CanSat 2021
Preliminary Design Review (PDR)
Version 1.0a

#1567
DJS Arya

Presentation Outline

Team Organization

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Acronyms (1/3)

Acronyms	Meaning
FSW	Flight Software Design
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
KBPS/ MBPS	kilobits per second/ megabits per second
SDHC	Secure Digital High Capacity

Acronyms	Meaning
BMP	Barometric Pressure
.csv	Comma Separated Version
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
KHz/GHz/ MHz	kilohertz/ megahertz/ gigahertz
mV/V	milliVolt/ Volt

Acronyms (2/3)

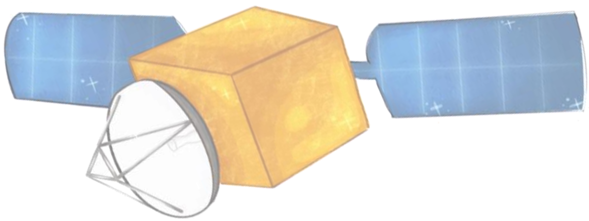
Acronyms	Meaning
LED	Light Emitting Diode
Ni-Cad/ Ni-MH/Li-ion	Nickel-Cadmium/ Nickel Metal Hydride/ Lithium ion
NMEA	National Marine Electronics Association
GGA	Generalized Gradient Approximation
PETG	Polyethylene Terephthalate Glycol
LoS	Line of Sight
MCU	Micro Controlling Unit
USB	Universal Serial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

Acronyms	Meaning
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
UTC	Universal Time Coordinated
mWh/Wh	milli Watt hour/ Watt hour

Acronyms (3/3)

Acronyms	Meaning
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
RSO	Range Safety Officer
ms/s/h	millisecond/second/ hour

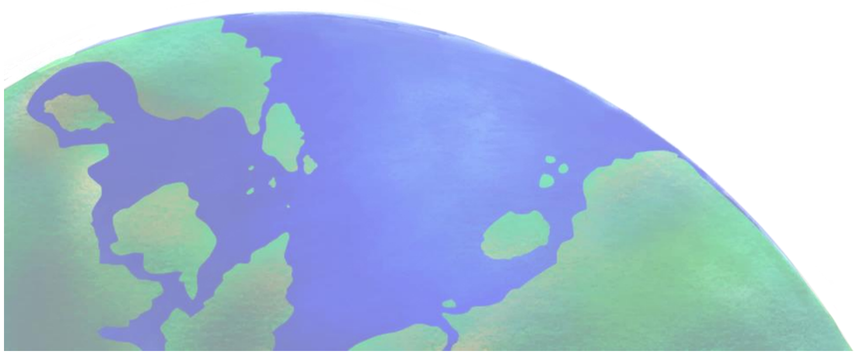
Acronyms	Meaning
SOE	Sequence of Events
TBD	To Be Determined
TBR	To Be Resolved
VM	Verification Method
PFR	Post Flight Review
UART	Universal Asynchronous Receiver Transmitter
CR	Competition Requirement
mm/cm/m/km	millimeter/ centimeter/ meter/ kilometer
DoF	Degree of Freedom
dB	decibel
dBi	decibel relative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



Systems 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 725m 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 Objectives

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

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		✓		✓

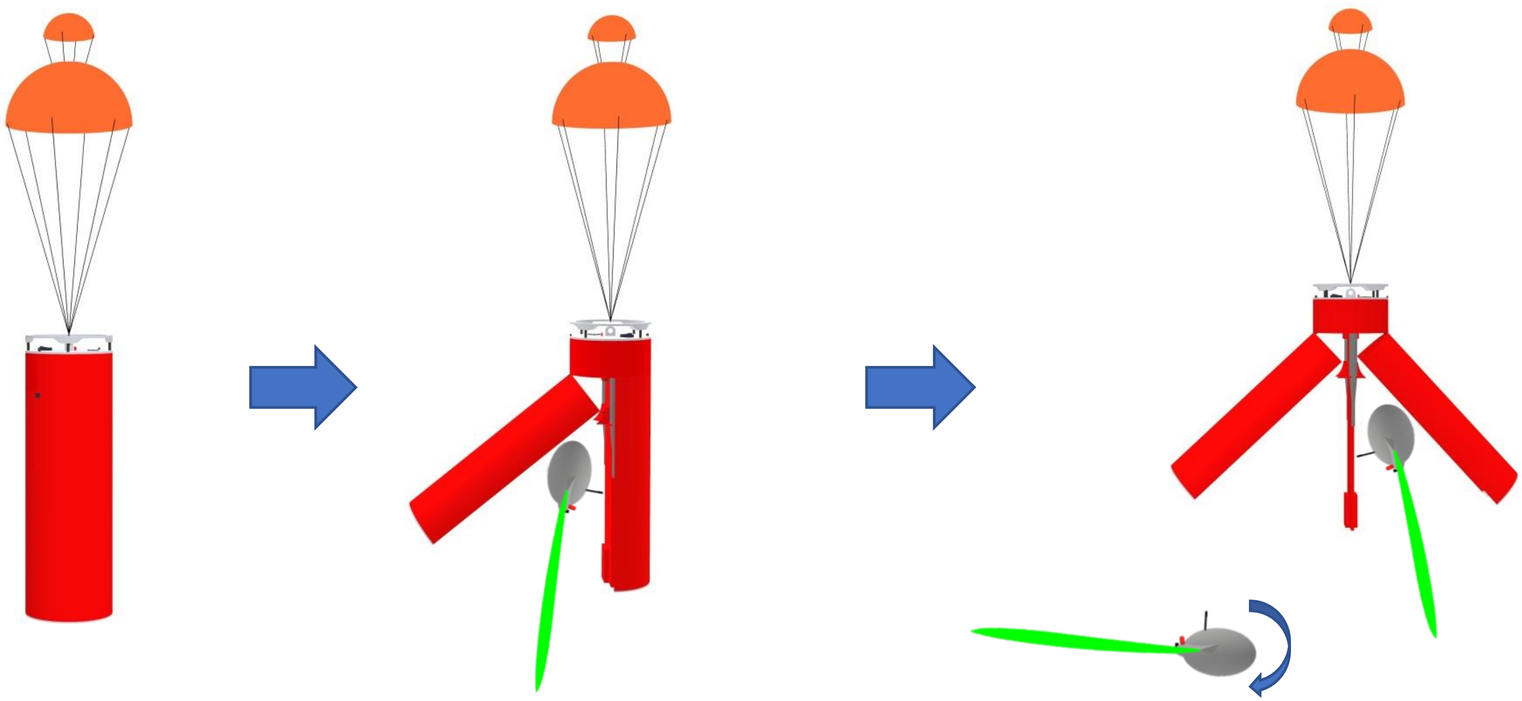
System Requirement Summary (15/15)

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 Level CanSat Configuration Trade and Selection (1/4)

Configuration 1	
General Description	• The payload has an ellipsoidal structure ensuring smooth airflow during its descent. • The container is held in stowed configuration by two fishing lines. • The payload is deployed using nichrome wire mechanism, and the elastic bands are used to open the container halves. • The electronics are located below the parachute compartment. • In order to keep it lightweight while having significant strength, the components are made of various materials with different properties.
Pros	• Container halves open providing more area for deployment. • Payload doesn't exert any extra force on the container wall. • Ellipsoidal structure of the maple seed directs the air towards the wing for greater lift. • The wing provides sufficient lift for autorotation.
Cons	• Heavier than dowel configuration. • Transmutability of airfoils is difficult to implement in the wing.

System Level CanSat Configuration Trade and Selection (2/4)



Position 1:
Container, along with the payloads gets deployed from the rocket.

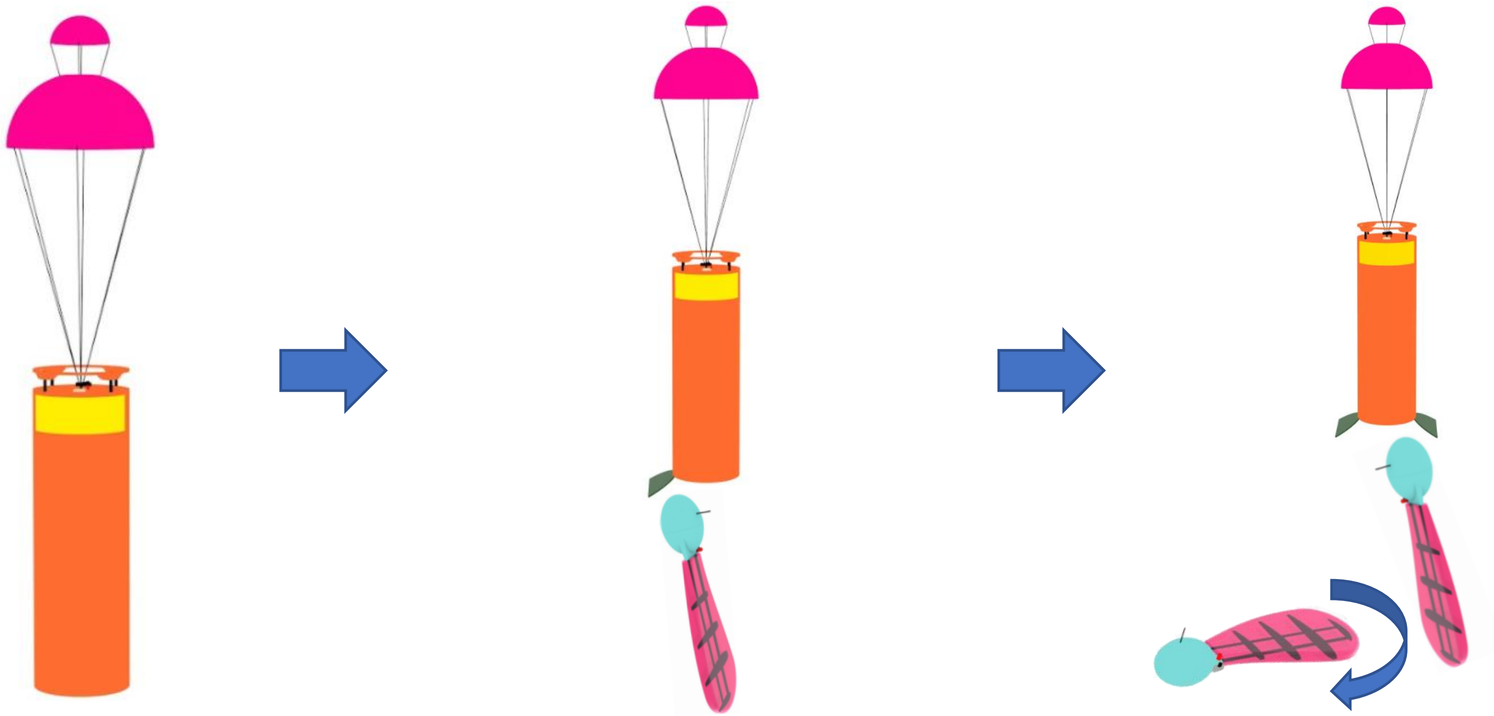
Position 2:
1st Payload gets deployed from container at 500m with the help of nichrome wire mechanism.

Position 3:
2nd Payload gets deployed from container at 400m with the help of nichrome wire mechanism while the 1st payload descends in autorotating motion.

System Level CanSat Configuration Trade and Selection (3/4)

Configuration 2	
General Description	• A dowel mechanism is used for payload. • A partition divides the container into two equal halves with payloads on either side. • The bottom surfaces are converted into flaps which open sideways with the help of hinges. • The electronics are in a compartment below the parachute plate.
Pros	• Transmutability of airfoils is easy • Lighter in weight
Cons	• High cambered/thick airfoils need to be selected to accommodate the dowels, hence occupying more space. • Difficult to manufacture • Space provided by the container for the deployment is less. • Due to the non-uniform body of wing, the payload is susceptible to physical damage.

System Level CanSat Configuration Trade and Selection (4/4)



Position 1:
Container, along with payloads gets deployed from the rocket.

Position 2:
1st Payload gets deployed from container at 500m with the help of nichrome wire mechanism.

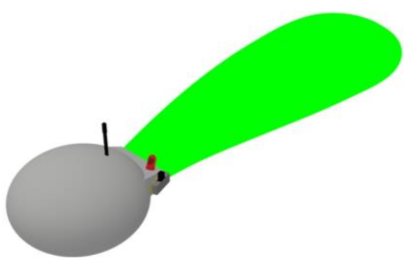
Position 3:
2nd Payload gets deployed from container at 400m with the help of nichrome wire mechanism while the 1st payload descends in autorotating motion.

System Level Configuration Selection

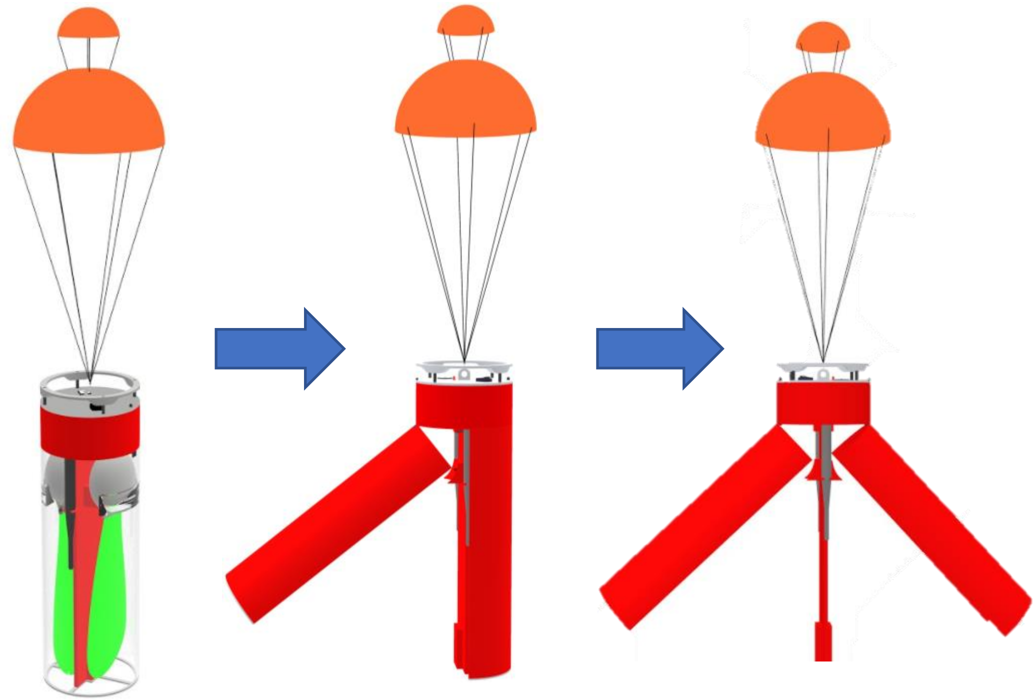
Configuration 1 Selected

Rationale:

- Electronics are easily accessible.
- Payload is aerodynamically stable.
- Payload wing is made up of balsa and monokote, making it lightweight while providing sufficient strength.
- The center of mass of the payload is located near the seed-wing attachment point for greater stability.



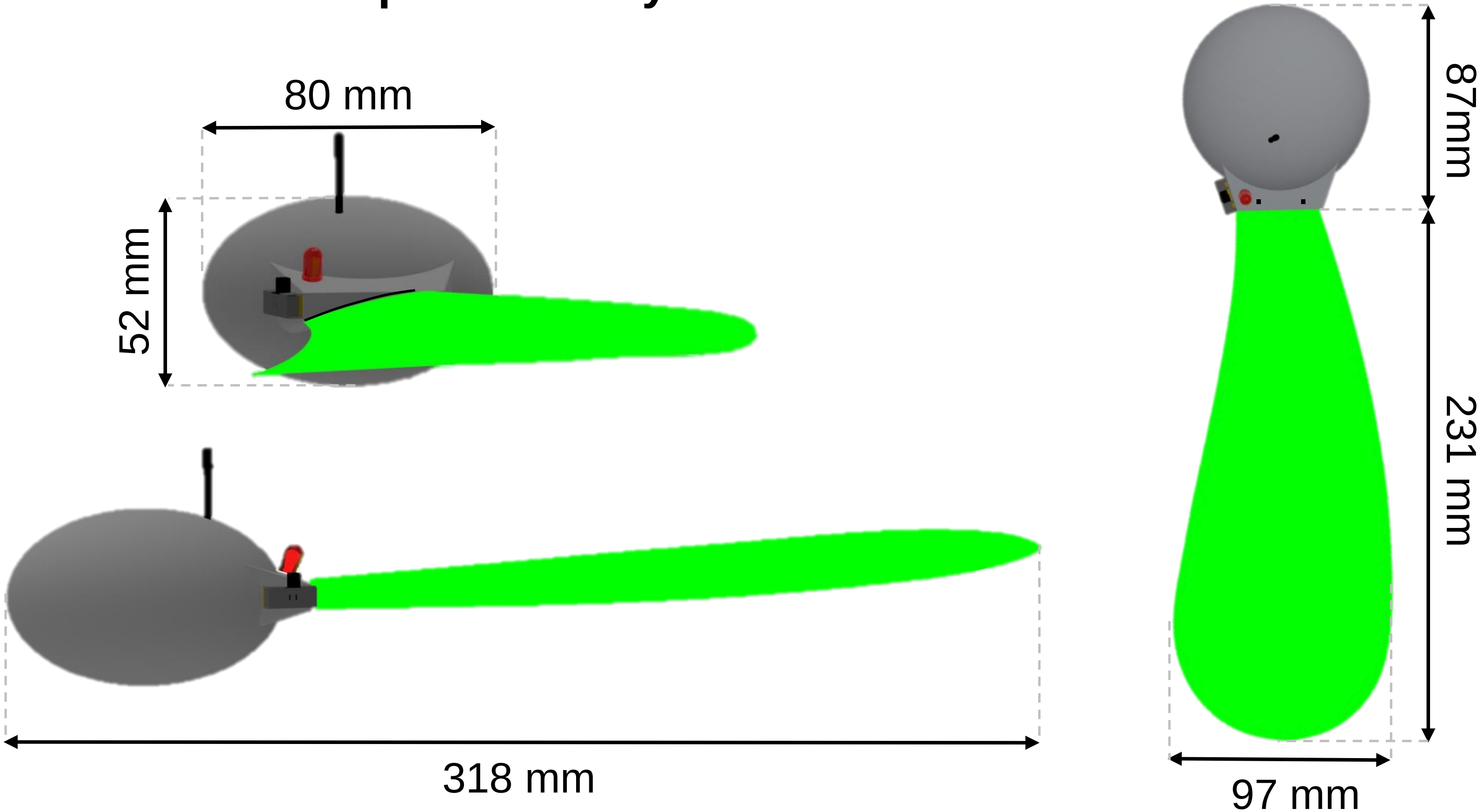
Payload



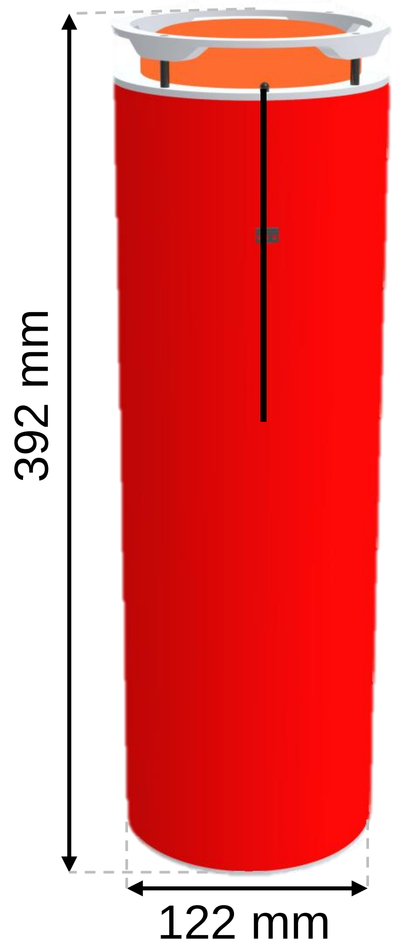
Launch Configuration *Container after 1st deployment* *Container after 2nd deployment*

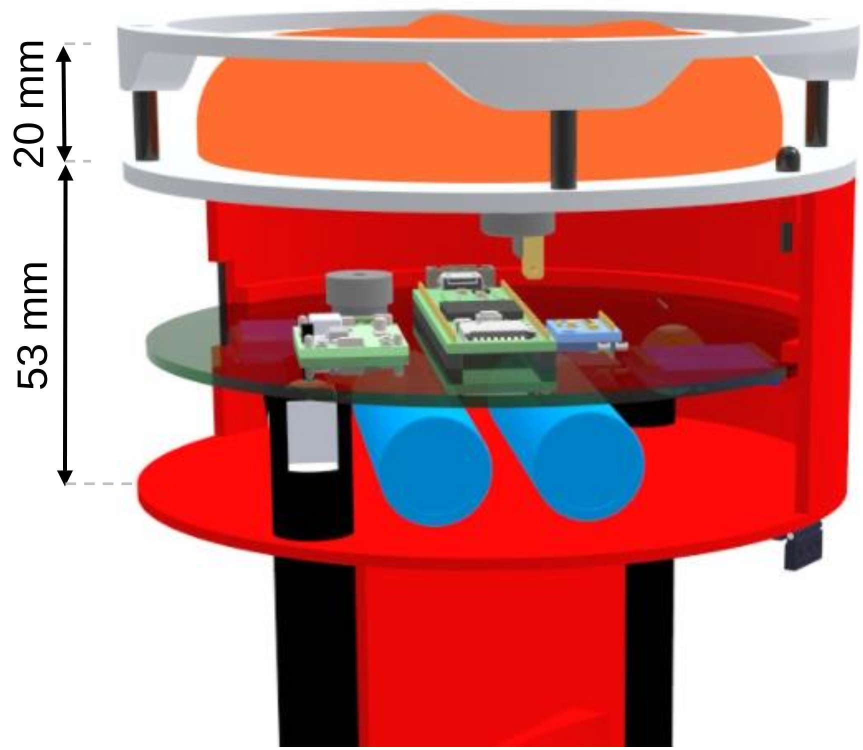
Physical Layout (1/8)

