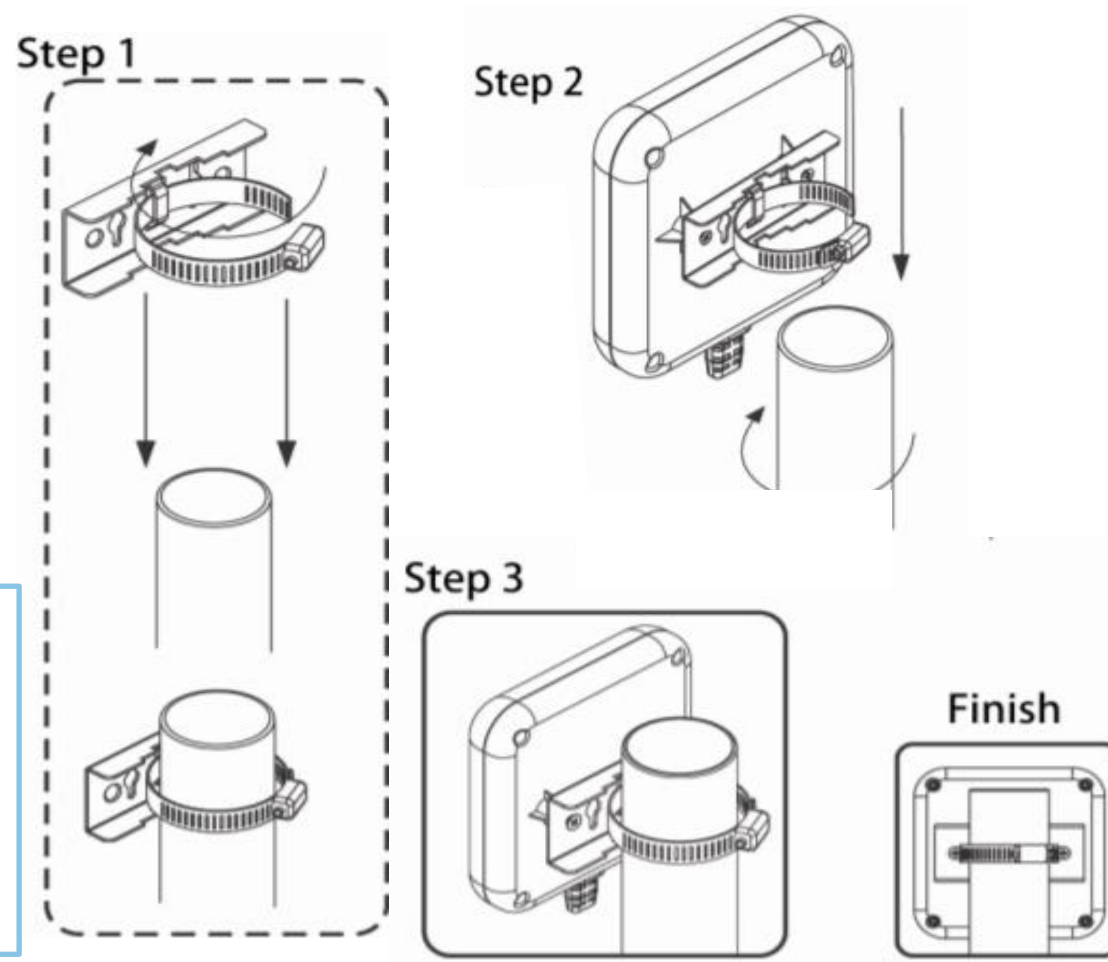
- Working and calibration of all sensors will be checked
- Calibrate the camera to the magnetic north of the earth
- Payload will be placed in container
- Payload Release mechanism will be integrated into the CanSat (fishing line)
- Parachute will be placed in the parachute compartment of container
- Checking the ON/OFF Switch
- Checking size and weight of CanSat
- Checking communication by sending handshake request

Overview of Mission Sequence of Events (3/5)

Ground Station Antenna construction

① Antenna	1 pc
② Holder	1 pc
③ Screws	2 pcs
④ Hose Clamp	1 pc





- **For simplicity, we have taken TL-ANT2409A throughout the Handheld pole mounting**
- **Mounting of TL-ANT2424B will be same**

Overview of Mission Sequence of Events (4/5)

Flight Recovery	Data Analysis	PFR

Flight Recovery

- Once the CanSat reaches ground level, the audio beacon is activated, and it is recovered.
- Photos will be clicked of the damaged container and payload once found before recovering it for proof.
- The camera video and data will be backed up in the laptop.
- Timely delivery of all the data in the SD card and video to the jury will be done after backup.

Data Analysis

- All the graphs will be checked on the GUI.
- All the CSV data recorded on the GUI will be compared and cross checked with the data stored on the SD card.
- Screenshots of all windows and instances will be taken.
- Real time graphics and values of each plot will be cross checked with actual practical weather conditions.
- The camera video will be reviewed.

PFR

- All the data from the camera and SD card will be cross verified, analyzed and inferences drawn from this will be documented as the PFR.
- The entire PFR report will be made and presented.
- **A copy of the same will be submitted to the jury.**

Overview of Mission Sequence(5/5)

Mission Control Officer
Satvik Deshmukh

CanSat Crew
- Vatsal Tapiawala
- Greeshma Gala
- Krittika Roy

Ground Station Crew
- Nisarg Shah
- Harshil Shah
- Khyati Morparia

CanSat Recovery
- Harshil Suvarna
- Shweta Chavan
- Anushka Kanabar

Field Safety Rules Compliance

Mission Operations Manual is a supplementary but necessary document that elucidates in detail the various procedures necessary to set up the entire CanSat and GCS system.
The Mission Operations Manual has been fully completed. (It will be presented in a three ring Binder)

The main objectives behind making it is –
"Clarity in the various steps to be followed while setting up the system so that every requirement of the Mission Guide is complied and followed, including safety rules and responsibilities of each role that can be assigned to a team member."

Main Blocks of Mission Operations Manual

1. **Configure the GCS**
2. **Prepare for the CanSat Launch**
3. **Checklist of all necessary precautions and tests to be done before launch**
4. **Launch process**
5. **Removal procedure**
6. **Recovery of Payload, Container and Onboard data**

CanSat Location and Recovery

Container Recovery

- Container color will be fluorescent red and hence easy to locate.
- The parachute will have a fluorescent orange color for the same reason.
- The audio beacon is of 95dB (which is more than 92 dB as per mission guide).
- A sticker with the team details and address will be attached to the container so that other teams can also recover our CanSat.
- GPS sensor will provide information about the trajectory and landing position.