Dimensions : Maple Seed Payload



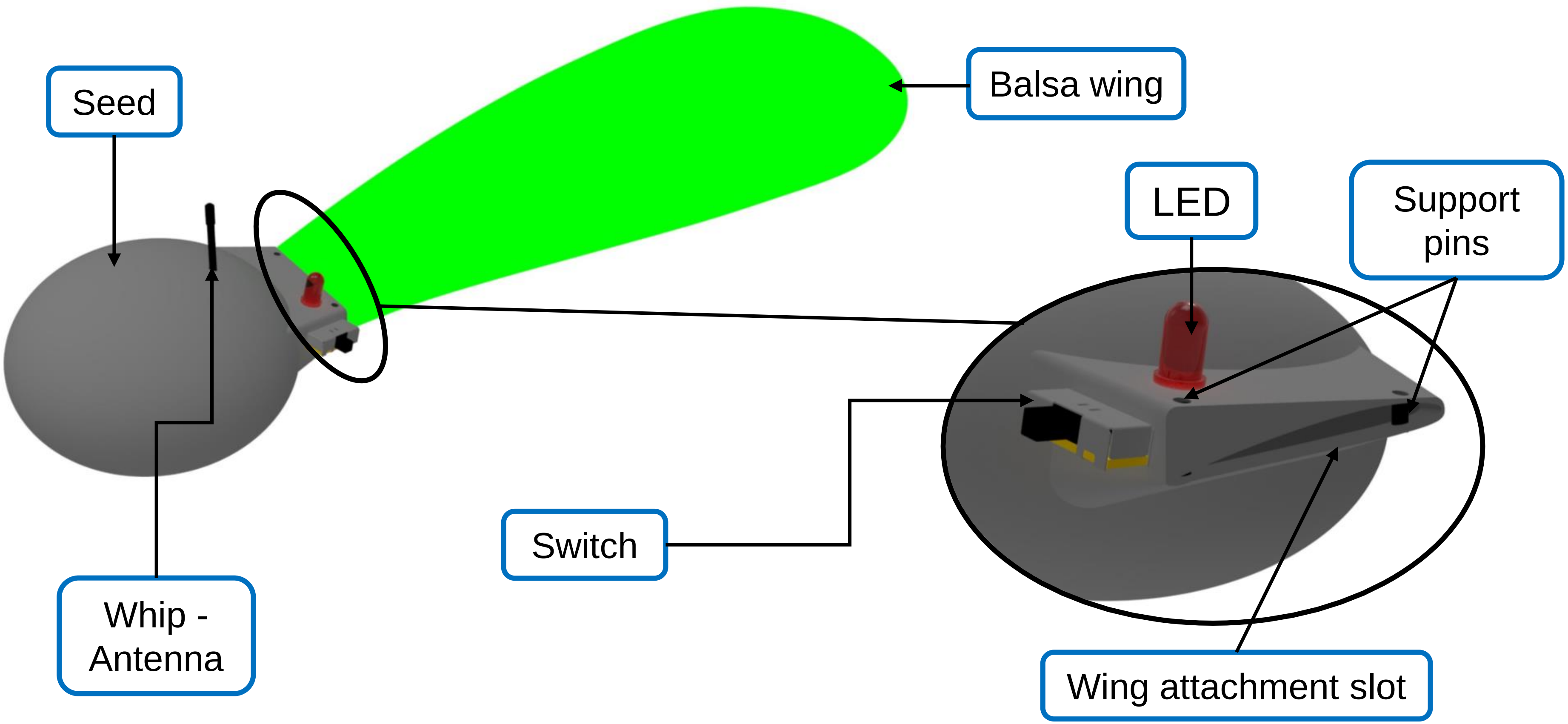
Dimensions : Container



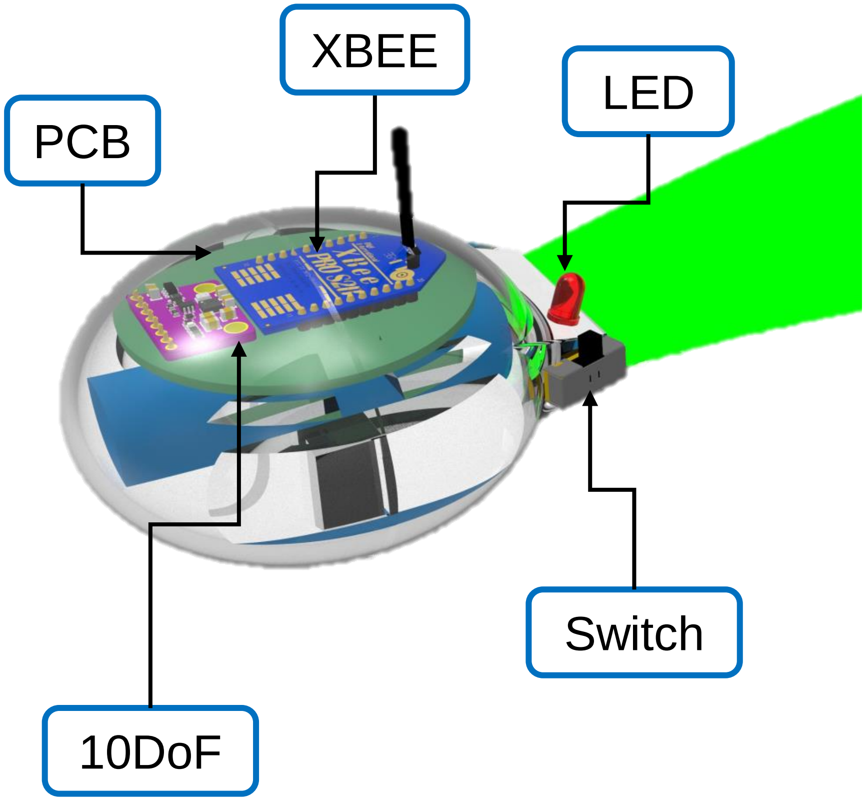


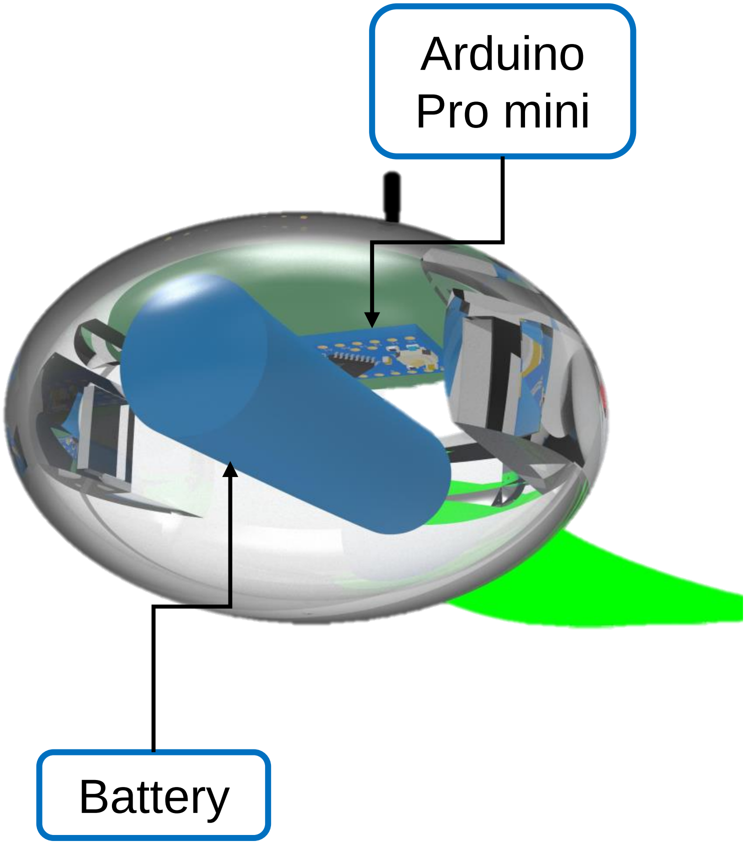
Physical Layout (3/8)

Placement of Major Components : Payload

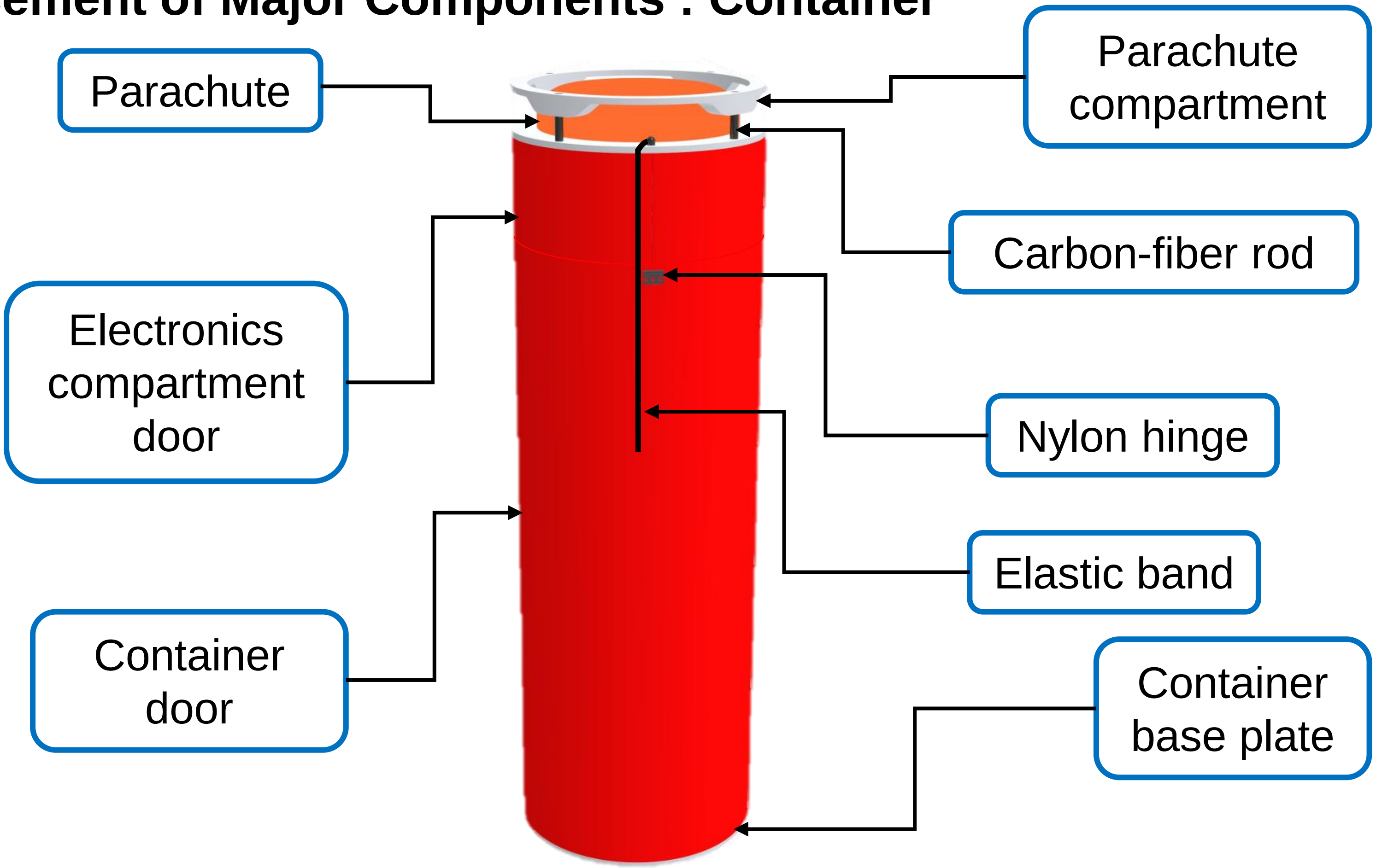


Placement of Major Components (Electronics): Payload



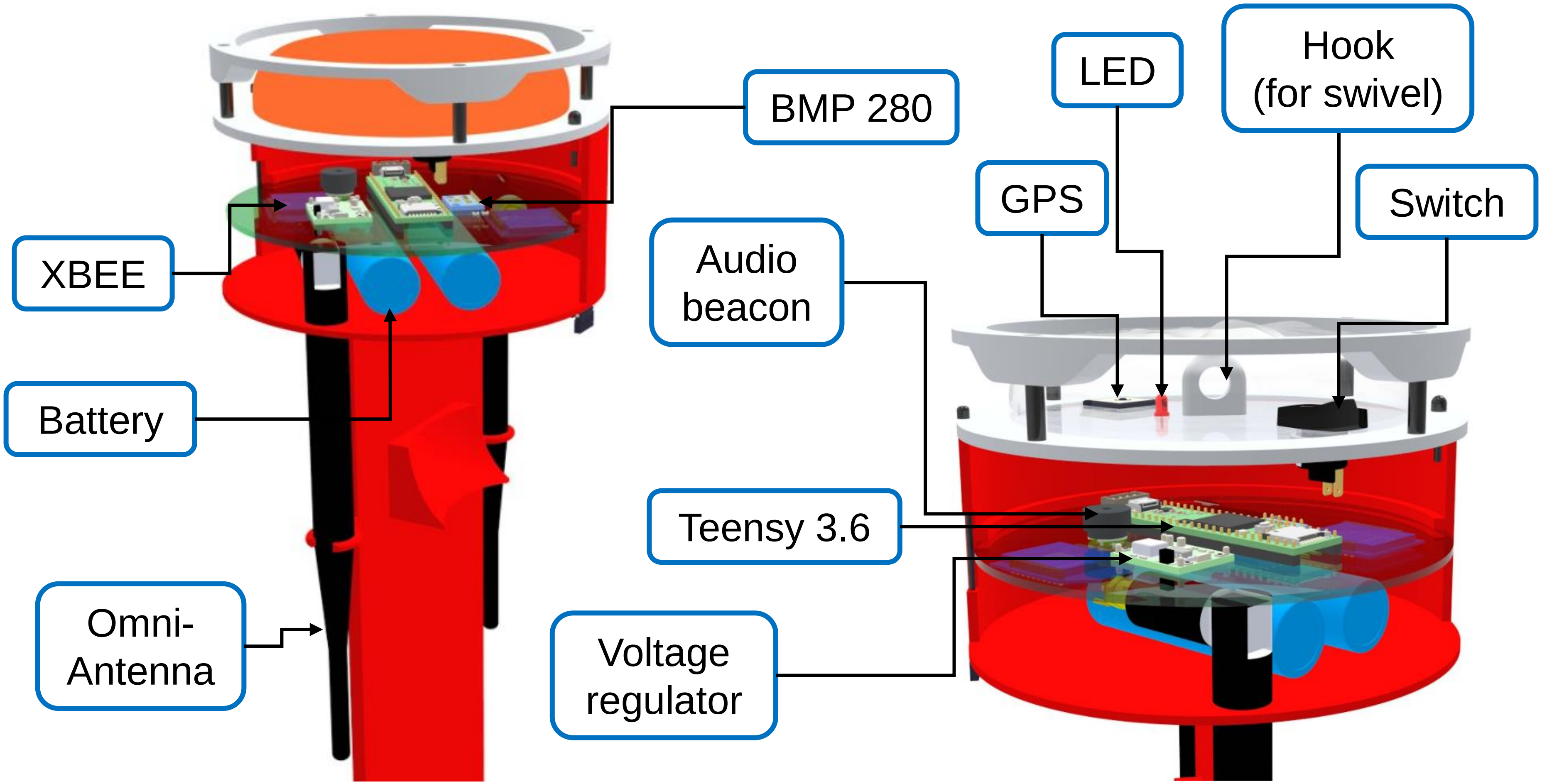


Placement of Major Components : Container

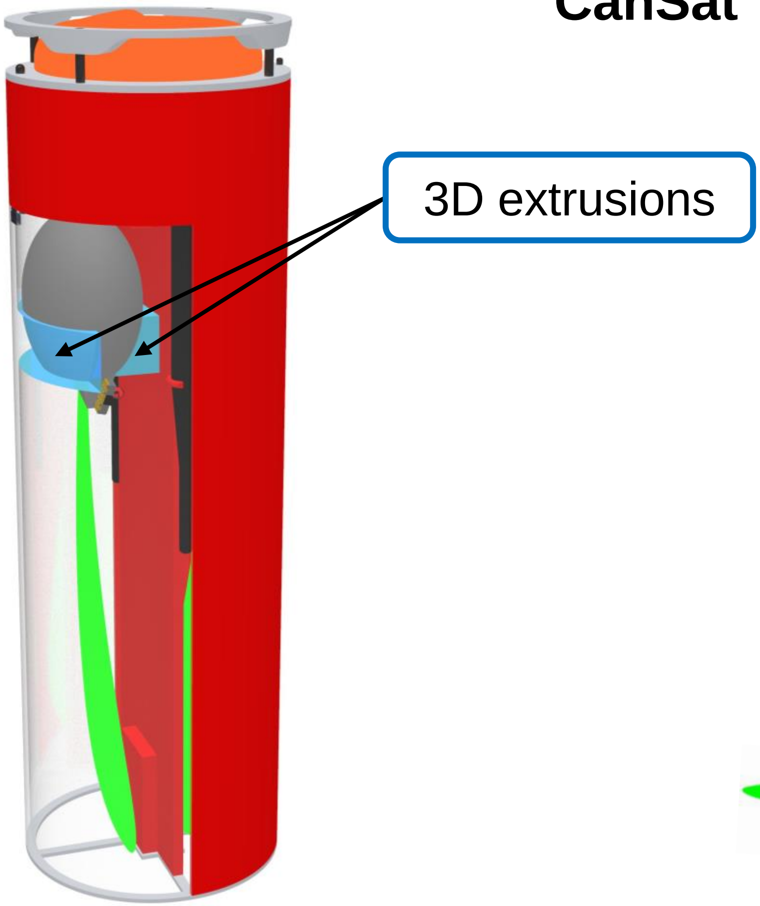


Physical Layout (6/8)

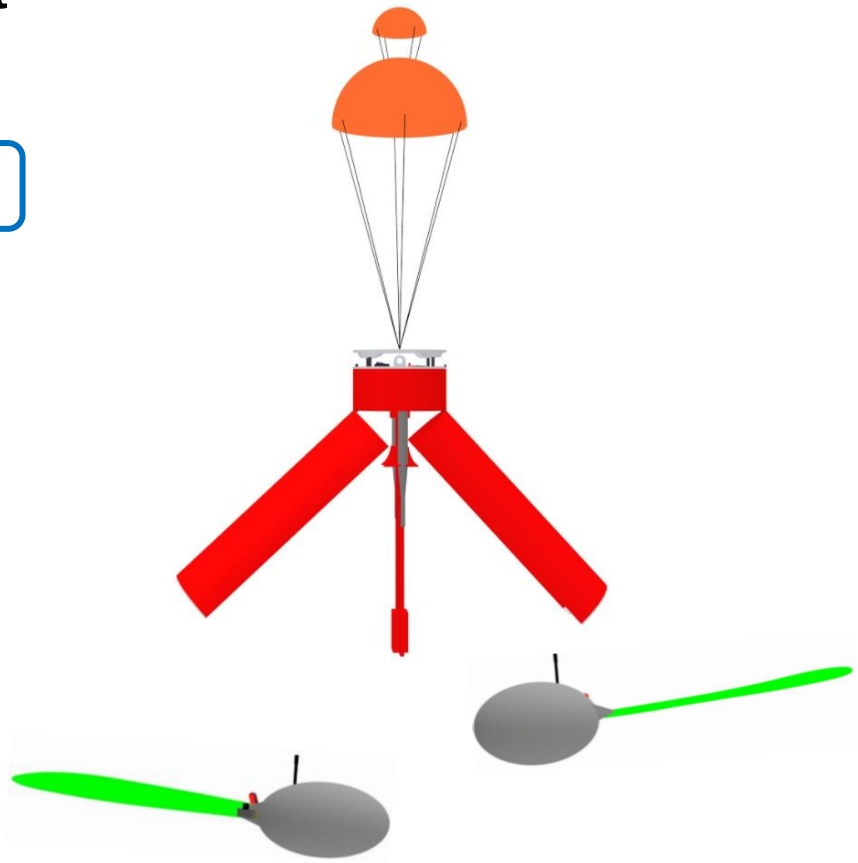
Placement of Major Components (Electronics) : Container