Payload Recovery

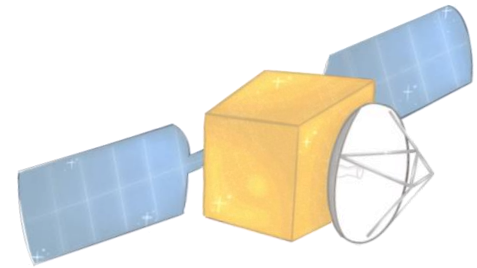
- The payload will transmit for five minutes after being released.
- Fluorescent green color of wing hence easy to locate
- A sticker with the team details and address will be attached to the payload as well so that other teams can also recover our CanSat.

Dwarkadas J. Sanghvi College of Engineering CANSAT Team
Team DJS ARYA #Team 1567
djsarya2021@gmail.com

College sticker

Mission Rehearsal Activities

Ground System Radio Link Check Procedures	• The XBees are communicating as required • The link between antenna and XBees are strong and efficient
Powering the CanSat On/Off	• The power switch is turned on and the CanSat is operated
Launch Configuration Preparations	• Final integration and component placing tests is done • Check if CanSat is ready to transmit telemetry
Loading CanSat in the launch vehicle	• CanSat is placed in the Rocket and final checks are done
Telemetry processing, Archiving and Analysis	• Telemetry data is analyzed in the Ground Station Software • The data will be saved in SD Card and .csv format
Recovery	• The Recovery team is ready • The team will track the Payload and Container with their color, GPS and Audio beacon



Requirements Compliance

Presenter's Name: Anushka Kanabar

Requirements Compliance Overview

The current design complies with all the mission requirements

- The design shall be tested to ensure Requirement Compliance, following the procedure explained in the CanSat Integration and Testing section of this document.
- Design shall undergo various environmental tests and the Environmental Test Document shall be drafted.
- The following slides demonstrate compliance with all the requirements.
- The color coding used throughout the requirement compliance is according to the legend given below.

Fully Complied
Partially Complied
Not complied

Requirements Compliance(1/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR1	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.		128	Current weight is 592.2gm (within tolerance)
#CR2	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.		41,42	Fully Complied
#CR3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.		42,77,106	Fully Complied
#CR4	The container shall be a fluorescent color; pink, red or orange.		91,262	Container is fluorescent red in colour
#CR5	The container shall be solid and fully enclose the science payloads. Small holes to allow access to turn on the science payloads is allowed. The end of the container where the payload deploys may be open.		107,120	Fully Compiled
#CR6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat		41,42	Fully Complied
#CR7	The rocket airframe shall not be used as part of the CanSat operations		41,42	Fully Complied

Requirements Compliance(2/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR8	The container 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.		67,77,78, 117,118	Fully Complied
#CR9	The Parachutes shall be fluorescent Pink or Orange		67,69,262	Fully Complied
#CR10	The descent rate of the CanSat (container and science payload) shall be 15 meters/second +/- 5m/s. .		68,79-89	Tested and Fully Complied
#CR11	All structures shall be built to survive 15 Gs of launch acceleration.		234	Tested and Fully Complied
#CR12	All structures shall be built to survive 30 Gs of shock.		123,240,243	Tested during drop tests and fully complied with
#CR13	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high-performance adhesives.		119,120	Fully Complied
#CR14	All mechanisms shall be capable of maintaining their configuration or states under all forces.		240,241	Tested during drop tests and Fully Complied with
#CR15	Mechanisms shall not use pyrotechnics or chemicals.		235	Fully Complied

Requirements Compliance(3/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR16	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.		235	Fully Complied
#CR17	Both the container and payloads shall be labeled with team contact information including email address. .		262	Fully Complied
#CR18	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.		284	Cost presently approximately $564
#CR19	XBee radios shall be used for telemetry 2.4 GHz Series radios are allowed. 900 MHz XBee radios are also allowed.		141,142,143, 155	Fully Complied
#CR20	XBee radios shall have their NETID/PANID set to their team number		145	Fully Complied
#CR21	XBee radios shall not use broadcast mode.		145,156	XBee is used in unicast mode
#CR22	The science payload shall descend spinning passively like a maple seed with no propulsion.		73,117	Fully Complied

Requirements Compliance(4/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR23	The science payload shall have a maximum descent rate of 20 m/s. .		68,79-89	Fully Complied
#CR24	The wing of the science payload shall be colored fluorescent orange, pink or green.		66,69,72,91, 101,262	Fully Complied
#CR25	The science payload shall measure altitude using an air pressure sensor.		51,52	Fully Complied
#CR26	The science payload shall measure air temperature.		53,54	Fully Complied
#CR27	The science payload shall measure rotation rate as it descends.		55,56	Fully Complied
#CR28	The science payload shall transmit all sensor data once per second.		156	Fully Complied
#CR29	The science payload telemetry shall be transmitted to the container only.		144,155,156	Fully Complied
#CR30	The science payload shall have their NETID/PANID set to their team number plus five. If team number is 1000, sensor payload NETID is 1005.		156	Fully Complied
#CR31	The container shall include electronics to receive sensor payload telemetry.		137-145	It contains XBee Pro S2C radio module

Requirements Compliance(5/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR32	The container shall include electronics and mechanisms to release the science payloads.		115,116	Nichrome Wire release mechanism is used
#CR33	The container shall include a GPS sensor to track its position.		37,59,60,108, 109,225,262	Fully Complied
#CR34	The container shall include a pressure sensor to measure altitude.		57,58	Fully Complied
#CR35	The container shall measure its battery voltage.		45,61,62	Fully Complied
#CR36	The container shall transmit its telemetry and the payload telemetry received once per second in the format described in the Telemetry Requirements section.		143-150	Fully Complied
#CR37	The container shall stop transmitting telemetry when it lands.		28,30,187, 290,292	Fully Complied
#CR38	The container and science payloads must include an easily accessible power switch that can be accessed without disassembling the CanSat and science payloads and in the stowed configuration.		99,108,109, 167	Fully Complied