CanSat

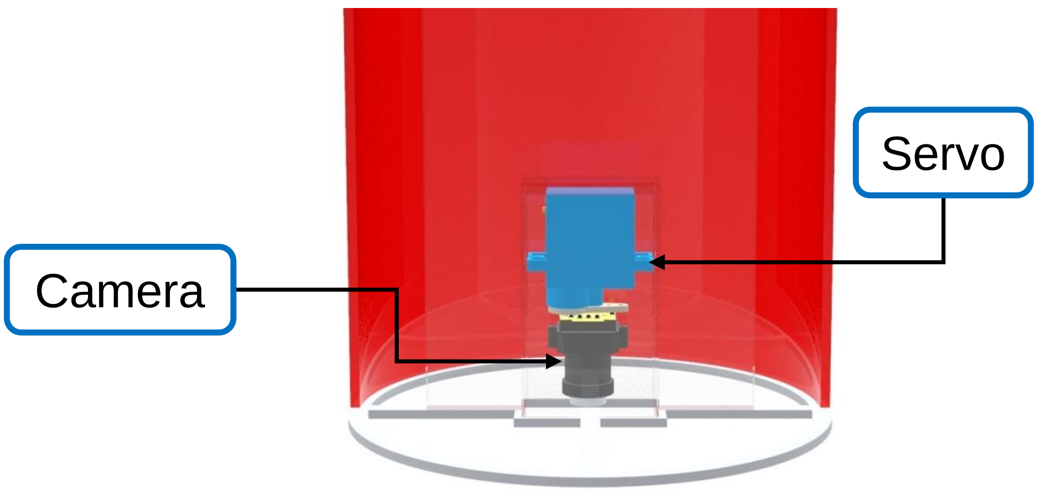


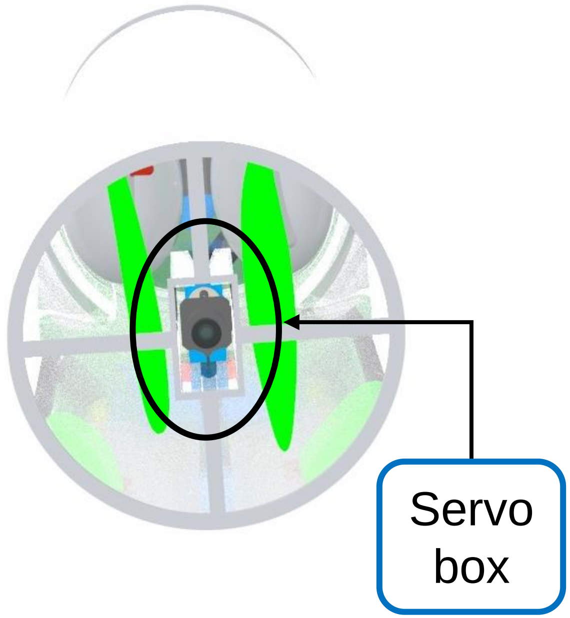
Launch(Stowed) configuration



Complete Deployed Configuration

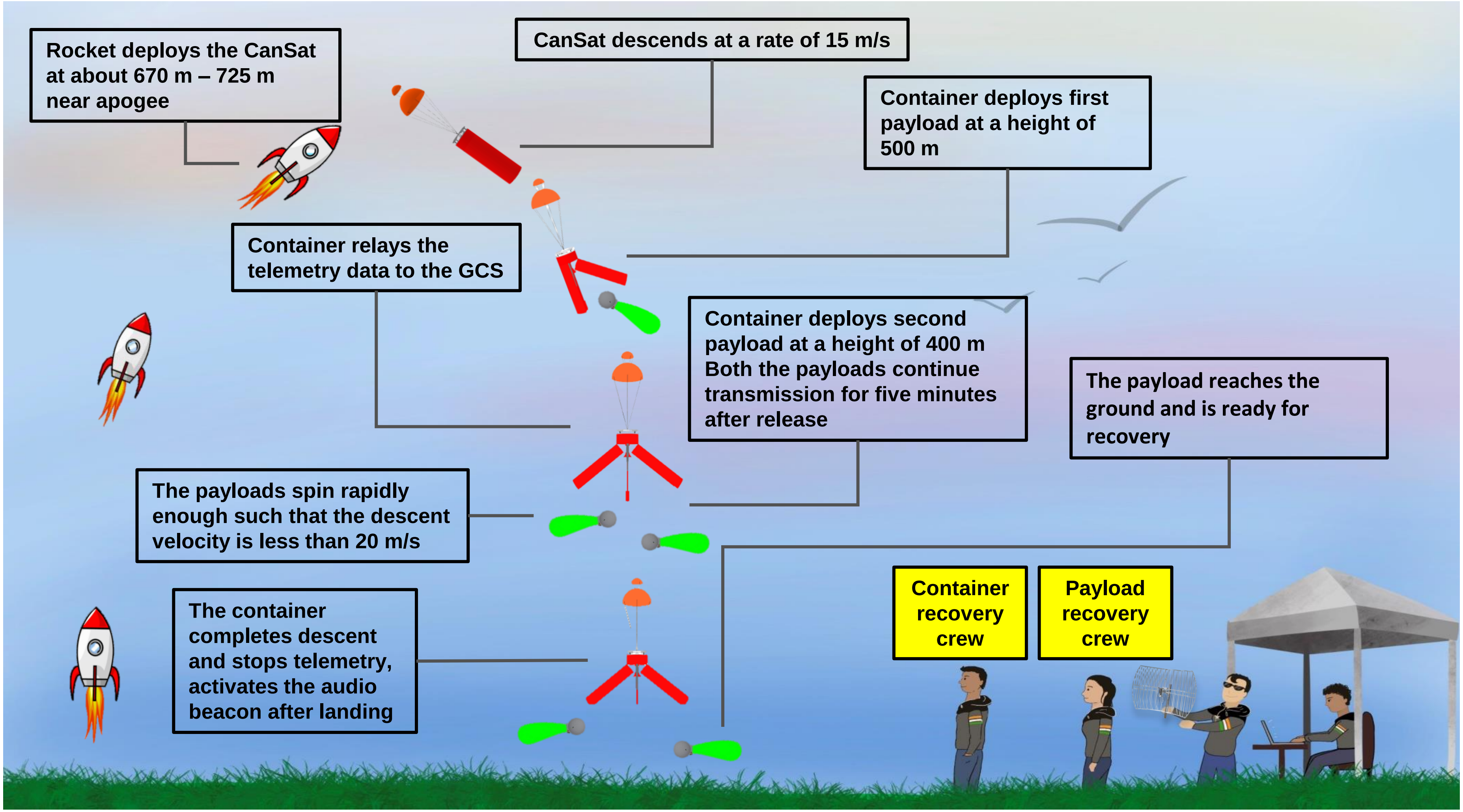
Physical Layout (8/8)





The camera stabilization system comprises of a servo for free rotation of the camera about the vertical axis. A wide-angle camera is used to capture the deployment of the payloads.

System Concept of Operation (1/2)



System Concept of Operation (2/2)

Pre-launch

- Establish the Ground Control Station
- Review compatibility of CanSat with rocket
- Perform final check of CanSat and its components

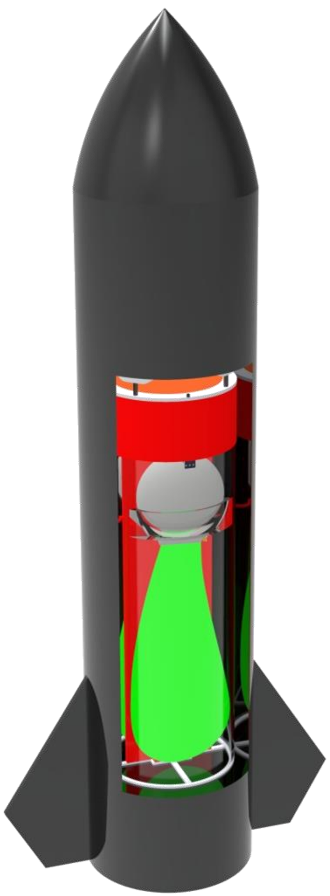
Launch

- Rocket launch
- Deployment of CanSat
- Descent of container and deployment of payloads
- Receive and record telemetry from container and payloads
- Create .csv file using GCS software

Post-launch

- Recovery of the CanSat
- Inspect the payload for any damage
- Deliver the received data to the judges
- Analyze the data received
- Prepare for PFR
- Present the PFR to the judges

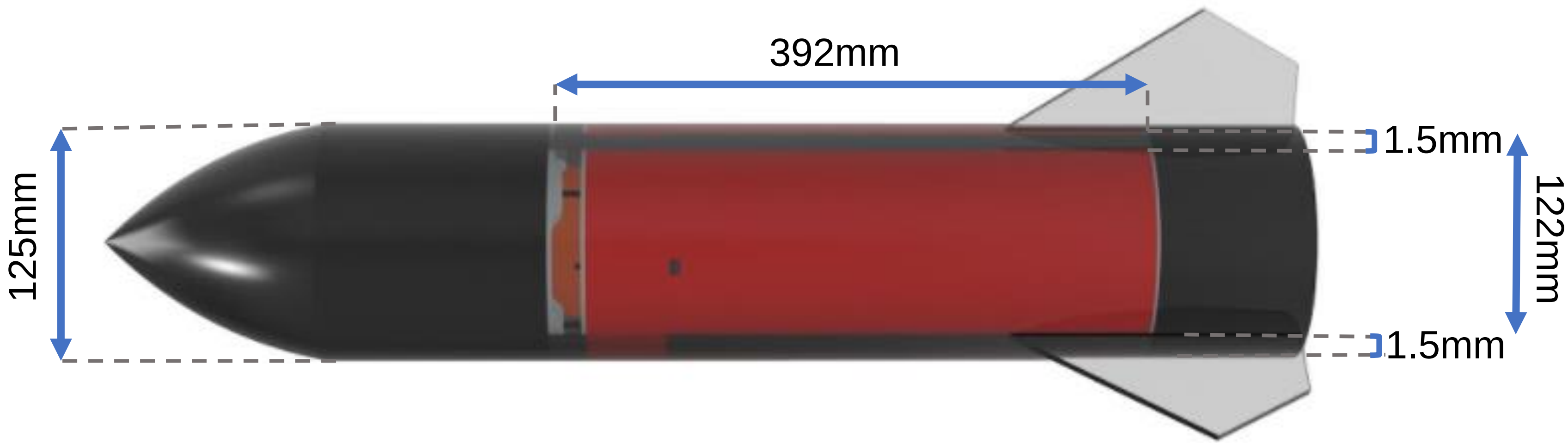
Launch Vehicle Compatibility (1/2)



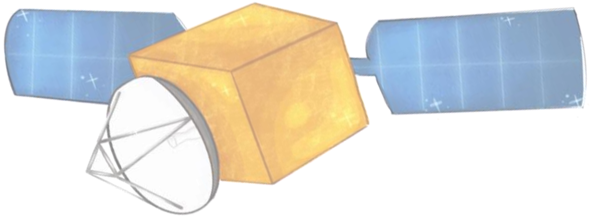
Title	Parameter	Dimensions in Mission Guide (mm)	Actual CanSat Dimension (mm)	Clearance (mm)
Rocket payload section	Height	400	392	8
	Diameter	125	122	3
Payloads (x2)	Length of seed	-	87	-
	Wing span	-	231	-
Parachute dimension after separation	Diameter	-	170	-

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.



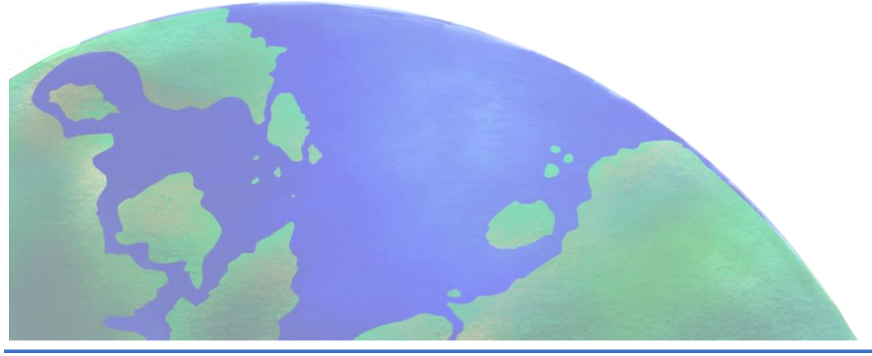
These dimensions will enable smooth separation of the container from the rocket.



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 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 descent

Sensor Subsystems 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 Subsystems 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 Subsystems 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 Subsystems 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 Trade & Selection

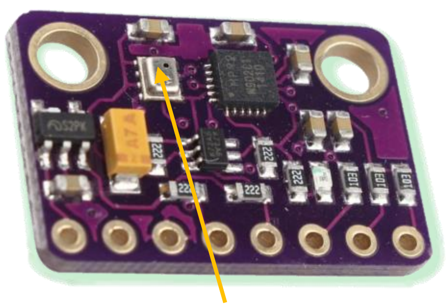
Component Name	Interfaces	Supply Voltage (V)	Current Consumption (µA)	Pressure Range (hPa)	Accuracy (hPa)	Dimension (mm)	Weight (gm)	Cost (₹)
BMP180	SPI, I2C	3.3	3.2	300 – 1250	±0.5	2.0 x 2.0 x 0.75	0.561	300
BMP280	**SPI, I2C**	**3.3**	**2.7**	**300 – 1100**	**±1.0**	**2.0 x 2.5 x 0.95**	**0.048**	**225**
MPL3115A2	SPI, I2C	3.3	2.28	300 - 1100	±1.0	2.5 x 2.5 x 0.93	0.055	270

Selected Component : BMP280

- Least current consumption
- Appropriate pressure range
- High accuracy
- Better suited in terms of dimensions, weight and cost
- Shared I2C Bus (lesser wiring)
- Included on the 10-DoF IMU Board

Formula Used:

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



BMP280

Payload Air Temperature Sensor Trade & Selection

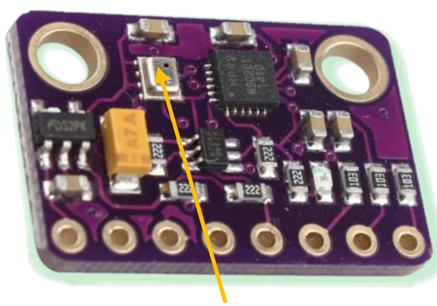
Component Name	Interfaces	Supply Voltage (V)	Current Consumption (µA)	Temperature Range (°C)	Accuracy (hPa)	Dimension (mm)	Weight (gm)	Cost (₹)
BMP180	SPI, I2C	3.3	3.2	-40 to +85	±0.5	2.0 x 2.0 x 0.75	0.561	300
BMP280	**SPI, I2C**	**3.3**	**2.7**	**-40 to +85**	**±1.0**	**2.0 x 2.5 x 0.95**	**0.048**	**225**
MPL3115A2	SPI, I2C	3.3	2.28	-40 to +85	±1.0	2.5 x 2.5 x 0.93	0.055	270

Selected Component : BMP280

- Least current consumption
- Appropriate temperature range
- High accuracy
- Better suited in terms of dimensions, weight and cost
- Shared I2C Bus (lesser wiring)
- Included on the 10-DoF IMU Board

Formula Used:

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



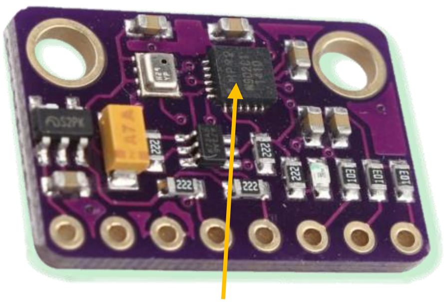
BMP280

Payload Rotation Sensor Trade & Selection

Component Name	Interfaces	Operating Voltage (V)	Current Consumption (mA)	Degrees of Freedom	Resolution (bit)	Dimension (mm)	Weight (gm)	Cost (₹)
ADXL 345	SPI, I2C	3.3	0.145	3	10	3 x 5 x 1	0.02	129.00
MPU 9250	**SPI, I2C**	**3.3**	**3.5**	**9**	**16**	**3 x 3 x 1**	**0.11**	**439.00**
MPU 6050	I2C	3.3	3.9	6	16	4 x 4 x 0.9	0.13	117.00

Selected Component : MPU 9250

- Best suited for RPM calculations
- Provides a high bit resolution
- Permissible current consumption
- Due to space constrictions, MPU 9250 is more compatible with selected design.
- Included on the 10-DoF IMU Board



MPU9250

Container Air Pressure Sensor Trade & Selection

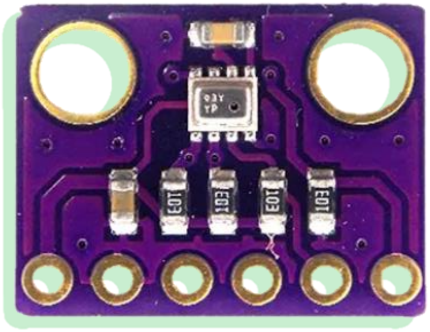
Component Name	Interfaces	Operating Voltage (V)	Current Consumption (μA)	Pressure Range (hPa)	Accuracy (hPa)	Dimension (mm)	Weight (gm)	Cost (₹)
BMP180	SPI, I2C	3.3	3.2	300 – 1250	±0.5	2.0 x 2.0 x 0.75	2.8	2000
BMP280	**SPI, I2C**	**3.3**	**2.7**	**300 – 1100**	**±1.0**	**2.0 x 2.5 x 0.95**	**4**	**225**
MPL3115A2	SPI, I2C	3.6	2.8	300 - 1100	±1.0	2.5 x 2.5 x 0.93	1.2	270

Selected Component : BMP280

- Least Current Consumption
- Appropriate pressure range
- Reliable Accuracy
- Better suited in terms of dimensions, weight and cost.
- Shared I2C Bus (lesser wiring)
- Easily available as compared to others.

Formula Used:

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



Container GPS Sensor Trade & Selection

Component Name	Interfaces	Operating Voltage (V)	Tracking Current (mA)	Sensitivity (dBm)	Position Accuracy (m)	Dimension (mm)	Weight (gm)	Cost (₹)
Adafruit Ultimate GPS	**UART,I2C, SPI**	**5**	**25**	**-165**	**1.8**	**25.5 x 35 x 6.5**	**8.5**	**2900**
Ublox NEO-M8N	UART,I2C, SPI	3.3	23	-167	2.5	35 x 26 x 2.4	17	1825
L80	UART	3.3	20	-165	<2.5	16 x 16 x 6.45	6	600

Selected Component : Adafruit Ultimate GPS

- High positional accuracy range
- External antenna is compatible
- Uses GGA protocol NMEA0183 to satisfy mission requirements.
- Greater compatibility with planned model
- Positive result during past experiences

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 Battery Voltage Sensor Trade & Selection

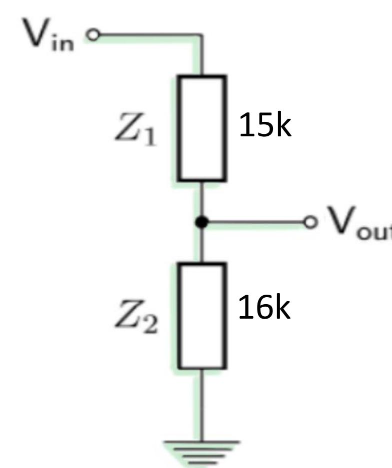
Component Name	Interfaces	Operating Voltage (V)	Operating Current (μA)	Resolution (mV)	Rate of Error (%)	Dimension (mm)	Weight (gm)	Cost (₹)
KitsGuru 045	Single Wire	0 - 25	0.25	0.01	0.1	10 x 5	3	129
INA226	I2C	2.7 – 5.5	0.33	0.01	0.5	3 x 3	0.5	199
Teensy 3.6's Analog Input Pin + Voltage Divider	**-**	**-**	**Negligible**	**-**	**0.001**	**Negligible**	**Negligible**	**<10**

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

- Simpler construction (only 2 resistors) and better use of on-board components
- Large operating range
- Low error rate thus giving greater accuracy
- The use of common resistors as a voltage divider promotes cost and space efficiency.

Formula Used:

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

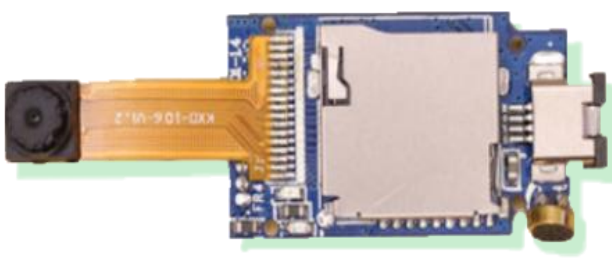


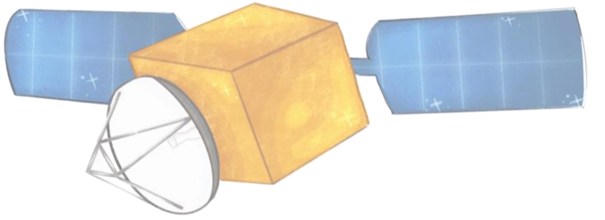
Bonus Camera Trade & Selection

Component Name	Interfaces	Operating Voltage (V)	Operating Current (mA)	Video Resolution (pixels)	Frames Per Second (fps)	SD card slot	Dimension (mm)	Weight (gm)	Cost (₹)
Adafruit Mini Spy Camera	**Digital**	**5**	**110**	**640x480**	**30**	**Yes**	**28.5 x 17 x 4.2**	**2.8**	**920**
600 Tvl Mini FPV	Digital	5	120	1280x960	30	No	12.5 x 12.5 x 17	3.8	1035
SQ11	Digital	5	125	640x480	30	Yes	22 x 22 x 22	4	2210

Selected Component : Adafruit Mini Spy Camera

- The resolution suffices the bonus mission requirements.
- The camera is enabled by digital signal easily.
- Switch is not required to activate the camera, unlike SQ11.
- Less cost
- On-board SD card slot, unlike 600 Tvl Mini FPV

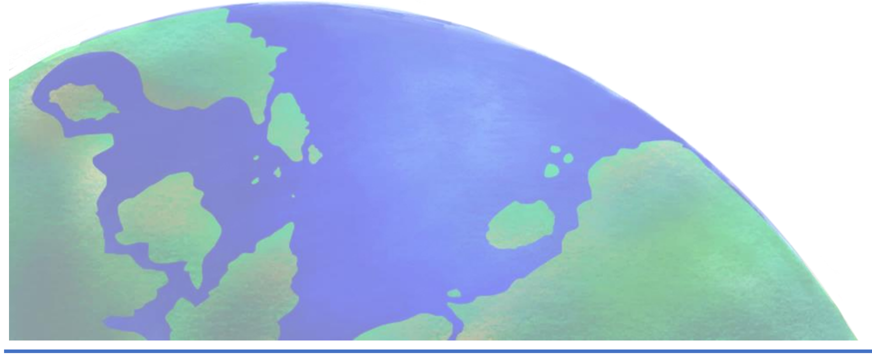




Descent Control Design

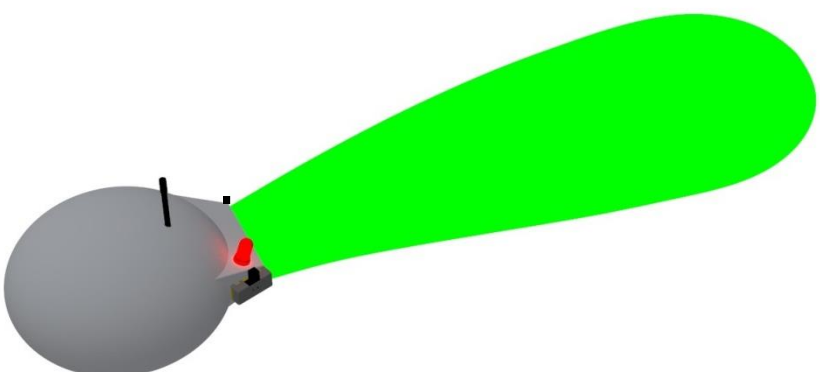
Presenter’s Name:

Greeshma Gala

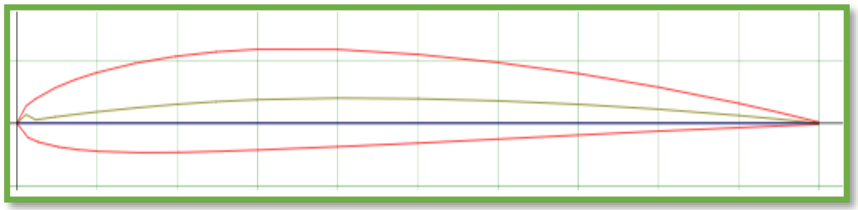


Payload Descent Control System

- 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 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

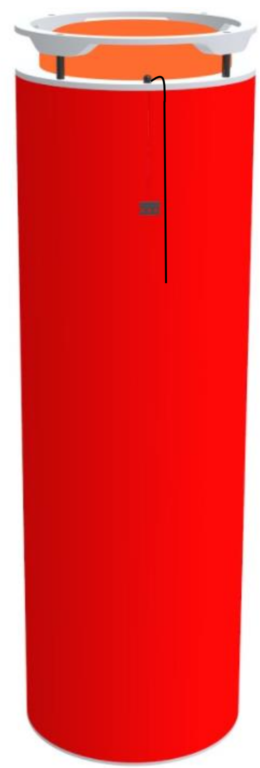


NACA 2408

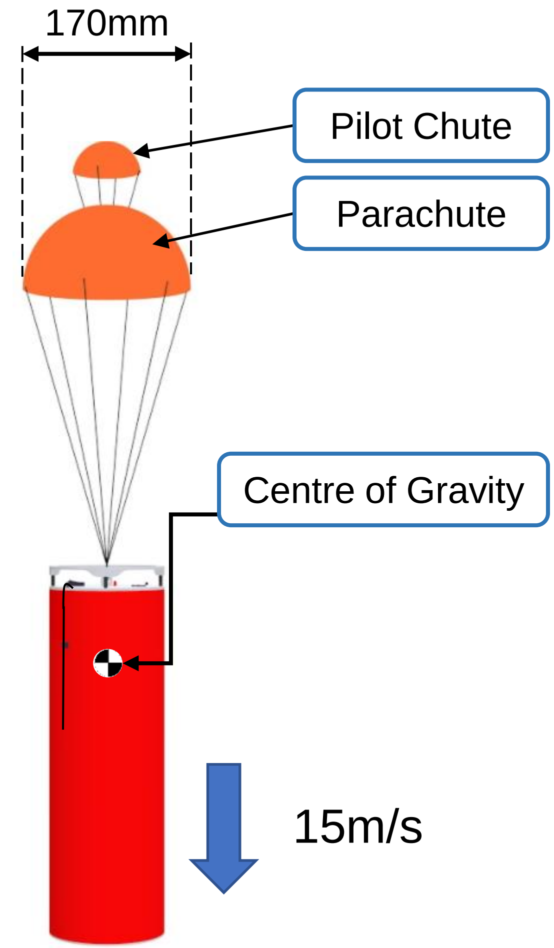
Descent Control Overview (2/4)

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 selected long enough and a pilot chute is added to ensure descent and spin stability.



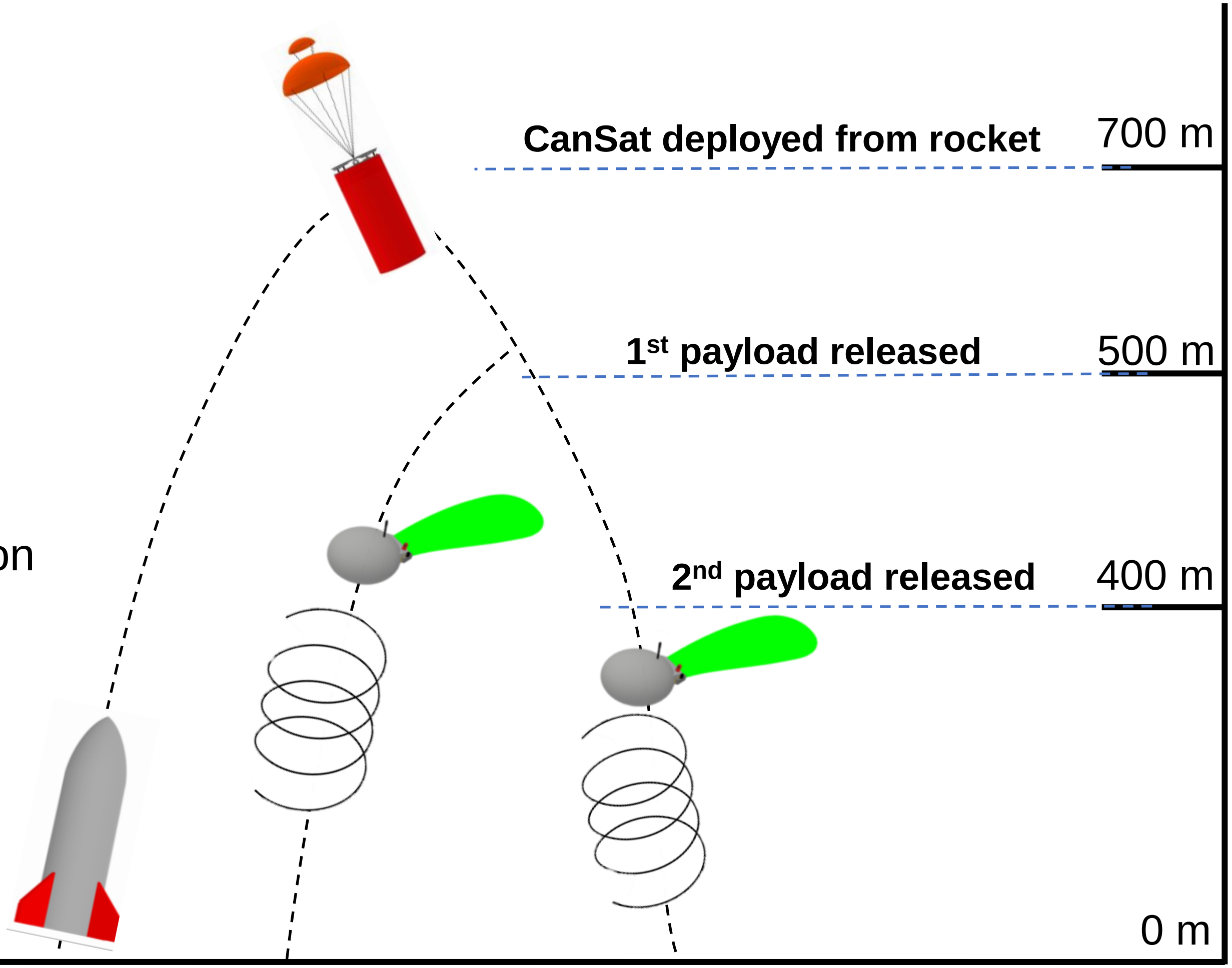
Undeployed Parachute



Deployed Parachute

Descent Control Overview (3/4)

- Descent velocity for CanSat (payload + container) is found to be 15m/s.
- The payload descends with a constant velocity less than 20m/s.
- The payload auto-rotates during its 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 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 Strategy Selection and Trade (1/4)

PAYLOAD DEPLOYMENT DESCENT CONTROL STRATEGY

Configuration 1: Balsa Wing

- Strength is greater than dowel structure
- Wing airfoil profile is uniform
- Spin stabilization is achieved
- Structure is more aerodynamically stable
- Easier to manufacture

Configuration 2: Dowel Structure

- Lightweight
- Alignment of the dowel holes is difficult due to their small size.
- An uneven wing shape is formed which affects the aerodynamic stability of the payload.

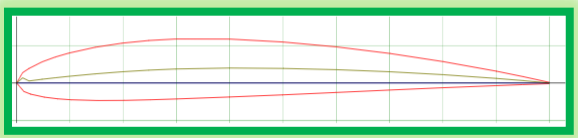
Selection	Rationale
Configuration 1: Balsa Wing	• Uniform airfoil profile wing, thus aerodynamically more stable. • Greater structural strength and high durability.

Payload Descent Control Strategy Selection and Trade (2/4)

PAYLOAD DEPLOYMENT DESCENT CONTROL STRATEGY (AIRFOIL COMPARISON)

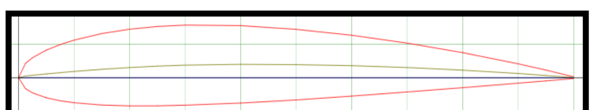
1 NACA 2408

- It attains a maximum thickness of 8% at 29.9% of the chord.
- It attains a maximum camber of 2% at 40% of the chord.



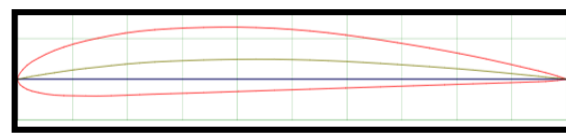
2 NACA 2412

- It attains a maximum thickness of 12% at 30% of the chord.
- It attains a maximum camber of 2% at 40% of the chord.



3 GOE 795

- It attains a maximum thickness of 8% at 30.9% of the chord.
- It attains a maximum camber of 2.4% at 43.5% of the chord.



XFLR5 ANALYSIS

(Keeping Wingspan=229 mm, Wing area=33886.28 mm^2, AOA= 11°)

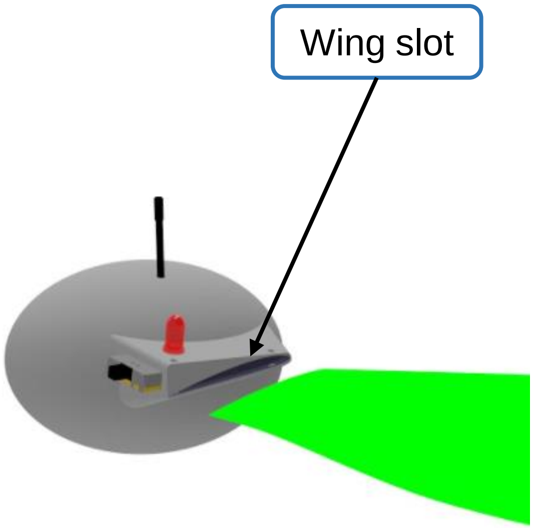
	NACA 2408	GOE 795	NACA 2412
C_L	0.910	0.797	0.898
C_D	0.039	0.038	0.046
C_L/C_D	19.875	20.720	23.025
L	8.2181 N	7.1976 N	8.1098 N
D	0.3522 N	0.3431 N	0.4154 N
L/D	23.3336	20.9781	19.5228

- **NACA 2408** is selected for Design 1 as it has higher Lift-to-Drag ratio.
- **GOE 795** is selected for Design 2 as it provides space to accommodate the dowel.

L → Lift, C_L → Coefficient of Lift, D → Drag, C_D → Coefficient of Drag

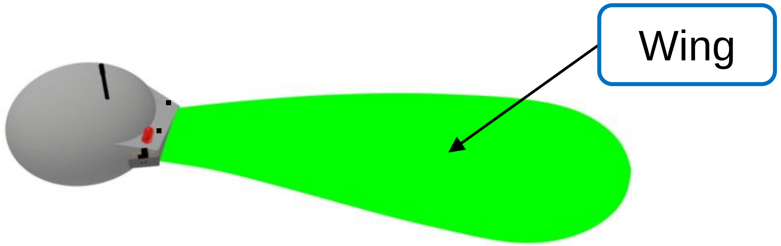
Payload Descent Control Strategy Selection and Trade (4/4)

Selection	Rationale
Selected Payload: NACA 2408	• Selected for Configuration 1(Balsa wing) • Thinner/Less cambered as compared to other two airfoils • Occupies less space • Provides sufficient lift for autorotation • Due to the less camber, twist angles can be varied greatly.
Rejected Payload: GOE 795	• Selected for Configuration 2(Dowel structure) • Thicker/high cambered as compared to other two airfoils. • Allows easy accommodation of the dowel rods • Requires more space • Faces more horizontal drag



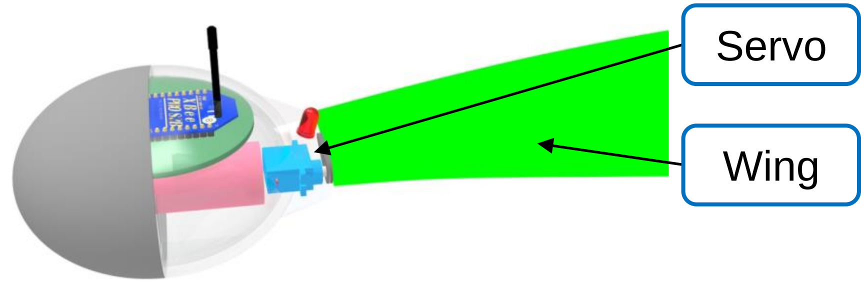
- The payloads are stowed in its deployed configuration in the container before release.
- Once released, the payload falls in a characteristic helical motion. The lift on the wing due to the falling velocity of the seed and the acting aerodynamic forces exerts a torque to spin the seed about the vertical axis, initiating the gyration of the payload.

Configuration 1: Passive



- Centre of mass of the payload is towards the seed for a uniform rotation motion.
- The wing of the payload is at a fixed angle.
- The required speed of rotation and descent is achieved using the calculated length and angle of the wing.

Configuration 2: Active



- The centre of mass is not fixed, hence servo is used to maintain stability in mid air motion.
- Extra weight is added due to servo motor and an extra battery to operate it.
- The angle of attack keeps on changing according to the required speed of rotation and descent.

Selection	Rationale
Configuration 1: Passive	• Less electronics required • Lightweight • Easy to manufacture • Cost efficient

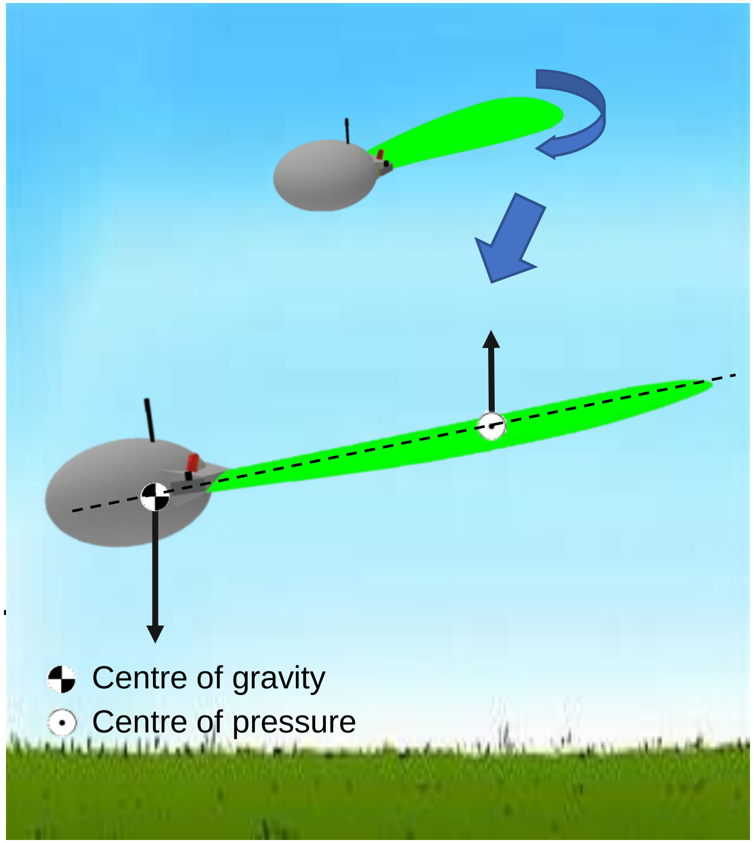
Maintaining Nadir Direction:

Active:

- A closed loop control system controls the angle of attack of the wing during the payload's descent.
- Nadir direction will be controlled by the 10-DoF sensor.
- The control system will prevent tumbling of payload by tuning to fastest possible response.

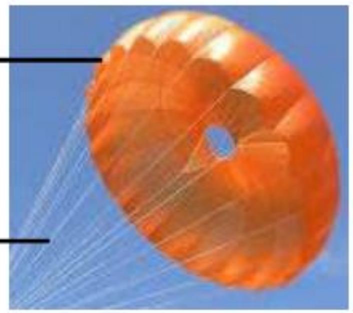
Passive (Selected):

- 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.
- Tumbling will be prevented by making sure that the centre of gravity is in place.



Container Descent Control Strategy Selection and Trade (1/2)

Configuration 1



DOME
- High drag coefficient
- Durable
- Occupies less space in container

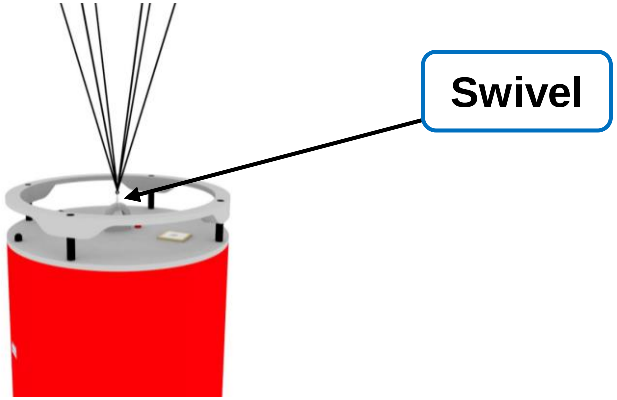
Configuration 2

X TYPE
- Comparatively lower drag coefficient
- Stacking is easy
- High vertical speed

Selection	Rationale
Configuration 1: Dome Type	• High drag coefficient • Durable • Occupies less space

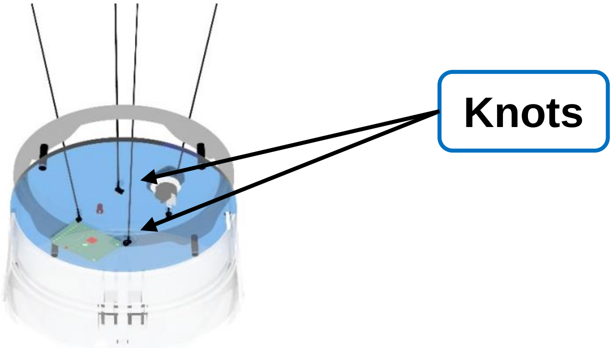
Container Descent Control Strategy Selection and Trade (2/2)

Configuration 1: Fishing Swivel



- The structure of the fishing swivel allows free rotation of the parachute.
- Keeps the container stable during descent.
- Prevents tangling of the parachute strings.

Configuration 2 : Knots on the bottom plate



- Rotation of the parachute causes the container to rotate.
- Parachute strings tangle during descent.
- Puts strain on the parachute plate.

Selection	Rationale
Configuration 1: Fishing swivel	• Allows free rotation of the parachute without affecting the container. • Easily available • There is no strain on the parachute plate

Descent Rate Estimates (1/10)

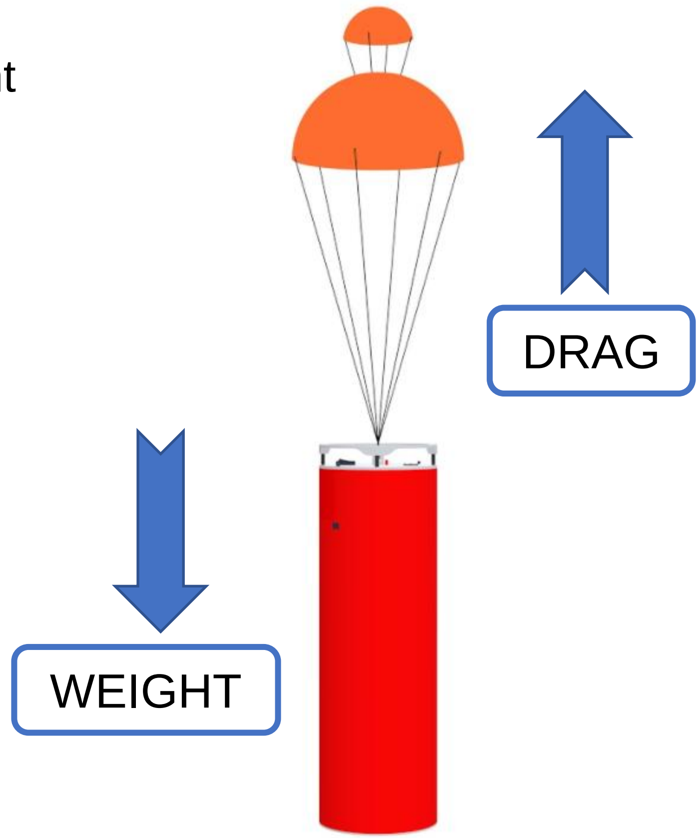
CANSAT AFTER RELEASE:

- 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:

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

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 kg/m^3**
- Drag Force = F_D
- Projected area of parachute = A



Descent Rate Estimates (2/10)

Now,

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

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

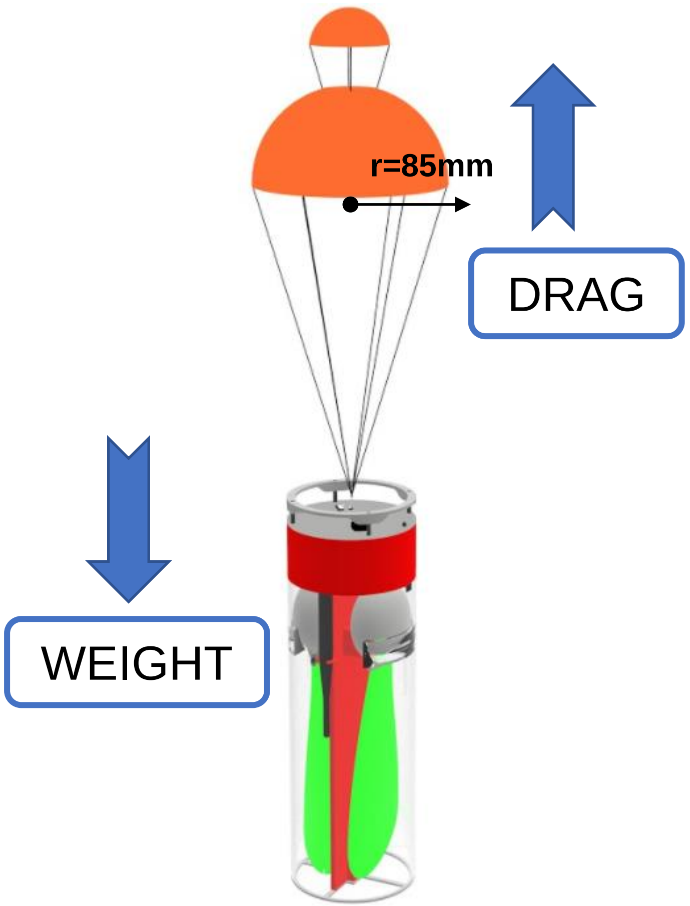
$$\mathbf{A = 0.022\ m^2}$$

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 (3/10)

- 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 near perfect aerodynamic stability.

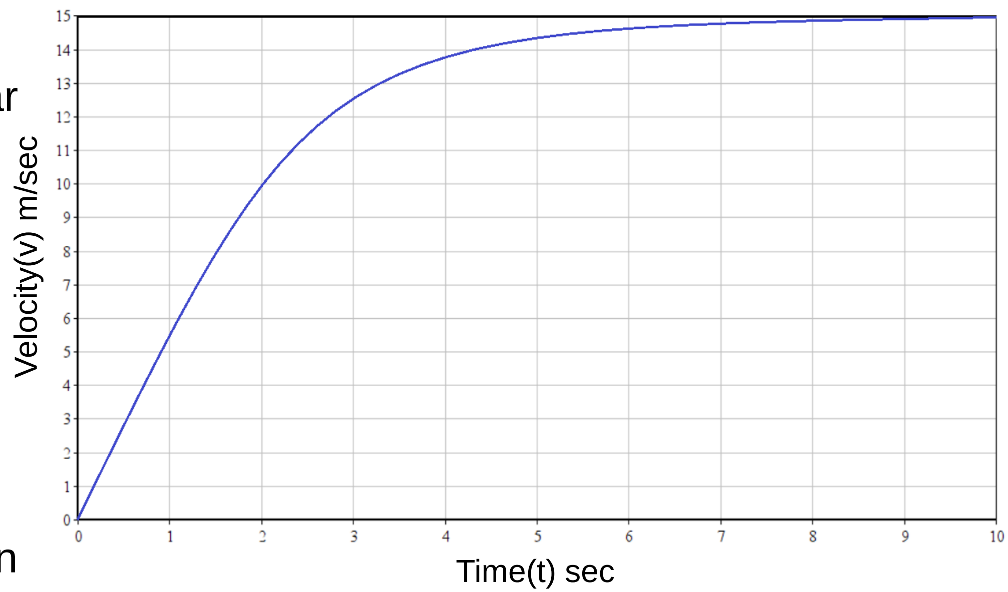
  $\therefore$ **A = 0.0022 m^2**

  But $A = \pi r^2$,

  $\therefore$ **$r_{(spill)} \approx$ 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

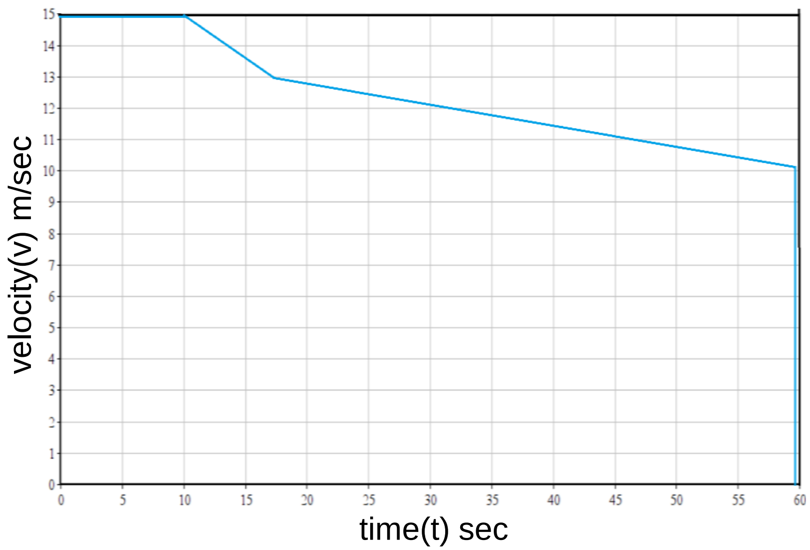


CONTAINER

- 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,

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

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

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

Descent Rate Estimates (5/10)

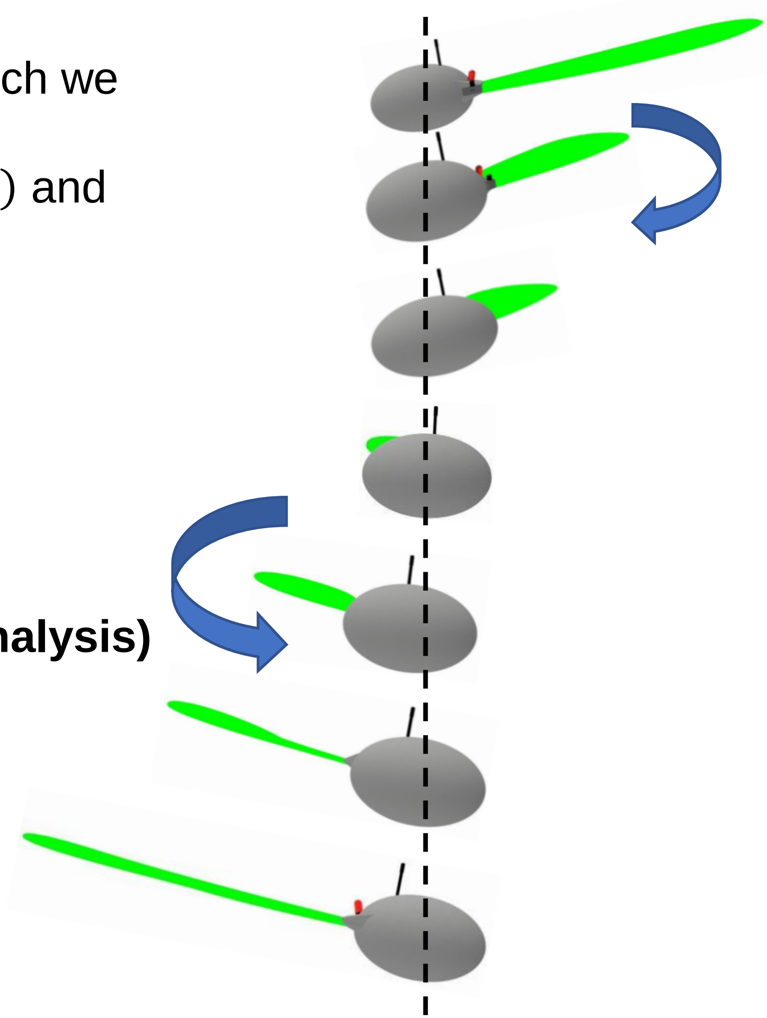
PAYLOAD

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 = $\mathbf{1.332\ kg/m^3}$
- Radius of rotation (r) = **0.229 m**
- Acceleration due to gravity (g) **= 9.81 m/s²**

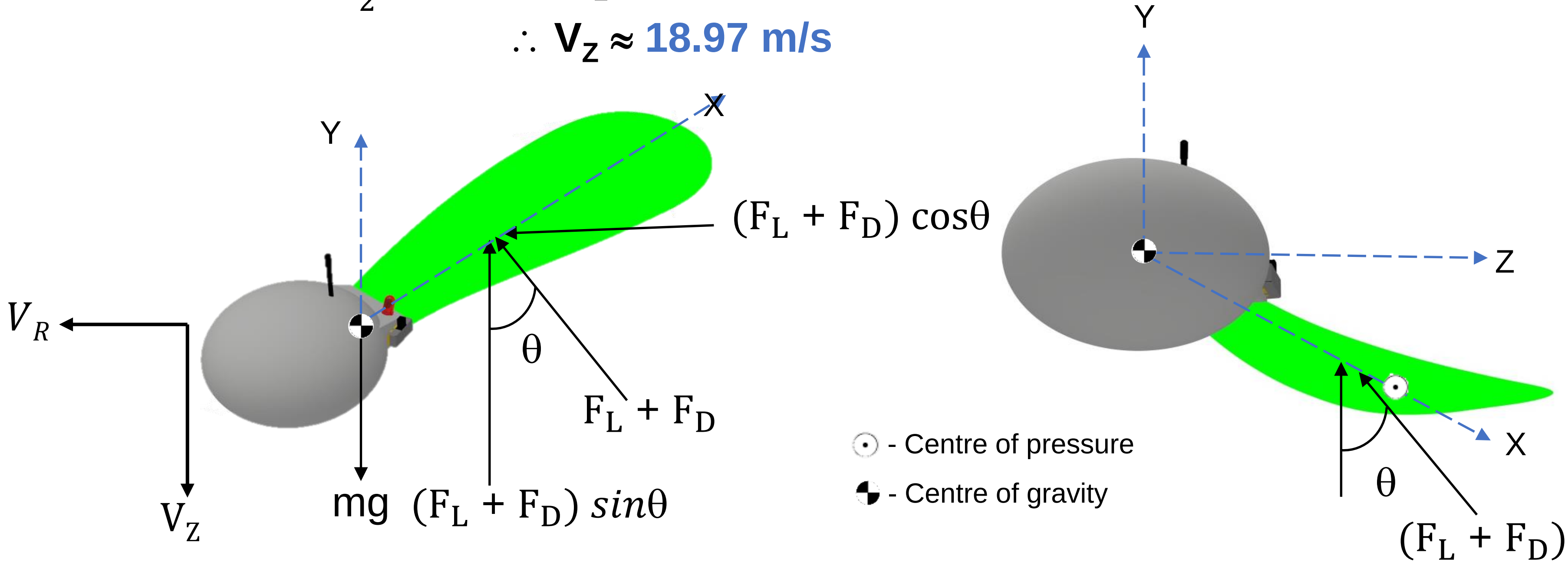
Descent Rate Estimates (6/10)

- 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

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

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

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

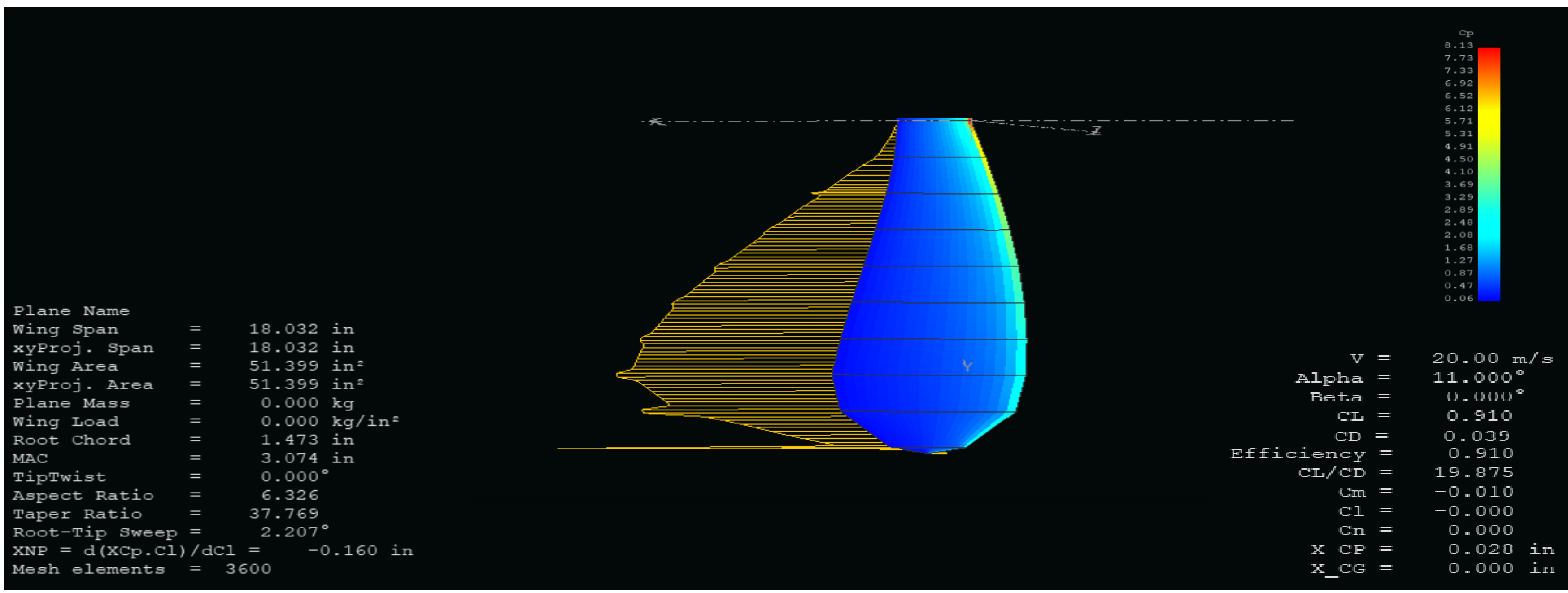


Descent Rate Estimates (7/10)

- 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.



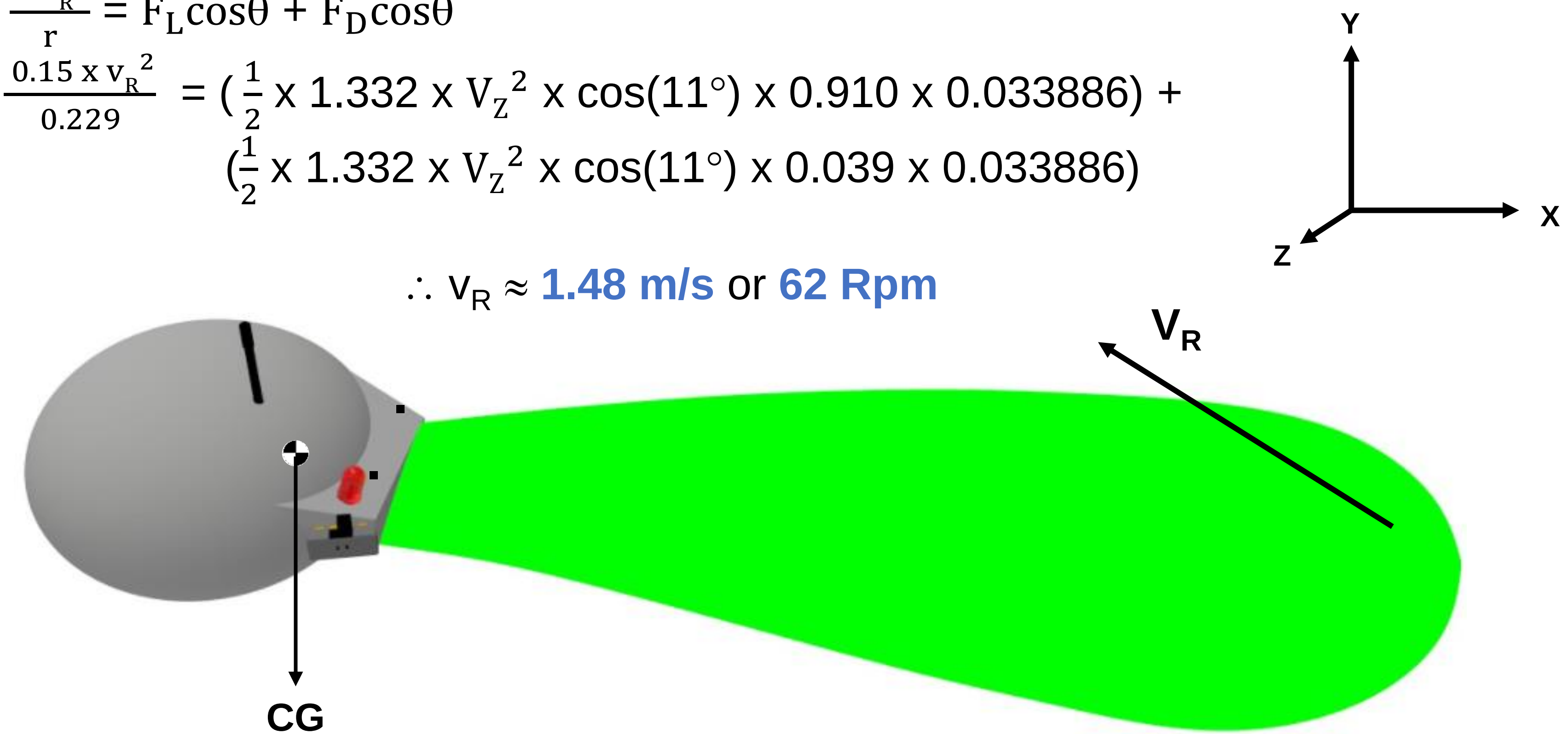
Descent Rate Estimates (8/10)

- 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

$$\therefore \frac{m v_R^2}{r} = F_L \cos\theta + F_D \cos\theta$$

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

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



Descent Rate Estimates (9/10)

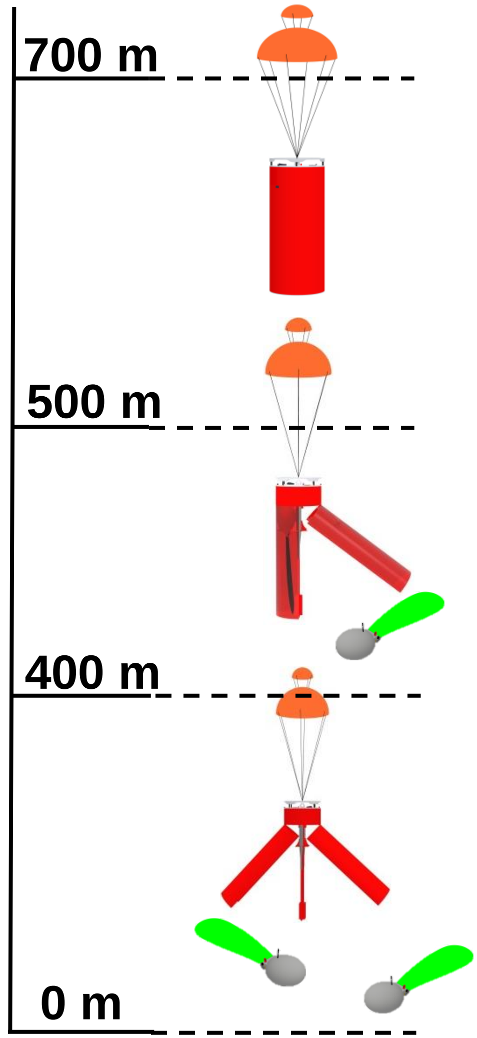
DESCENT TIME CALCULATIONS:

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
  $s = 500m$, $v = 18.97\ m/s \Rightarrow$ $\therefore$ **t ≈ 26.4 s**
- For the second payload
  $s = 400m$, $v = 18.97\ m/s \Rightarrow$ $\therefore$ **t ≈ 21.1 s**
- For the container, the descent is in three stages

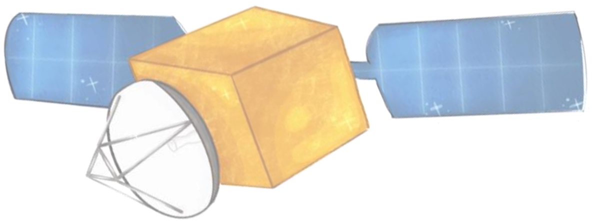
After deployment from rocket before payload releases
$s = 200m$ (700m - 500m), $v = 15\ m/s \Rightarrow$ $\therefore$ **t ≈ 13.3 s**
After the release of the first payload –
$s = 100m$ (500m – 400m), $v = 13\ m/s \Rightarrow$ $\therefore$ **t ≈ 7.7 s**
After the release of the second payload till ground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



Descent Rate Estimates (10/10)

Descent Rate Summary

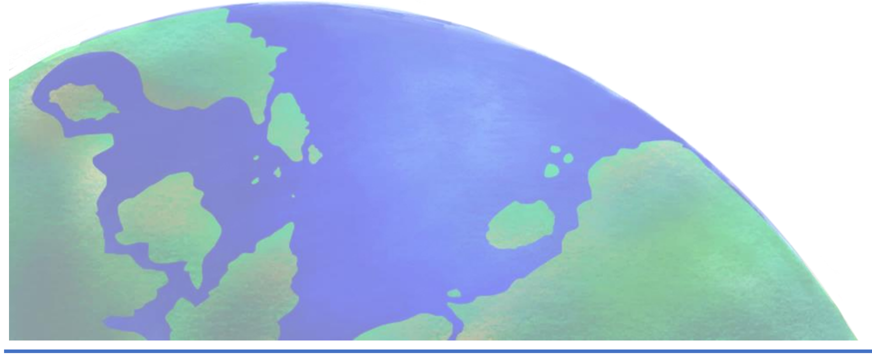
SYSTEM	DESCENT ESTIMATES
Container + Payload	15 m/s
Container after 1st payload is released	13 m/s
Container after 2nd payload is released	10.8 m/s
Payload	Vertical Velocity: 18.97 m/s Auto-rotating Velocity: 1.48 m/s