Requirements Compliance(6/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR39	The container must 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.		120,167,169	Fully Complied
#CR40	An audio beacon is required for the container. It may be powered after landing or operate continuously.		259,262,263	Fully Complied
#CR41	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.		262	95 dB audio beacon is selected
#CR42	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.		140,168,173	Lithium-ion battery is selected
#CR44	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.		169	Fully Compiled
#CR45	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.		120,168,173	Battery is firmly stowed in the container and payload

Requirements Compliance(7/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR46	The CanSat must operate during the environmental tests laid out in Section 3.5.		123,246-248	Fully Complied
#CR47	The CanSat shall operate for a minimum of two hours when integrated into the rocket.		171,176,231, 256	Fully Complied
#CR48	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.		186-189	Fully Complied
#CR49	The container must maintain mission time throughout the whole mission even with processor resets or momentary power loss.		140,188	Fully Complied
#CR50	The container shall have its time set to UTC time to within one second before launch.		187,188	Fully Complied
#CR51	The container 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.		190,213	Fully Complied

Requirements Compliance(8/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR52	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the container altitude.		190,213	Fully Complied
#CR53	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.		150,190,212	Fully Complied
#CR54	The ground station shall command the CanSat to start transmitting telemetry prior to launch.		150,208	The GUI has a “Start Telemetry” button for this feature
#CR55	The ground station shall generate csv files of all sensor data as specified in the Telemetry requirements section.		208,209	Fully Complied
#CR56	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.		146,188	GUI shows mission time with 1s resolution
#CR57	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.		186-188	Fully Complied
#CR58	Each team shall develop their own ground station.		200-215,256	Fully Complied

Requirements Compliance(9/10)

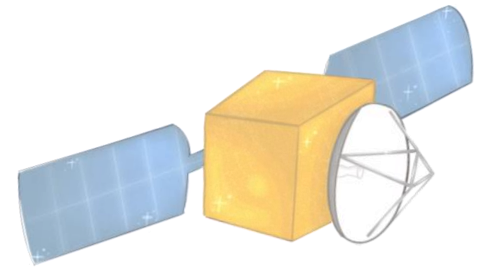
Req ID	Requirement	Compliance	Slide No.	Comments
#CR59	All telemetry shall be displayed in real time during descent on the ground station.		206,209-211	Fully Complied
#CR60	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		206,211	All data is plotted and displayed with proper units on the GUI
#CR61	Teams shall plot each telemetry data field in real time during flight.		208-215	Fully Complied
#CR62	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBee radio and a hand-held antenna.		200	Fully Complied
#CR63	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.		200	Fully Complied
#CR64	The ground station software shall be able to command the container to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.		190,212,213	Fully Complied

Requirements Compliance(10/10)

Req ID	Requirement	Compliance	Slide No.	Comments
#CR65	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 container.		190,212,213	Fully Complied
#CR66	The science payloads shall not transmit telemetry during the launch, and the container shall command the science payloads to begin telemetry transmission upon release from the container.		186,189	Fully Complied

Bonus Objectives

Req ID	Requirement	Compliance	Slide No.	Comments
#BNS1	A video camera shall be integrated into the container and point toward the ground. The camera shall capture the release of both science payloads and capture the descent of the science payloads. The video shall be spin stabilized with the view not rotating more than +/- 30 degrees. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the container is retrieved..		40,63,64	Fully Complied



Management

Presenter's Name:
Anushka Kanabar

Status of Procurements (1/3)

Electronic Components:

Subsystem	Components	Model Number	Quantity	Order Date	Status
Electronics (Container)	Antenna	2.4GHz Male Omni Antenna	2	29.09.2020	Procured
	Atmospheric Sensor	BMP280	1	29.09.2020	Procured
	Battery	LG Li-ion Battery	2	30.09.2020	Procured
	Buzzer	Piezo 5V 95DB	1	30.09.2020	Procured
	Camera	Adafruit Mini Spy Camera	1	12.10.2021	Procured
	Coin Cell 3V	CR2032	1	10.10.2020	Procured
	GPS	Adafruit Ultimate GPS	1	28.09.2020	Procured
	Microcontroller	Teensy 3.6	1	28.09.2020	Procured
	Servo	MG995	1	14.09.2020	Procured
	Storage	SanDisk 16GB SD Card	1	18.10.2020	Procured
	Voltage Regulator	Pololu Voltage Regulator	1	15.10.2020	Procured
	XBee	XBee S2C Pro	2	01.10.2020	Procured
	Voltage Divider	Resistors in Parallel	1	29.09.2020	Procured

Status of Procurements (2/3)

Electronic Components:

Subsytem	Components	Model Number	Quantity	Order Date	Status
Electronics (Payload)	Atmospheric Sensor + RPM Sensor	10-DoF IMU Board	1	29.09.2020	**Procured**
	Battery	LG Li-ion Battery	1	30.09.2020	**Procured**
	Microcontroller	Arduino pro mini	1	02.09.2020	**Procured**
	Voltage Regulator	Pololu Voltage Regulator	1	15.10.2020	**Procured**
	XBee	XBee Pro S2C with Whip Antenna	1	01.10.2020	**Procured**
Ground Control System (GCS)	XBee	XBee Pro S2C	1	01.10.2020	**Procured**
	XBee Adapter	CP2102	1	01.10.2020	**Procured**
	Antenna	TLANT2424B	1	29.09.2020	**Procured**
	Computer	ROG STRIX-G	1	-	**Private**

Status of Procurements (3/3)

Mechanical Components:

**Actual costs of all components are considered*

Subsystem	Mechanical Components	Details	Quantity	Order Date	Status
Mechanical	Payload Body, Container Body	Balsa 6mm Sheet 100x10 cm^2	5	12.10.2020	**Procured**
	Container Body	Carbon fiber Rods 3mm thick 1m long	4	12.10.2020	**Procured**
	Container Body	Monokote 3m	2	13.10.2020	**Procured**
	Container Body	Birch Wood 355x460 mm 3mm thick	1	17.03.2021	**Procured**
	Payload Body	PETG	3 kg	16.10.2020	**Procured**
	Parachute Material	Ripstop Nylon 50x50 cm^2	5	18.10.2020	**Procured**
	Release Mechanism	Nichrome Wire + MOSFETS + fishing line	-	25.10.2020	**Procured**
	Adhesives	Cyanoacrylate, Epoxy, etc.	-	19.10.2020	**Procured**
	Power tools	Drilling Machine, Hacksaw, etc.	**College Provided**		