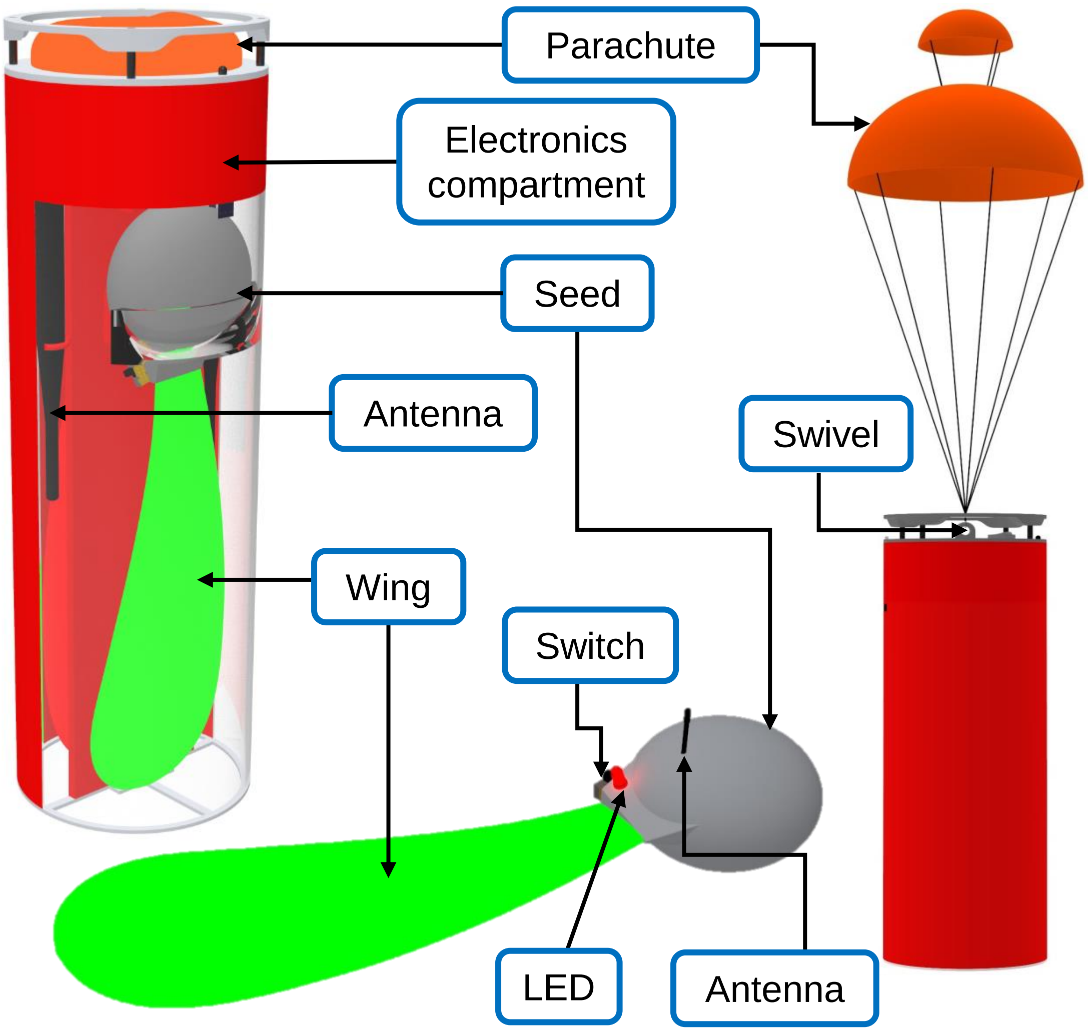
Mechanical Subsystem Design

Presenter’s Name:

Vatsal Tapiawala



Mechanical Subsystem Overview



Structure	Material Selection
Container	Balsa with fiber glass coating, carbon fiber rods, 3D printed fluorescent Red PETG
Payload	3D printed PETG for seed, Balsa & fluorescent green Monokote for wing, carbon fiber for support pins
Payload Release Mechanism	Nylon hinges, fishing line and nichrome wire

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	√	√		√

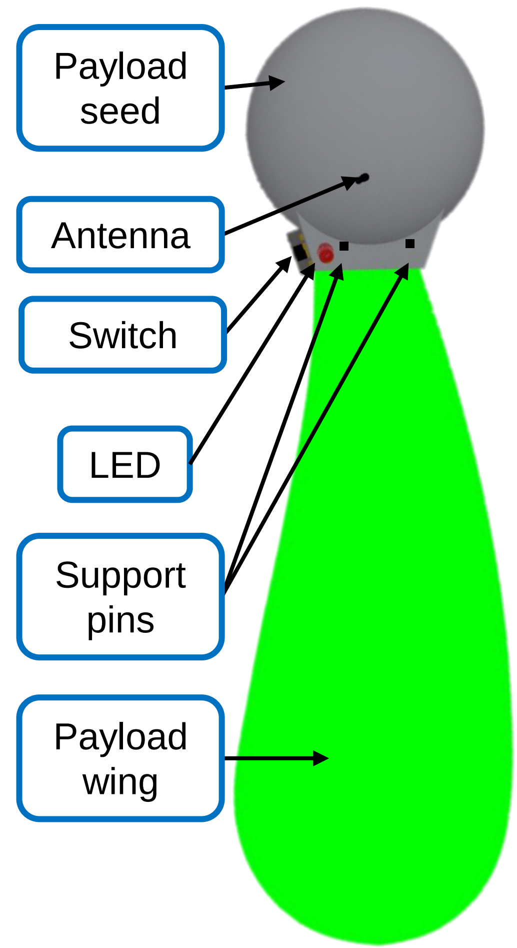
Mechanical Subsystem Requirements (4/4)

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 Trade & Selection (1/10)

Payload Mechanical Layout Design 1

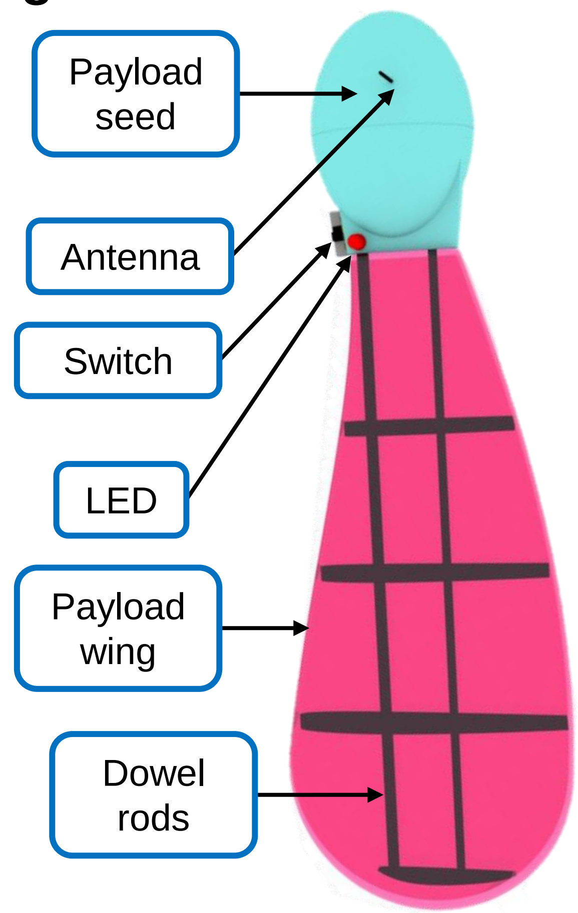
Advantages	Disadvantages
Sufficient space to accommodate electronics	Heavier than design 2
Aerodynamically more stable, due to its uniformity in airfoil.	Attaching the wing to the seed is difficult as compared to design 2
Greater structural strength than design 2	
Easier to manufacture	
Centre of Gravity is near seed wing attachment point for stability	



Payload Mechanical Layout of Components Trade & Selection (2/10)

Payload Mechanical Layout Design 2

Advantages	Disadvantages
Lighter than design 1	Difficult to manufacture
Transmutability of airfoils is easy	Less structural strength and durability
	Provides less space for electronics mounting
	Aerodynamically less stable than design 1
	Difficult to acquire accurate bending angle, twisting angle and dihedral angle



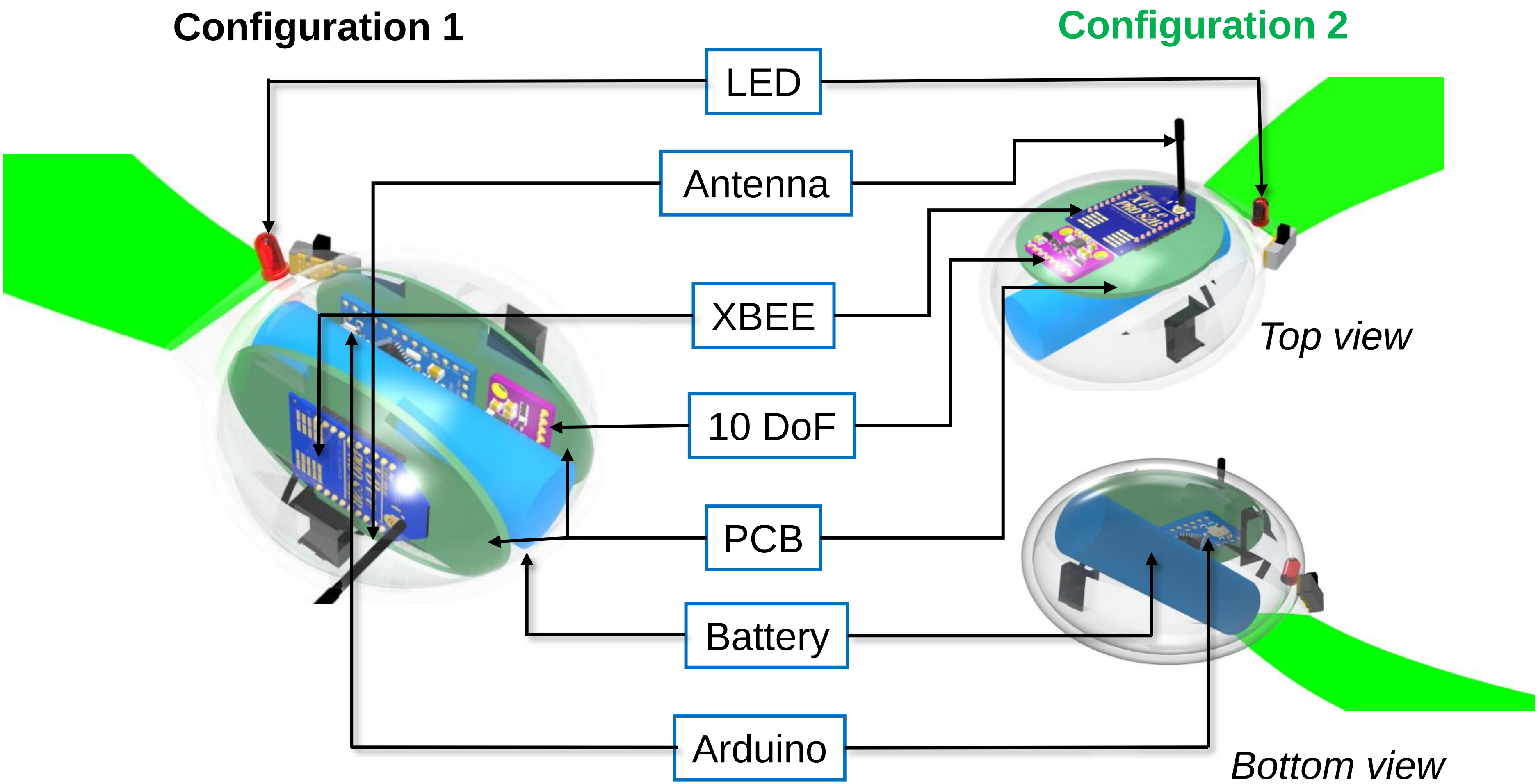
Payload Mechanical Layout of Components Trade & Selection (3/10)

	DESIGN 1			DESIGN 2		
	Low	Medium	High	Low	Medium	High
DURABILITY						
MASS						
COST						
STRENGTH						
STABILITY						
AERODYNAMIC DESIGN						

Selected Design	Rationale
Design 1	➢ Higher strength ➢ More durable ➢ More aerodynamically efficient

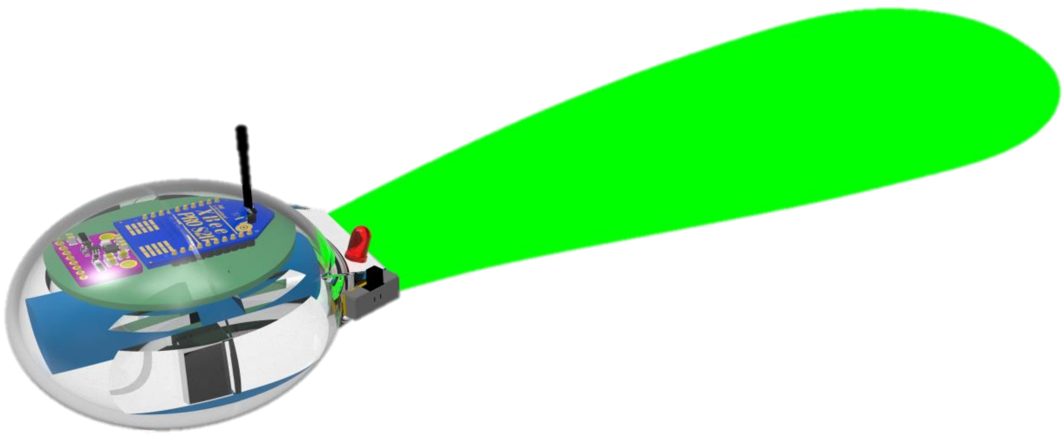
Payload Mechanical Layout of Components Trade & Selection (4/10)

ELECTRONIC COMPONENT PLACEMENT DESIGN



Payload Mechanical Layout of Components Trade & Selection (5/10)

CONFIGURATION 2 SELECTED



- Only one PCB is used in configuration 2, which reduces the weight of the payload greatly.
- In configuration 1, the CG gets shifted away from the wing-seed attachment due to two PCBs, which increases the chances of toppling. This is caused due to slight imbalance in force.
- In configuration 1, the PCB mountings are bigger than the selected configuration, this increases the weight.
- In configuration 1, the connections are difficult. So, configuration 2 is selected.

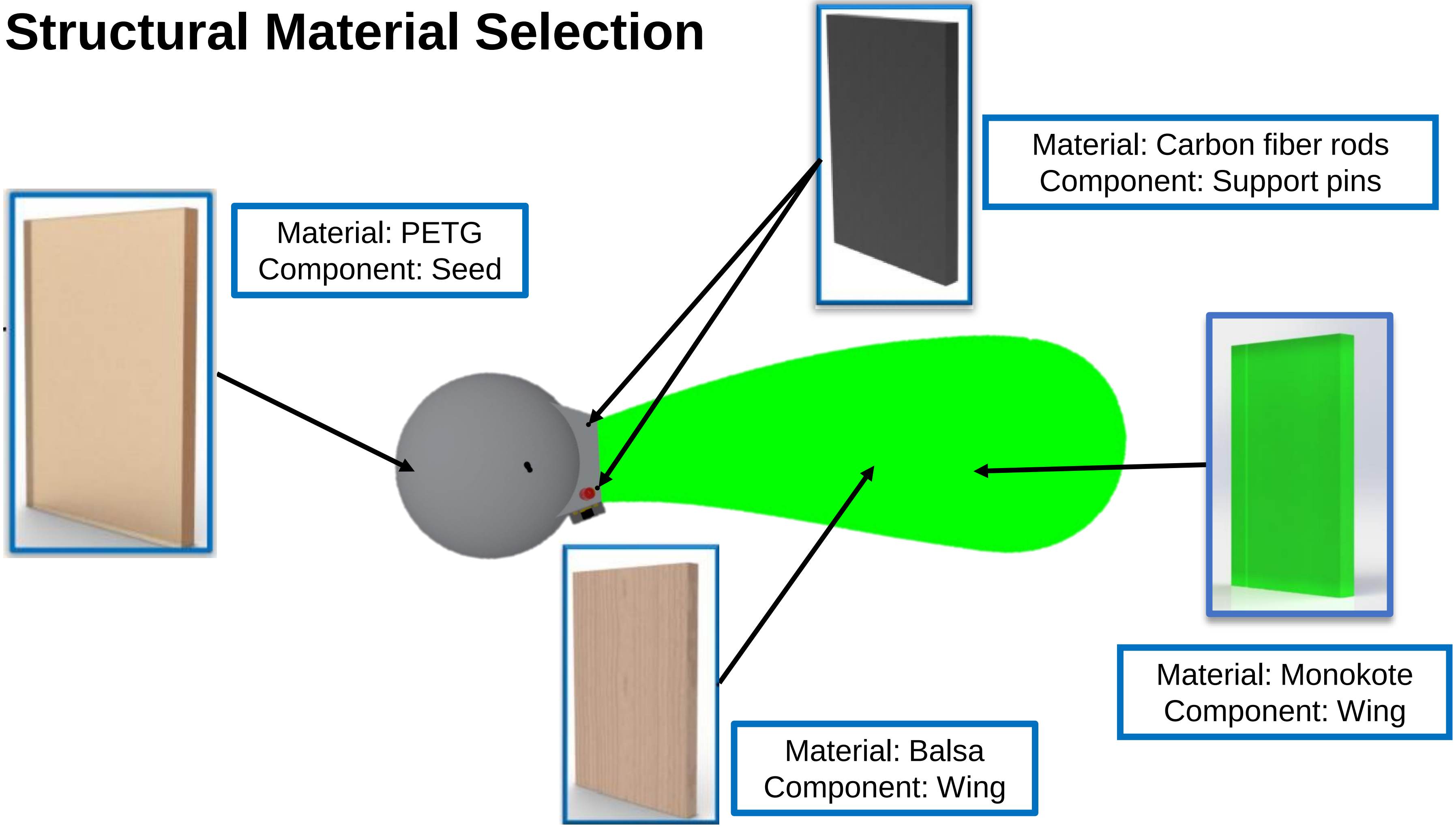
Payload Mechanical Layout of Components Trade & Selection (6/10)

Structural Material Selection

Components	Material Options	Materials Selected	Rationale
Payload Seed	1) 3D printed PETG 2) 3D printed ABS	3D printed PETG	• Greater strength • Lightweight and durable
Coating	1) Monokote 2) Fiberglass	Monokote	• Lightweight • Smoother finish, hence less skin friction drag
Payload Wing	1) Balsa 2) Carbon fiber	Balsa	• Lightweight and durable • Easy to manufacture
Wing Attachment Point	1) 3D printed PETG 2) 3D printed ABS	3D printed PETG	• Greater strength • Lightweight and durable

Payload Mechanical Layout of Components Trade & Selection (7/10)

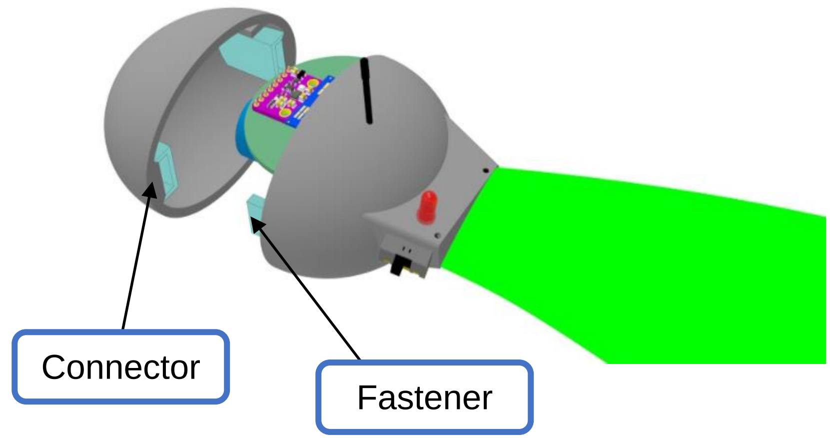
Structural Material Selection

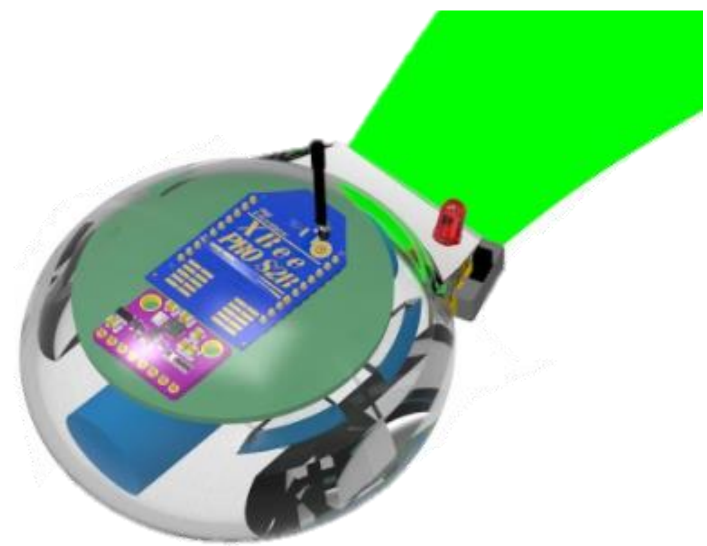


Payload Mechanical Layout of Components Trade & Selection (8/10)

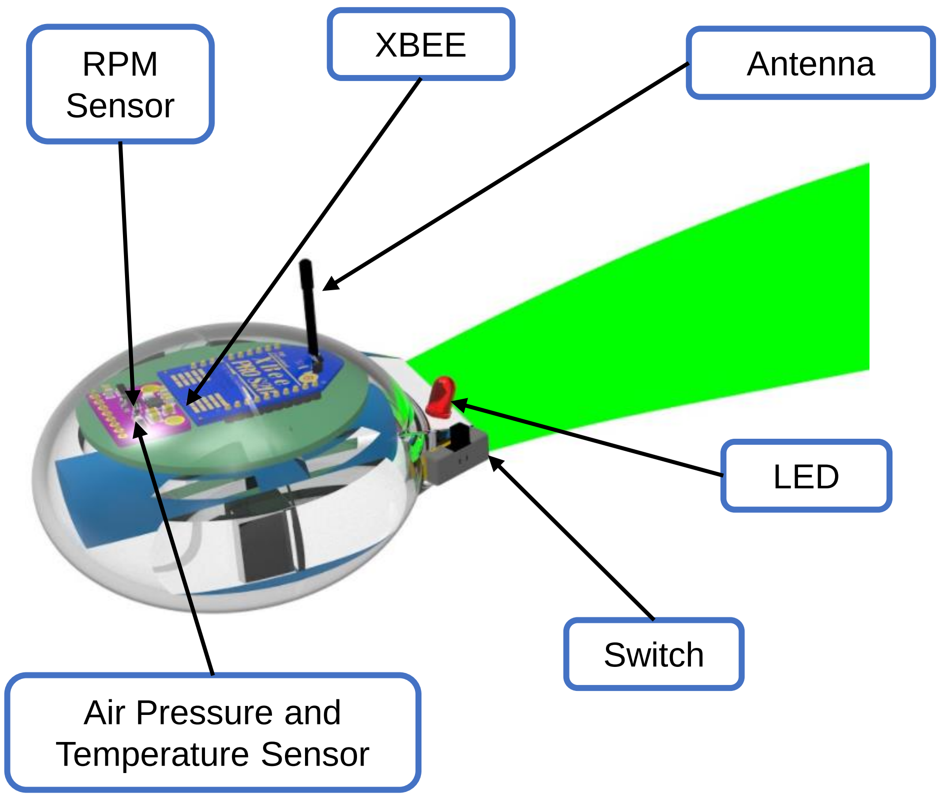
Payload Structure

- Electronic components are mounted in the seed on a two-layered PCB with XBEE and 10-DoF board on the top and microcontroller on the bottom layer, 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 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 slots 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 near the seed wing attachment point.
- The battery, being the heaviest component, is placed beneath the PCB to lower the center of gravity.