CanSat Budget – Hardware (1/3)

Container Electronic Components:

Electronic Components	Model Number	Quantity	Unit Price (₹)	Total Price (₹)
Antenna	2.4GHz Male Omni Antenna	1	550	550
Atmospheric Sensor	BMP280	1	225	225
Battery	LG Li-ion Battery	2	490	980
Buzzer	Piezo 5V 95DB	1	40	40
Camera	Adafruit Mini Spy Camera	1	920	920
Coin Cell 3V	CR2032	1	85	85
GPS	Adafruit Ultimate GPS	1	2900	2900
Microcontroller	Teensy 3.6	1	2900	2900
Servo	MG995	1	240	240
Storage	SanDisk 16GB SD Card	1	350	350
Voltage Regulator	Pololu Voltage Regulator	1	200	200
XBee	XBee S2C Pro	2	2150	4300
XBee Adapter	CP2102	2	300	600
Total Cost:				**14,290**

CanSat Budget – Hardware (2/3)

Payload Electronic Components:

Electronic Components	Model Number	Quantity	Unit Price (₹)	Total Price (₹)
Atmospheric Sensor + RPM Sensor	10-DOF IMU Board	1	589	**590**
Battery	LG Li-ion Battery	1	490	**490**
Microcontroller	Arduino pro mini	1	200	**200**
Voltage Regulator	Pololu Voltage Regulator	1	200	**200**
XBee	XBee S2C Pro with Whip Antenna	1	2150	**2150**
XBee Adapter	CP2102	1	300	**600**
Total Cost:				**4,230**

There are two payloads:
Total Cost of 2 Payload's Electronic Components is = 2 x 4230
= ₹8640

CanSat Budget – Hardware (3/3)

Mechanical Components:

Component	Details	Quantity	Unit Price (₹)	Price Total (₹)
Payload Body, Container Body	Balsa 6mm Sheet 100x10 cm^2	5	480.00	**2,400.00**
Container Body	Carbon fiber Rods 3mm thick, 1m long	4	330.00	**1,320.00**
Container Body	Monokote 3m	2	1100.00	**2,200.00**
Payload Body	PETG	3 kg	1,200.00	**3,600.00**
Parachute Material	Ripstop Nylon 50x50 cm^2	5	200.00	**1,000.00**
Release Mechanism	Nichrome Wire + MOSFETS + Fishing Wire	-	-	**100.00**
Adhesives	Cyanoacrylate, Epoxy, etc.	-	-	**2,000.00**
Power tools	Drilling Machine, Hacksaw, etc.	**College Provided**		
Total				**12,620.00**

CanSat Budget – Other Costs (1/2)

Ground Control Station Components:

GCS Components	Model	Quantity	Unit Cost (₹) (Actual)	Total Cost (₹) (Actual)
XBee	XBee PRO S2C	1	2,150.00	2,150.00
XBee Adapter	CP2102	1	300.00	300.00
Antenna	TLANT2424B	1	3,200.00	3,200.00
Computer	ROG STRIX-G	1	Private	
Total Costs:				5,650.00

Other Costs:

Other Costs	Quantity	Unit Cost (₹)	Total Cost (₹)
Rental & Travel Cost (Estimate)			
Travel (Round-trip ticket)	10	90,000.00	9,00,000.00
Hotel (For 3 days)	3	4,000.00	12,000.00
Rent Cars (For 3 days)	2	15,000.00	30,000.00
Prototyping & Testing Cost (Actual)			
Prototyping	6	39,780.00	2,38,680.00
Laser Cut	-	-	6,500.00
Computer (ROG STRIX-G)	1	Private	
3D Printing	College Provided		
Test Facilities and equipment	College Provided		
Fee	1		3,750.00
Total Cost:			11,90,930.00

CanSat Budget – Other Costs (2/2)

Conversion Rate: 1 USD($) = 73 INR(₹)

Item	Price (₹)	Price (USD)
Electronic Total Price	22,900	**313.69**
Mechanical Total Price	12,620	**172.88**
Ground Station Total Price	5,650	**77.40**
Total	**41,170**	**563.97**

Total cost for making one CanSat is USD 563.97 which is less than USD 1000

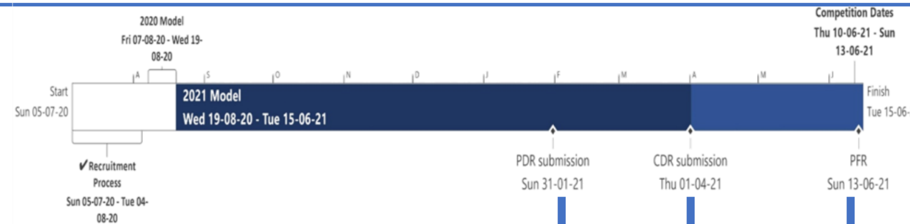
Source of income:

Source	Amount (₹)
College Funding	**1,50,000.00**
External Sponsors	**30,000.00**
Team Contribution	**20,000.00**
Total	**2,00,000.00**