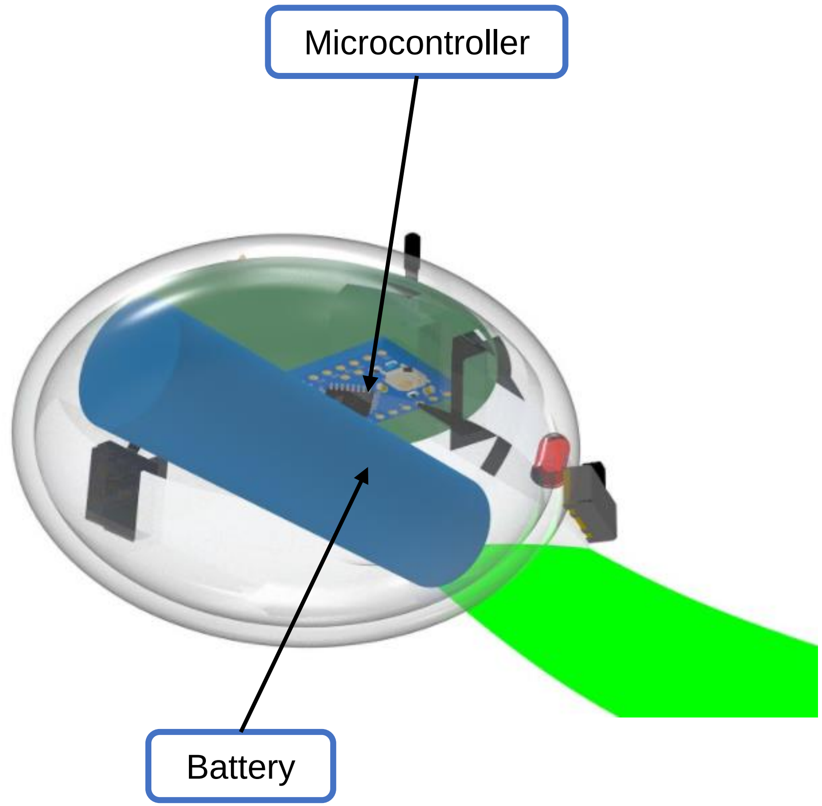




Electronic Components



Top Layer PCB

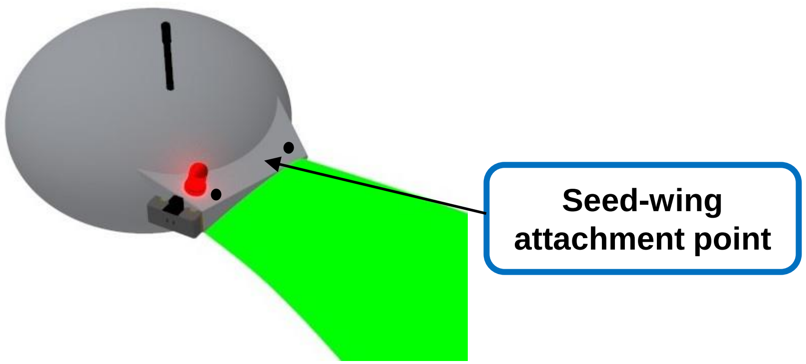


Bottom Layer PCB

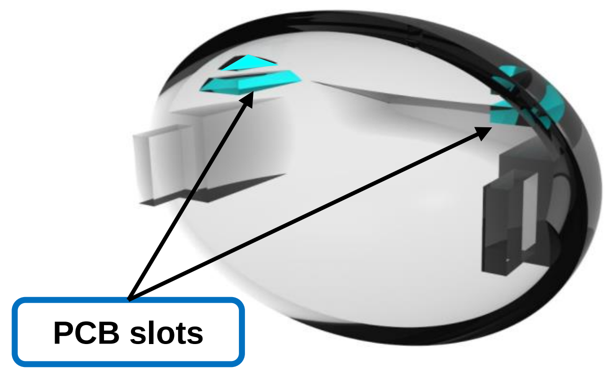
Payload Mechanical Layout of Components Trade & Selection (10/10)

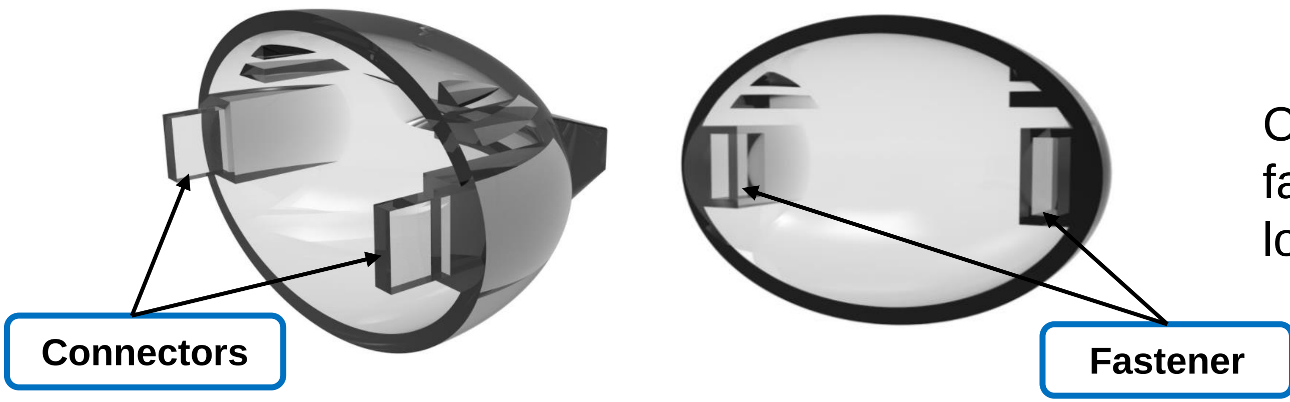
Major Mechanical Parts

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



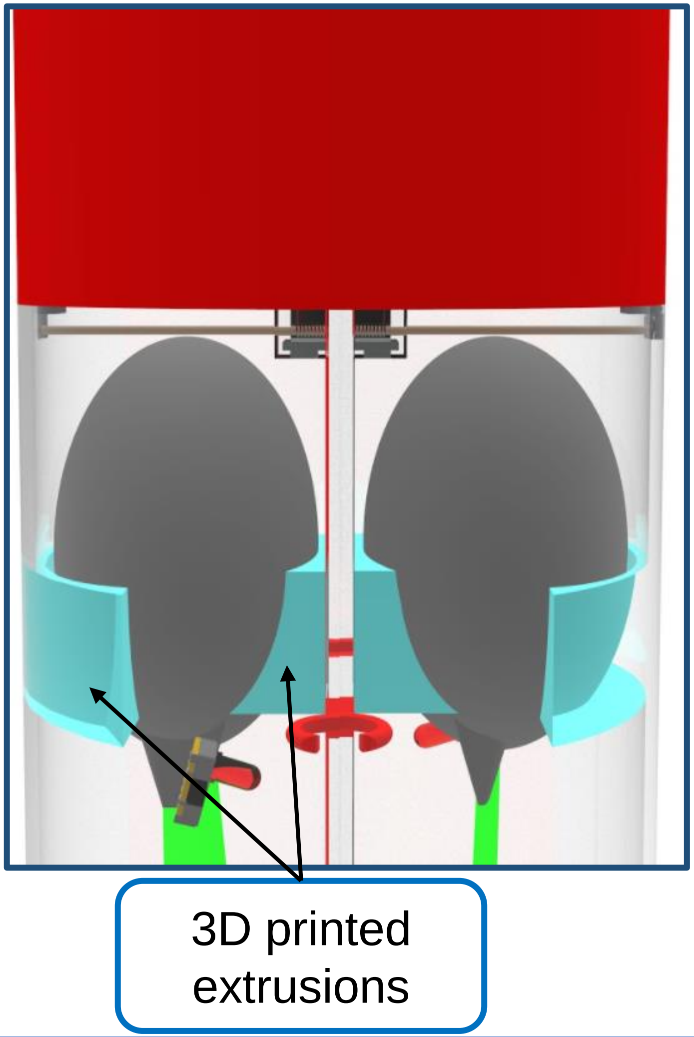


Connectors and fasteners are used to lock the seed

Payload Pre Deployment Configuration Trade & Selection (1/2)

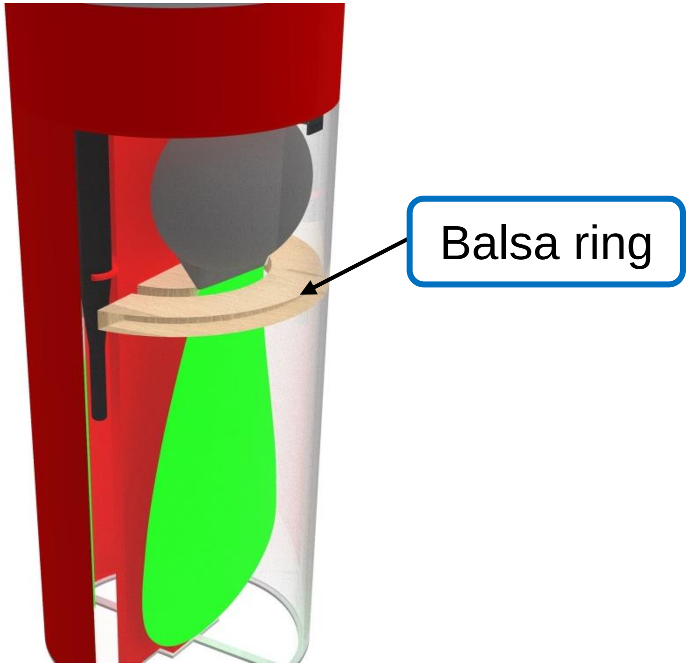
Configuration 1: 3D Printed Extrusions

- Each payload is stowed and locked in the container with the help of 3D printed extrusions made from PETG
- Two extrusions (one on the door and the other on the divider wall) are used to hold each payload and protect it from damage
- 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)
- When the container opens, the extrusions split deploying the payload
- These extrusions provides stability and rigid support while withstanding the launch



Configuration 2: Balsa Ring

- The payload is locked inside the container by the balsa disc located along the walls of the container.
- The disc locks the seed of the payload with one half of disc attached to the container partition and other part to the container wall.
- The balsa disc splits into two halves when the container opens for the deployment of the payload.

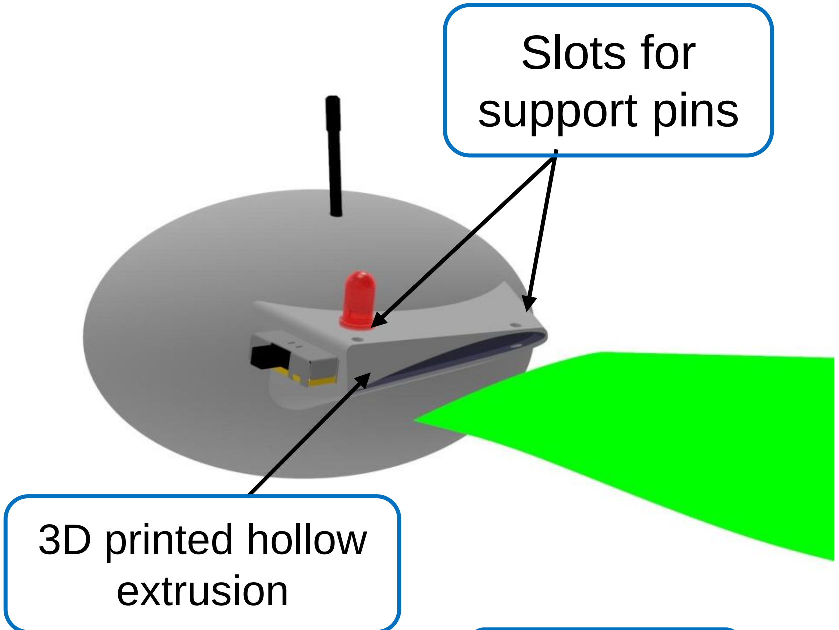


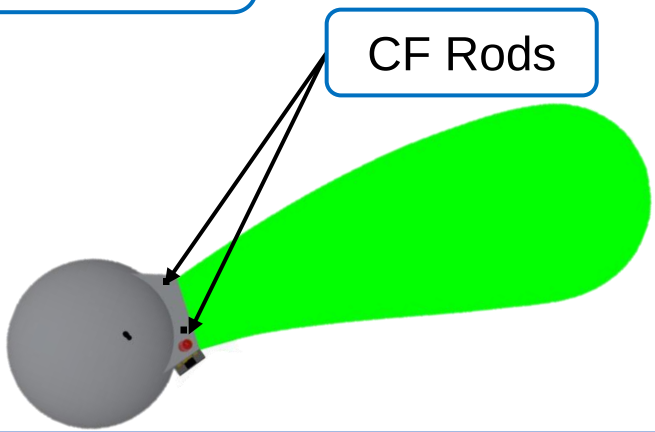
Selection	Rationale
Strategy 1: 3D Extrusion	• Easier to construct • Less obstruction for payload release • Increases the stability • Prevents vibration of payload

Payload Deployment Configuration Trade & Selection (1/2)

Configuration 1: Support pins

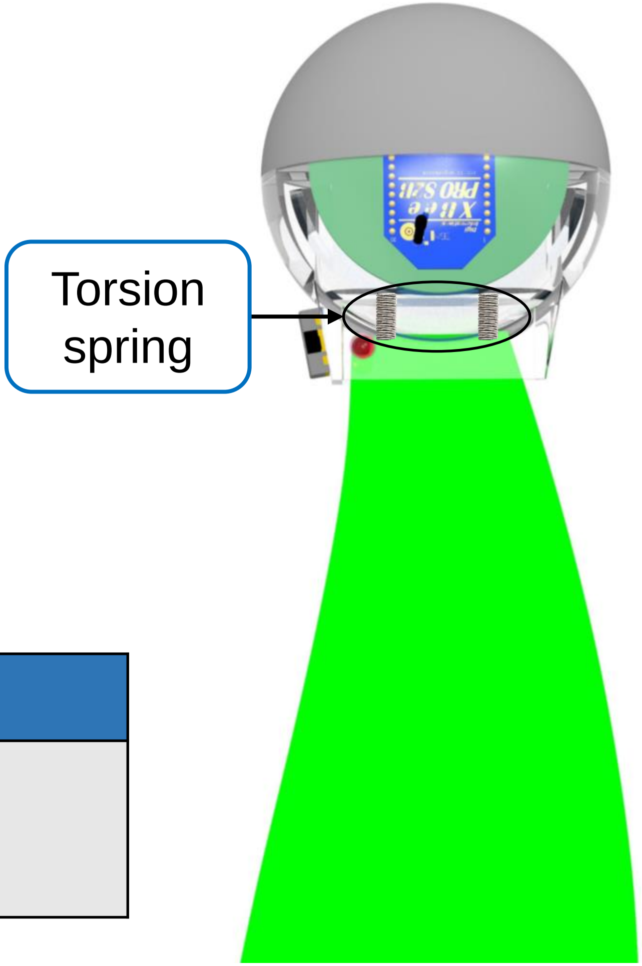
- The wing attachment point is a hollow extrusion having a shape of an airfoil on the seed to accommodate the wing.
- The hollow airfoil extrusion is at an angle of 11º to generate sufficient lift.
- The wing is locked to the seed using carbon fiber rods inserted into the slots present on the extrusion and the wing.
- This mechanism allows easy replacement of the wing through easy access to support pins.
- The mechanism implemented provides sufficient strength for the payload to survive the launch and the landing of the payload.





Configuration 2: Torsion Spring

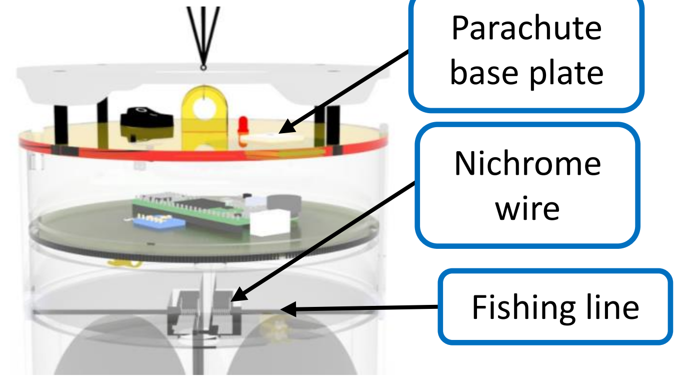
- The wing is attached to the seed with the help of torsion springs fitted in the hollow extrusions on the seed.
- The spring mechanism requires a strong base to prevent the wing from getting detached.
- This mechanism is more susceptible to failure during deployment.
- This mechanism allows us to increase the wing span.



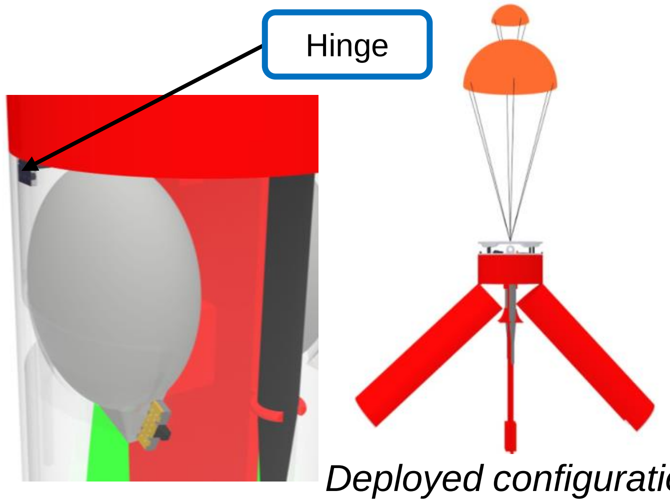
Selection	Rationale
Configuration 1: Support pins	• Easier to implement • Sturdier mechanism

Container Mechanical Layout Design 1

Advantages	Disadvantages
Doors are made up of balsa and fiberglass composite to make it lightweight and strong	Comparatively harder to assemble
Comparatively more volume to accommodate payloads with considerable clearance	Complex release mechanism
Container doors when open, provide more area to ensure smooth deployment of payload	
Container 1 has less 3D printed materials and is therefore lighter	
Does not have any sharp edges which prevents it from getting stuck in the rocket	



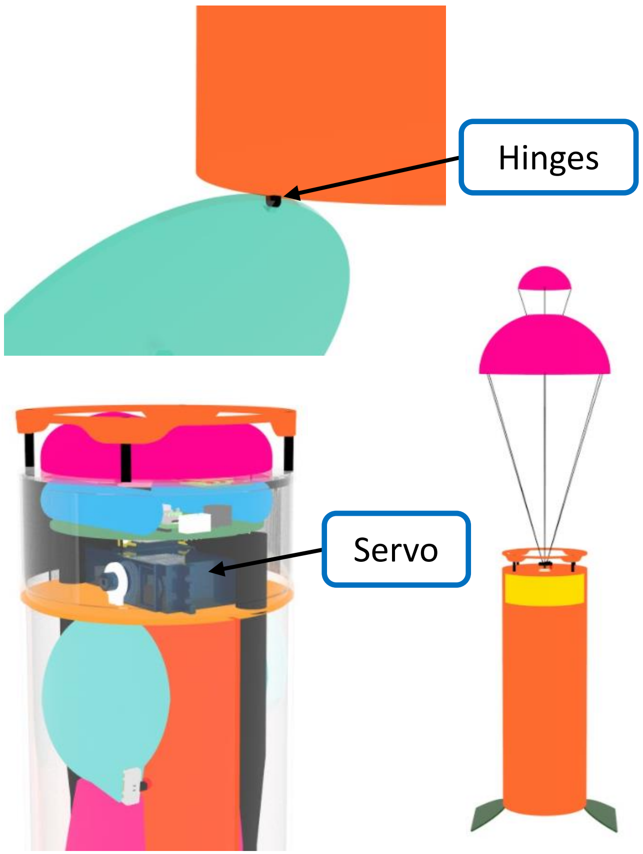
Payload Release Mechanism



Deployed configuration

Container Mechanical Layout Design 2

Advantages	Disadvantages
Easy to assemble	Installation of sliding door is quite a difficult process, with the possibility of it getting jammed
Easier release mechanism than design 1	As only the bottom flaps open during the release there are chances of the container blocking the payload due to less space
	Comparatively less space for electronic mounting than design 1
	Additional servo increases weight, takes more space and consumes more power