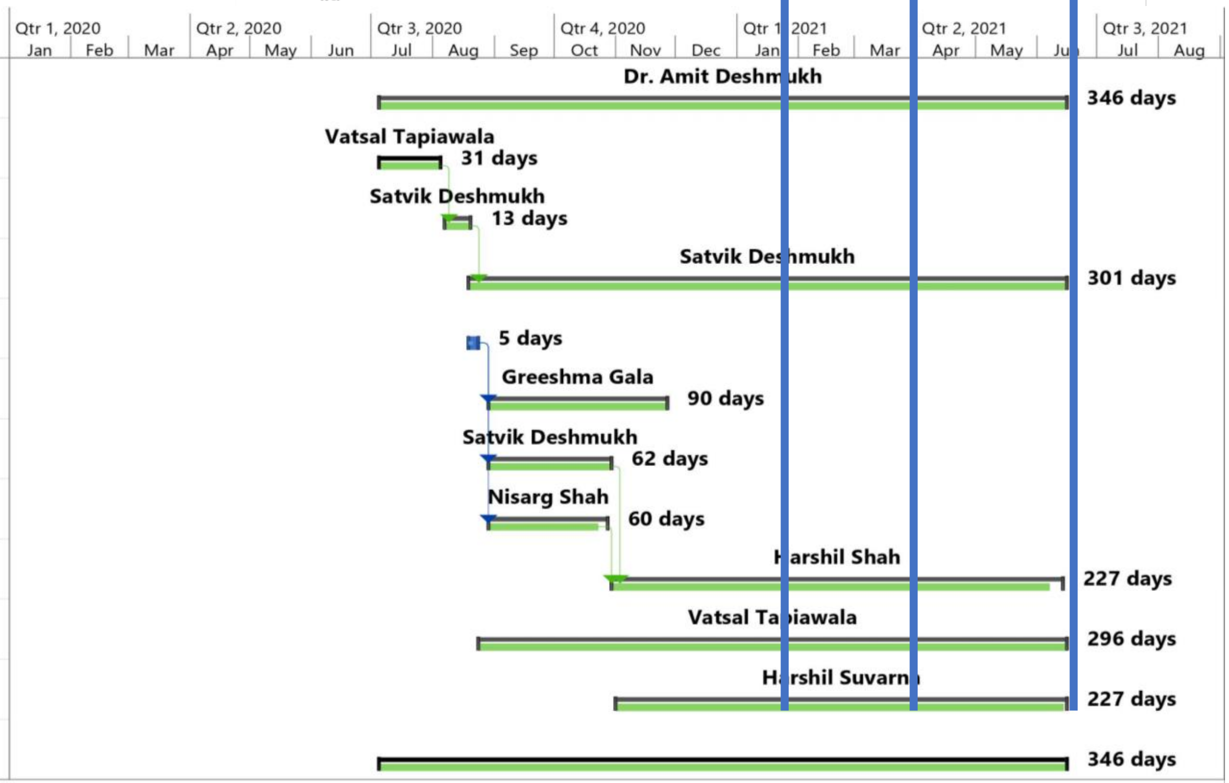
Note: Due to virtual competition, travel expense is excluded

Program Schedule Overview

Major Milestones



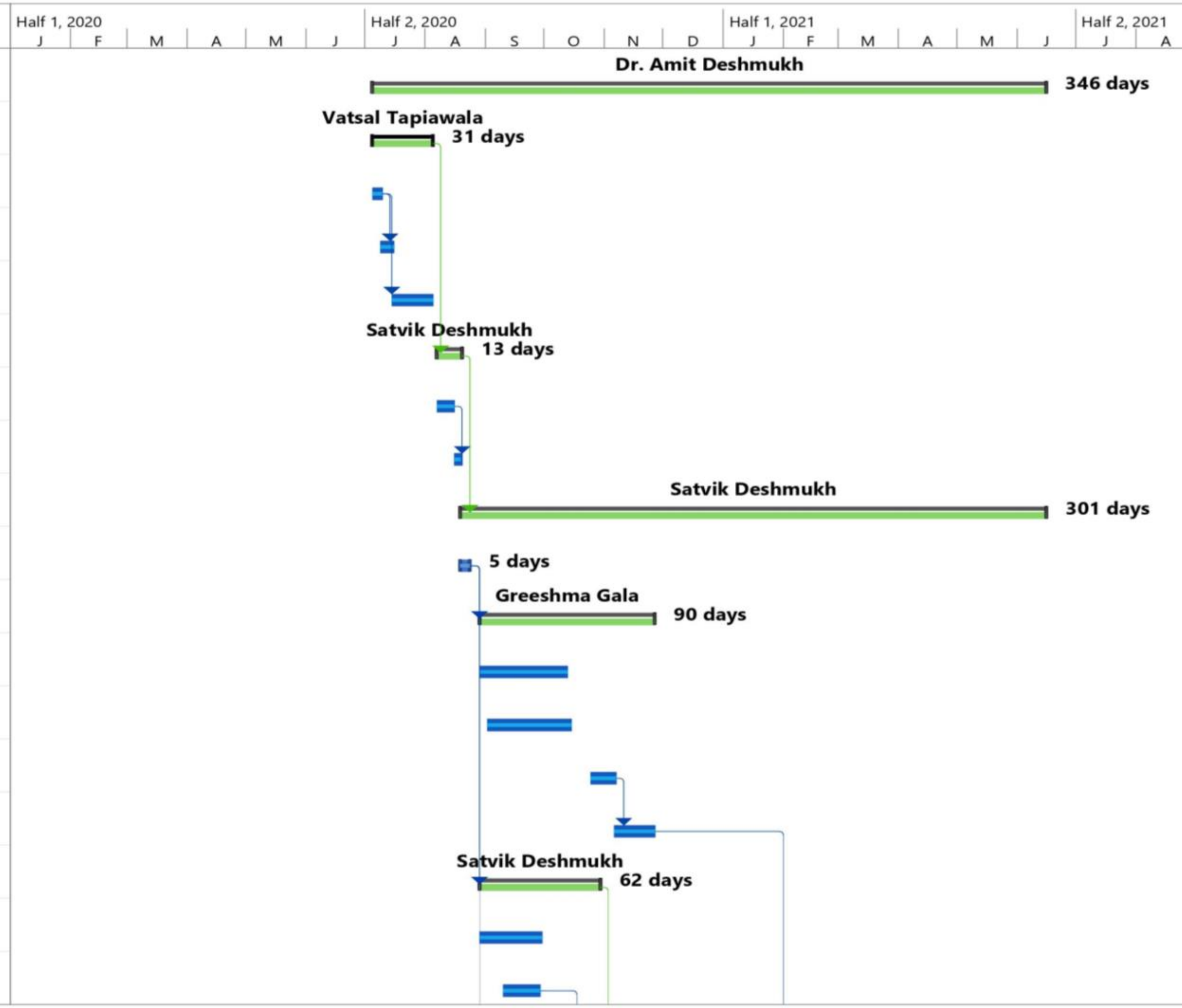
ID	Task Name	Start	Finish
1	**CanSat USA 2021**	Sun 05-07-20	Tue 15-06-21
2	Recruitment Process	Sun 05-07-20	Tue 04-08-20
6	2020 Model	Fri 07-08-20	Wed 19-08-20
9	2021 Model	Wed 19-08-20	Tue 15-06-21
10	Problem Statement Analysis	Wed 19-08-20	Sun 23-08-20
11	Mechanical & Aerodynamics	Sat 29-08-20	Thu 26-11-20
16	Electronics	Sat 29-08-20	Thu 29-10-20
20	Programming	Sat 29-08-20	Tue 27-10-20
24	Prototype Integration	Fri 30-10-20	Sun 13-06-21
30	Marketing & Finance	Mon 24-08-20	Tue 15-06-21
38	Submission Timeline	Sun 01-11-20	Tue 15-06-21
48	Academic Calendar	Sun 05-07-20	Tue 15-06-21



- **As of 1st April 2021, 90% of the total work is completed**

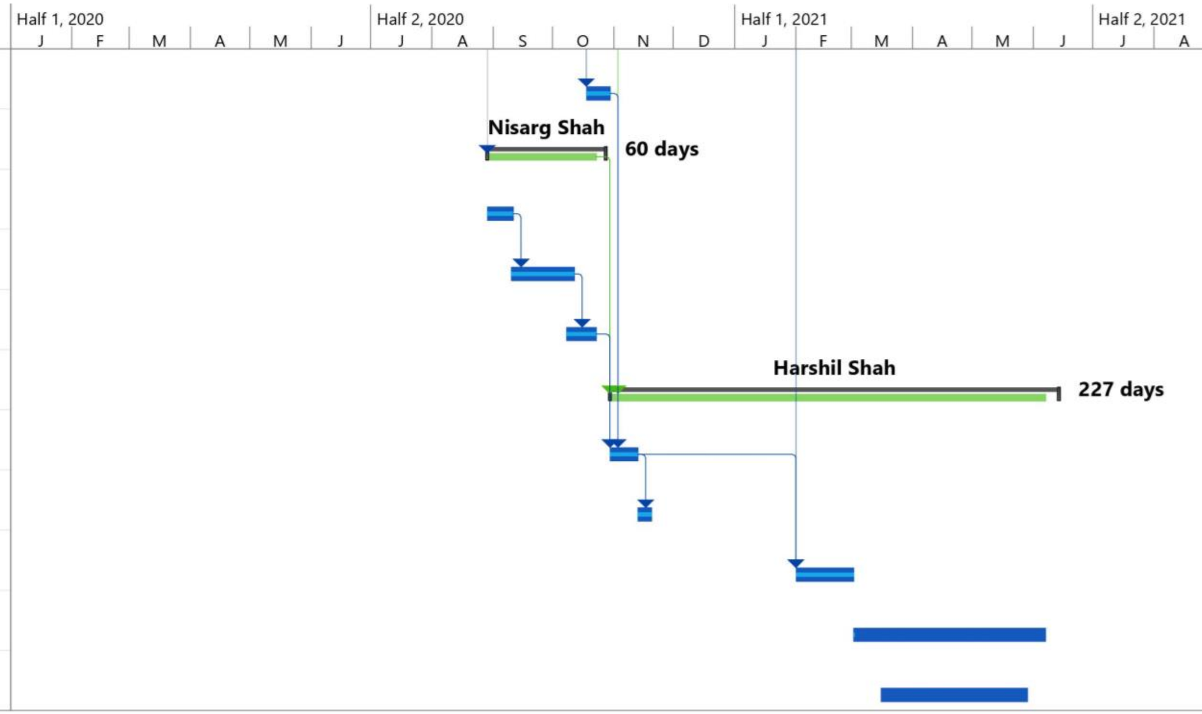
Detailed Program Schedule (1/4)

ID	Task Name	Start	Finish
1	**CanSat USA 2021**	**Sun 05-07-20**	**Tue 15-06-21**
2	**Recruitment Process**	**Sun 05-07-20**	**Tue 04-08-20**
3	Team Interviews	Sun 05-07-20	Thu 09-07-20
4	Literature Survey	Thu 09-07-20	Wed 15-07-20
5	Knowledge Exchange	Wed 15-07-20	Tue 04-08-20
6	**2020 Model**	**Fri 07-08-20**	**Wed 19-08-20**
7	Correction	Fri 07-08-20	Sat 15-08-20
8	Testing	Sun 16-08-20	Wed 19-08-20
9	**2021 Model**	**Wed 19-08-20**	**Tue 15-06-21**
10	Problem Statement Analysis	Wed 19-08-20	Sun 23-08-20
11	**Mechanical & Aerodynamics**	**Sat 29-08-20**	**Thu 26-11-20**
12	Design	Sat 29-08-20	Mon 12-10-20
13	Procure	Wed 02-09-20	Wed 14-10-20
14	Manufacture	Sun 25-10-20	Fri 06-11-20
15	Subsystem Assembly	Fri 06-11-20	Thu 26-11-20
16	**Electronics**	**Sat 29-08-20**	**Thu 29-10-20**
17	Design & Simulate	Sat 29-08-20	Tue 29-09-20
18	Procure	Thu 10-09-20	Mon 28-09-20



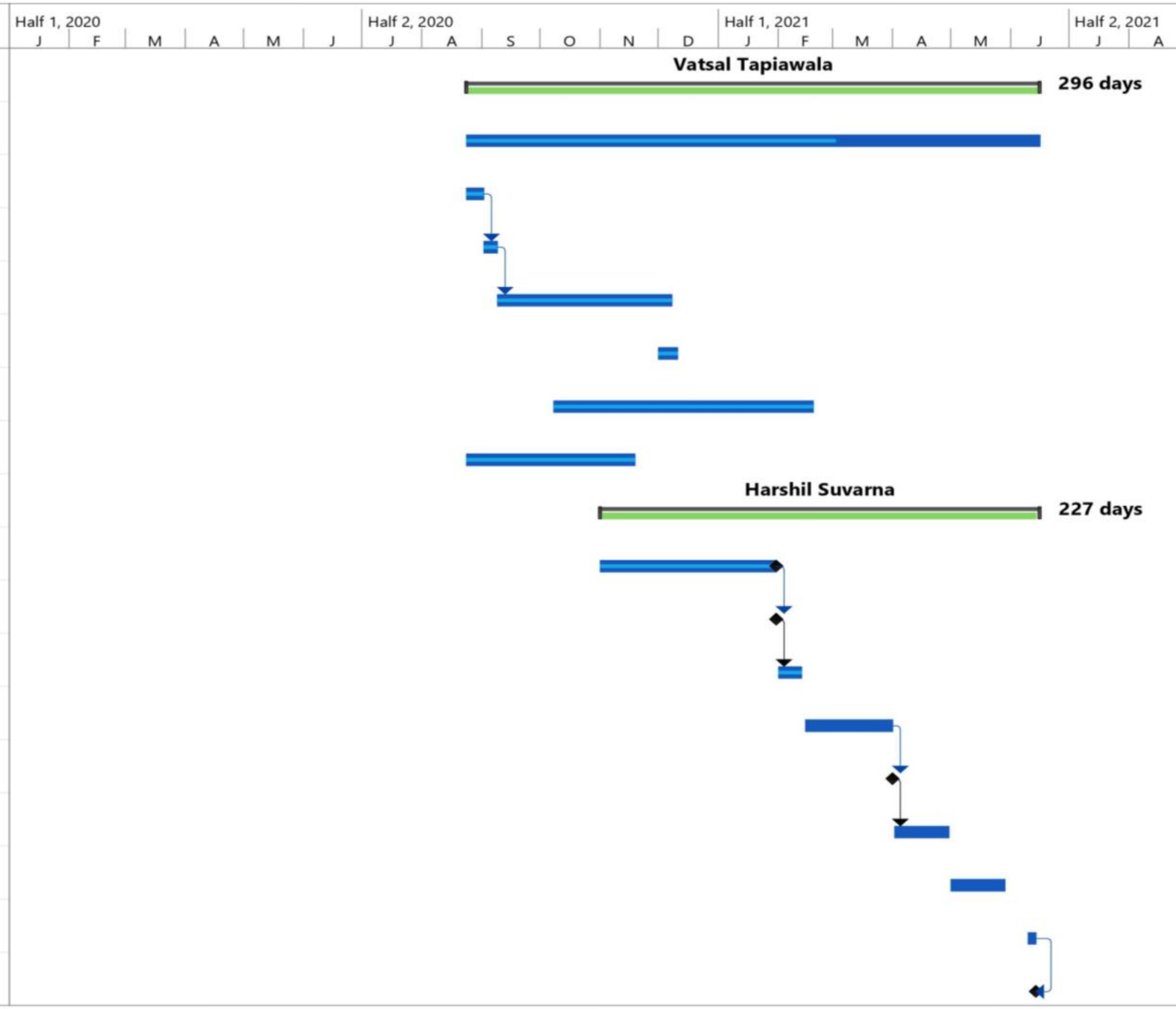
Detailed Program Schedule (2/4)

ID	Task Name	Start	Finish
19	Subsystem Integration & Testing	Sun 18-10-20	Thu 29-10-20
20	**Programming**	**Sat 29-08-20**	**Tue 27-10-20**
21	Platform Selection	Sat 29-08-20	Thu 10-09-20
22	Design	Thu 10-09-20	Sun 11-10-20
23	Test	Thu 08-10-20	Thu 22-10-20
24	**Prototype Integration**	**Fri 30-10-20**	**Sun 13-06-21**
25	Electronics & Programming Integration	Fri 30-10-20	Thu 12-11-20
26	Electronics & Programming Lab Test	Fri 13-11-20	Thu 19-11-20
27	Full System Integration	Mon 01-02-21	Mon 01-03-21
28	Full System Ground Test	Tue 02-03-21	Sun 06-06-21
29	Environmental Tests	Tue 16-03-21	Fri 28-05-21



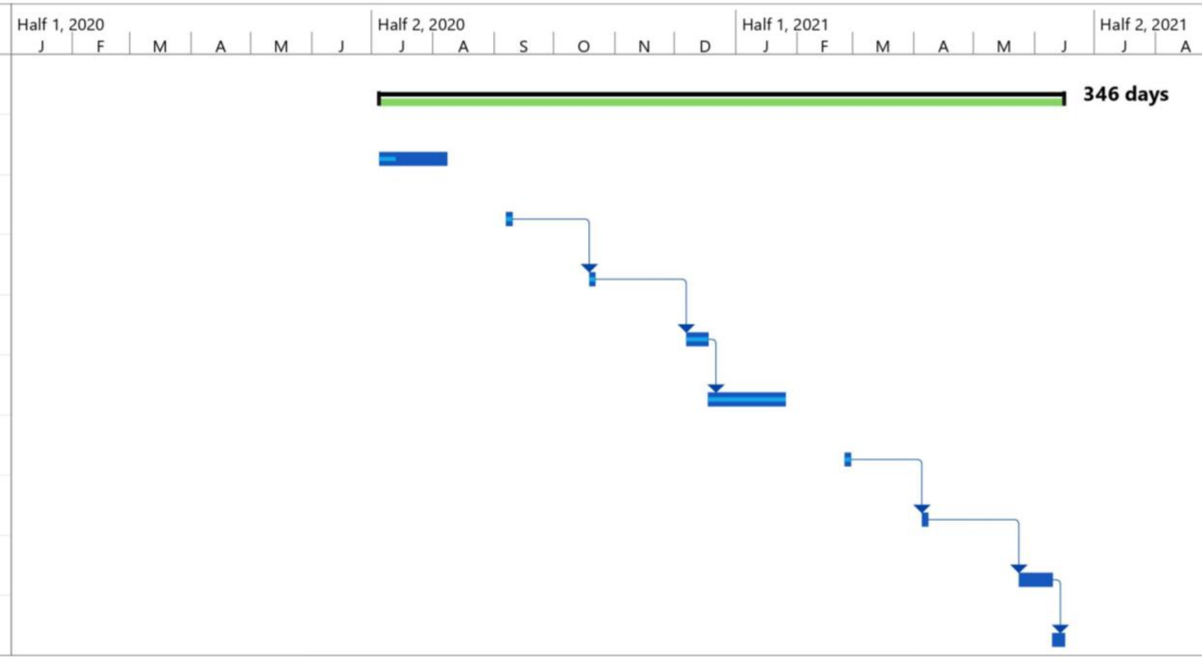
Detailed Program Schedule (3/4)

ID	Task Name	Start	Finish
30	**Marketing & Finance**	**Mon 24-08-20**	**Tue 15-06-21**
31	Social Media Updation	Mon 24-08-20	Tue 15-06-21
32	Funding Proposal for College	Mon 24-08-20	Tue 01-09-20
33	Marketing Proposal for Potential Sponsors	Wed 02-09-20	Tue 08-09-20
34	On-field Marketing	Wed 09-09-20	Mon 07-12-20
35	Merchandise Designing	Tue 01-12-20	Thu 10-12-20
36	Logistic Support	Thu 08-10-20	Thu 18-02-21
37	Covid-19 Awareness	Mon 24-08-20	Wed 18-11-20
38	**Submission Timeline**	**Sun 01-11-20**	**Tue 15-06-21**
39	PDR Building	Sun 01-11-20	Sat 30-01-21
40	PDR submission	Sun 31-01-21	Sun 31-01-21
41	PDR Presentation	Mon 01-02-21	Fri 12-02-21
42	CDR Building	Mon 15-02-21	Wed 31-03-21
43	CDR submission	Thu 01-04-21	Thu 01-04-21
44	CDR Presentation	Fri 02-04-21	Thu 29-04-21
45	Environmental Test	Sat 01-05-21	Fri 28-05-21
46	Competition Dates	Thu 10-06-21	Sun 13-06-21
47	PFR	Sun 13-06-21	Sun 13-06-21



Detailed Program Schedule (4/4)

ID	Task Name	Start	Finish
48	**Academic Calendar**	**Sun 05-07-20**	**Tue 15-06-21**
49	Vacation (Odd)	Sun 05-07-20	Fri 07-08-20
50	Term Test 1 (Odd)	Mon 07-09-20	Wed 09-09-20
51	Term Test 2 (Odd)	Mon 19-10-20	Wed 21-10-20
52	End Semester Examination (Odd)	Mon 07-12-20	Thu 17-12-20
53	Vacation (Even)	Fri 18-12-20	Mon 25-01-21
54	Term Test 1 (Even)	Thu 25-02-21	Sat 27-02-21
55	Term Test 2 (Even)	Mon 05-04-21	Wed 07-04-21
56	End Semester Examination (Even)	Mon 24-05-21	Wed 09-06-21
57	Vacation (Odd)	Thu 10-06-21	Tue 15-06-21



Task		Inactive Task		Manual Summary Rollup		External Milestone	
Split		Inactive Milestone		Manual Summary		Deadline	
Milestone		Inactive Summary		Start-only		Progress	
Summary		Manual Task		Finish-only		Manual Progress	
Project Summary		Duration-only		External Tasks			

Mission Rehearsals (1/3)

1

Start Up

- Set up the CanSat by suspending it with a cord
- Turn on the ground station laptop and start the laptop software
- Verify that the telemetry is received by the ground station and the judges

2

Drop Test

- Raise the CanSat by holding the cord at the point where it is attached to the CanSat
- Let go of the CanSat at the request of the judges who should have full view of the CanSat through web camera

3

Flight Simulation

- With the CanSat suspended, the flight profile will provide simulated altitude information once a second to determine its altitude
- Place each payload on spin table after it is released and observe the rotation speed
- Observe that the container stops transmitting telemetry after altitude drops to a low constant value

4

Bonus Demonstration

- The team shall print out the provided target which will be sent just before the time for the demonstration
- The stabilization of camera shall be tested by twisting the cord and releasing it
- The team submit the video to the given website after completion of demonstration

Mission Rehearsals (2/3)

Mission Control Officer

Satvik Deshmukh

Start up Procedures

- Vatsal Tapiawala
- Harshil Suvarna
- Khyati Morparia

Drop Test Procedures

- Harshil Shah
- Krittika Roy

Flight Simulation Demonstration

- Nisarg Shah
- Greeshma Gala

Bonus Demonstration

- Shweta Chavan
- Anushka Kanabar

Mission Rehearsals (3/3)

Demonstration Procedure	Criterion for Success
Start up Procedure	• To verify if the telemetry is streaming to the ground station is uninterrupted and the judges receive the data for the same
Drop Test Procedure	• No parts of the CanSat or payload fallout during the test
Flight Simulation Demonstration	• The flight profile should provide simulated altitude information to the container • After the release, the rotation rate of the payloads are plotted • The container stops telemetry after altitude drops to a low constant value
Bonus Demonstration during Flight Simulation Demonstration	• The camera will provide a stable video feed during the demonstration.

We plan to conduct 7 dry-runs before the live demonstration procedure

Shipping and Transportation

- All the packaging will be done professionally by using crimping and bubble wrapping equipment
- Sturdy cartons and soft padding would be used to make sure the electronics and mechanical components are not damaged
- According to the baggage guidelines of the airlines shortlisted by us, this idea will not violate any rules and regulations for the luggage that can be carried
- It will be 'checked in' in the same way as any other electronic device
- We decided to carry the tools and equipment necessary that are not easily available there
- If needed, we can purchase the other tools required
- The CanSat was carried to the launch site in boxes which will have protective inner linings.

This is how packaging was done in 2018-19 Labels of '**FRAGILE**' and '**THIS SIDE UP**' were added for easy and safe handling of our cartons

Rationale

- In this way, we will minimize our extra costs for a shipping/cargo company
- This allows extra funds to be used for essential technical changes
- We can also make sure of the safety of the CanSat inside the Carton

Due to the current COVID-19 pandemic and the competition being held online these procedures aren't being followed unlike in case of an actual launch

Conclusions (1/2)

	Major accomplishments	Major unfinished work
Electronics and Programming	▪ The selection of components is concluded and PCBs are fabricated. ▪ **The flight software is 100% completed.** ▪ Simulation test and implementation of the entire electronics system is done. ▪ GUI is intricately designed for the virtual demonstration.	▪ The entire electronic subsystem is to be tested to ensure its smooth synchronization in flight mode and simulation mode
Mechanics and Aerodynamics	▪ The mechanical design was finalized after weighing the perks and drawbacks of various structural parts. ▪ Majority of the tests were successfully performed.	▪ Due to ongoing COVID-19 pandemic the complete integration and testing of the CanSat is yet to be done.
Administration and Finance	▪ Funding proposal was approved by the college. ▪ PDR was completed ▪ Various sponsorship deals were secured ▪ Initiation of environmental test document ▪ Recruitment for the upcoming year was completed. ▪ CDR was completed	▪ Financial income has been partially secured.

Conclusions (2/2)

We are on track with the schedule that we have set, and all our deadlines have been met.
DJS Arya is all set for the Environmental Test Documentation and live demonstration.