Payload release mechanism

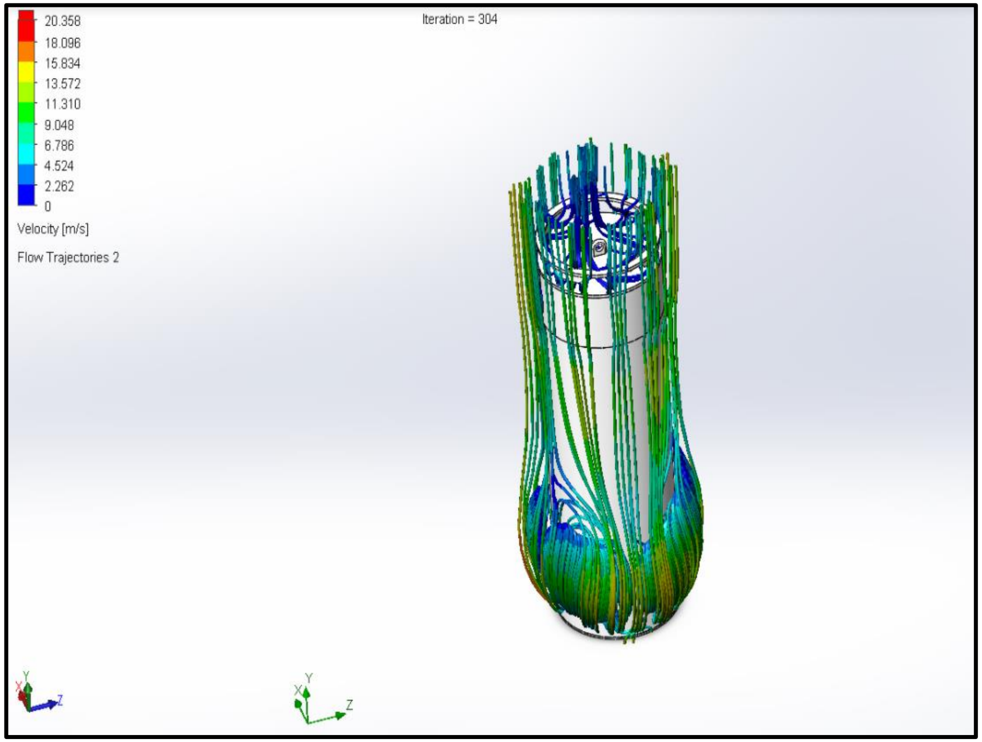
Deployed configuration

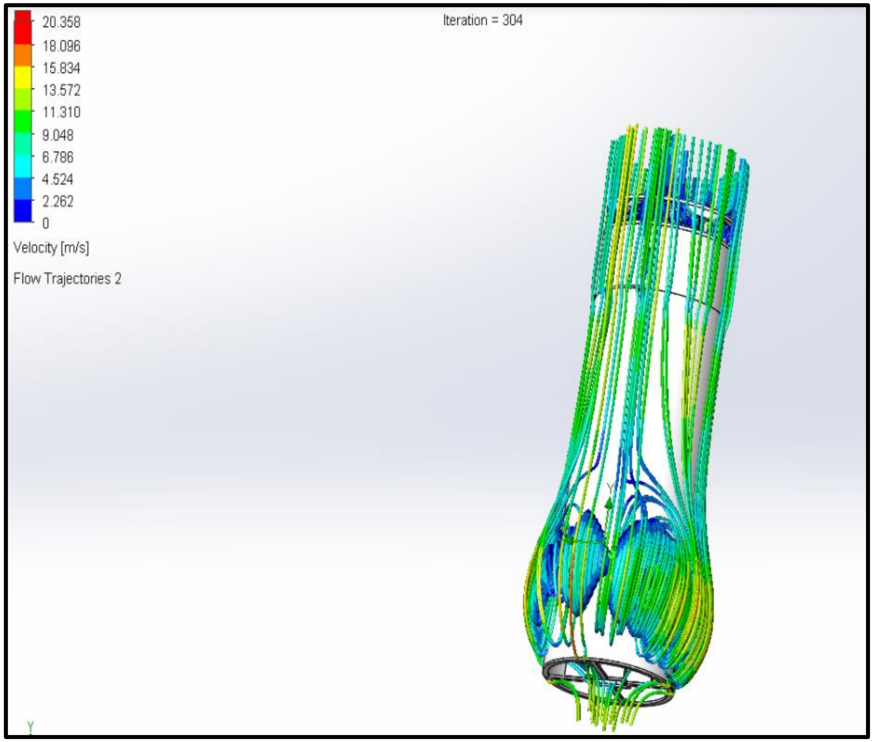
Container Mechanical Layout of Components Trade & Selection (3/10)

	DESIGN 1			DESIGN 2		
	Low	Medium	High	Low	Medium	High
DURABILITY						
MASS						
COST						
STRENGTH						
STABILITY						
AERODYNAMIC DESIGN						

Selected design	Rationale
Design 1	• High stability • More efficient aerodynamically • Low cost • More volume for payload • Less weight

Flow simulation (Selected design)

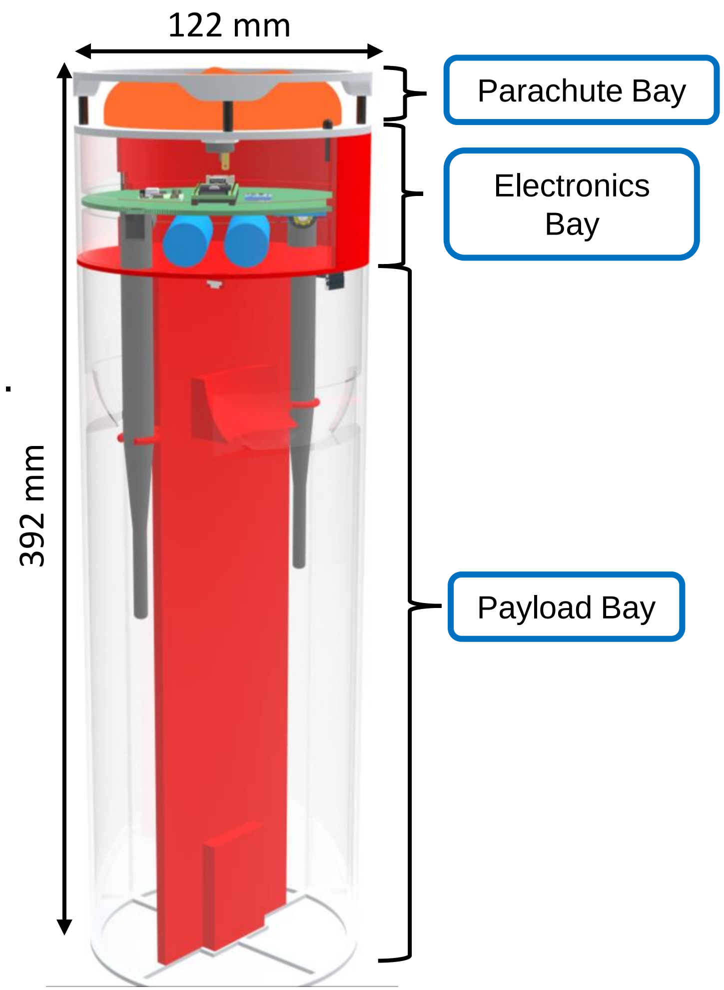




- The Flow Simulation is carried under a shock load of 30Gs for the container
- The colors indicate the stress on the container

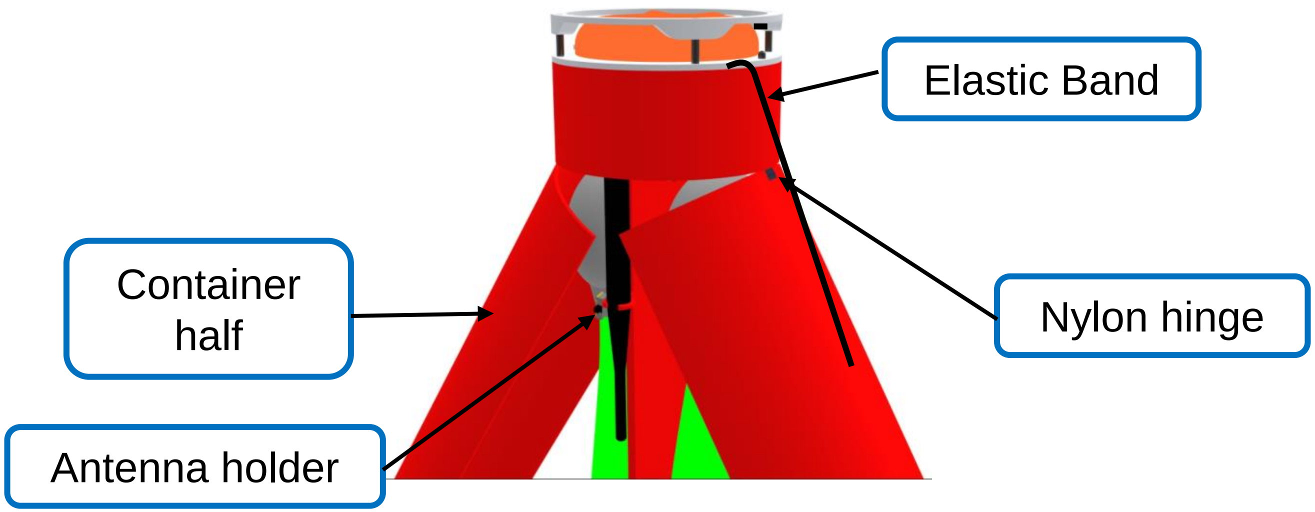
Container Structure:

- 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 antennae
- 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 of payloads.



Container Mechanical Layout of Components Trade & Selection (6/10)

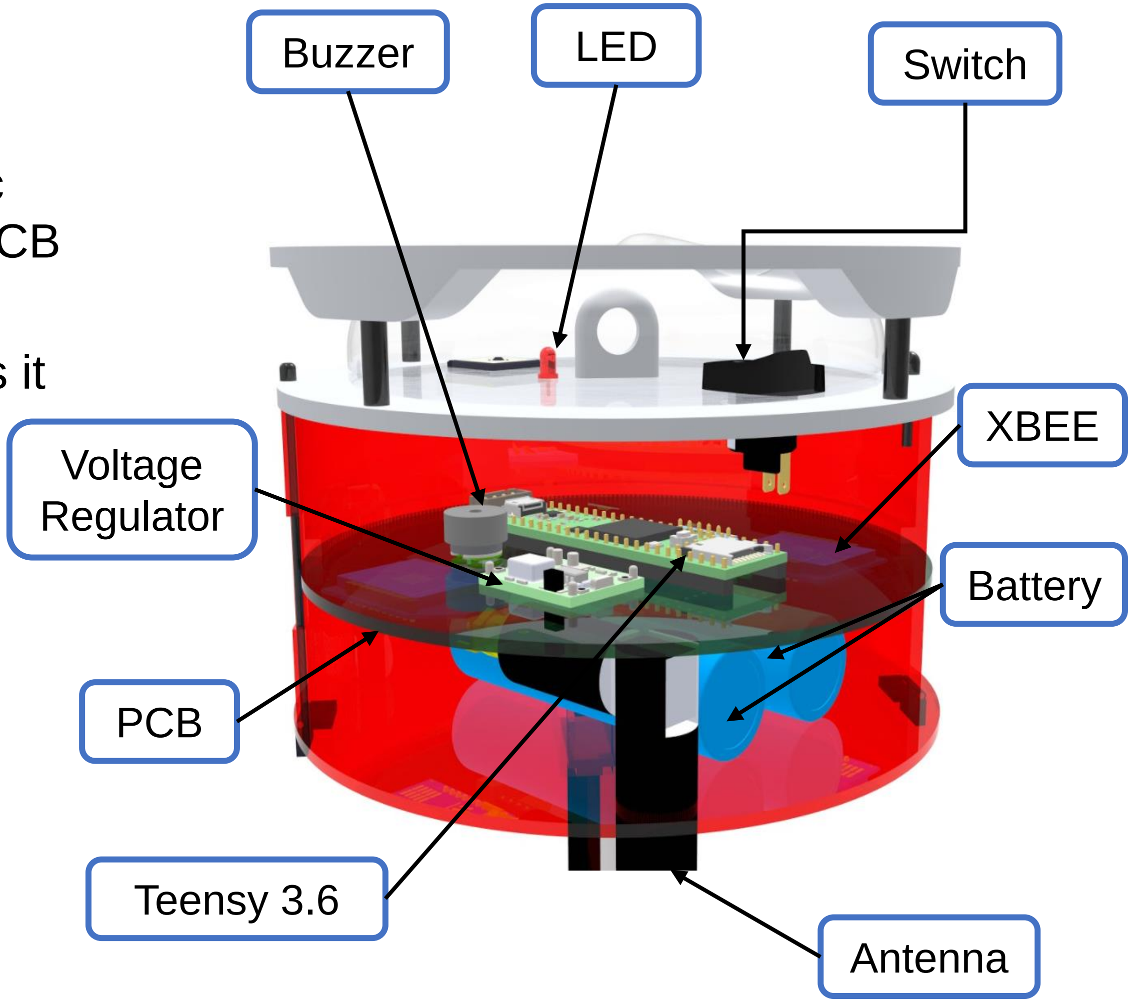
- Nylon hinges are used to open the container for the release of the science payloads at their respective heights
- Fishing lines are used to keep the container in closed configuration while the container descends
- They also assist in the asymmetric opening of the container
- The balsa cover of the container keeps the payload intact during the launch such that it is fully enclosed
- Parachute is kept open to atmosphere and uses wind resistance as a passive mechanism to open after deployment from the rocket



Container Mechanical Layout of Components Trade & Selection (7/10)

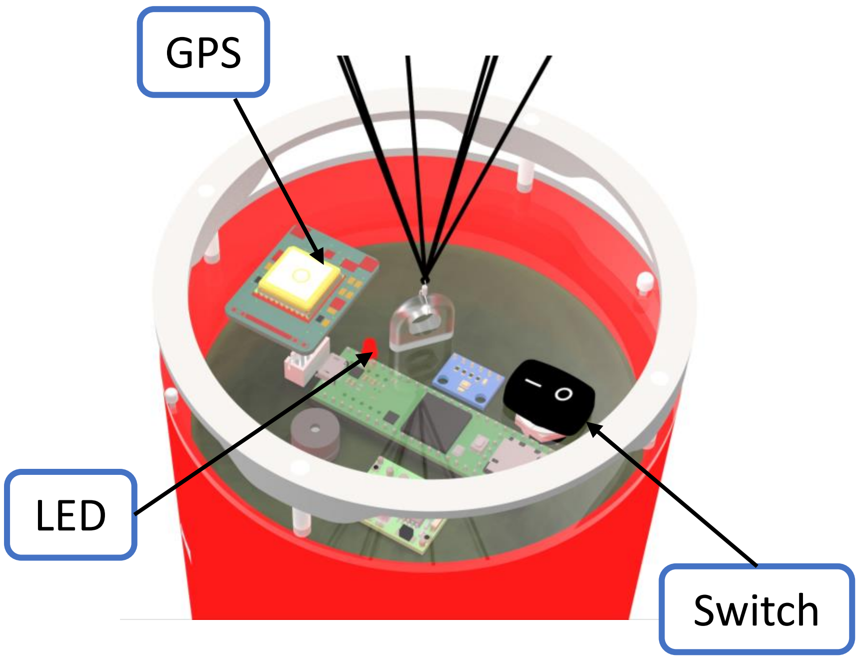
Electronic Components

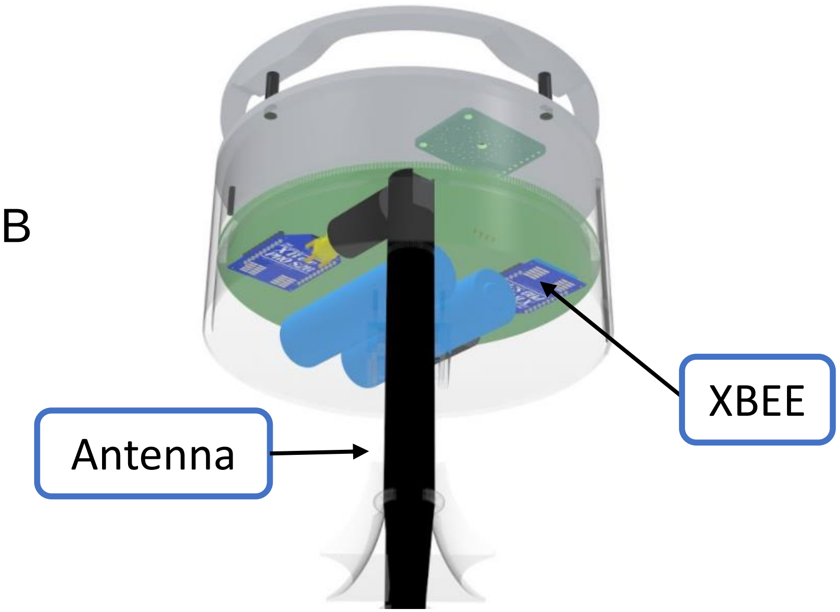
- The electronics bay of the container houses the electronic components mounted on the PCB
- The PCB is placed in the 3D printed PCB slot which protects it from shock due to violent deployment from the rocket
- The Centre of Gravity of the container is balanced with the placement of batteries in the electronics compartment
- The electronics bay is easily accessible with pin-door mechanism



Container Mechanical Layout of Components Trade & Selection (8/10)

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





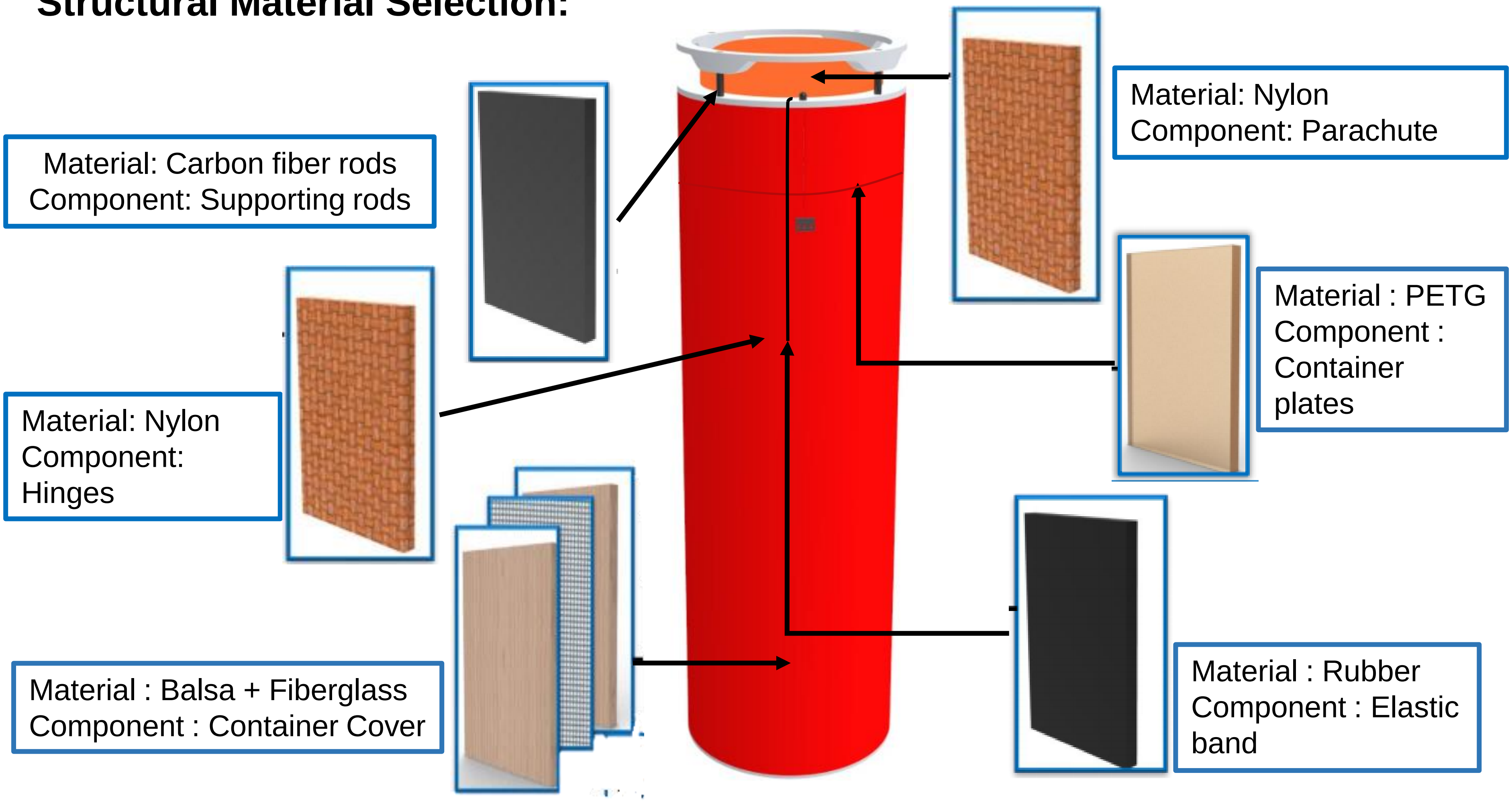
- The XBEEs and the antennae are placed on the lower side of the PCB for an easy relay with the payloads
- Antennae are kept in place with the help of antenna holders, which are along the partition of the container

Structural Material Selection:

Component	Material Options	Material Selected	Rationale
Container body	1) Balsa with fiberglass coating 2) Impact-resistant plastic	Balsa with fiberglass coating	Balsa is more durable and better for the environment
Container rings	1) ABS 2) PETG	PETG	PETG is more durable and is easier to 3D print
Parachute	1) Ripstop Nylon 2) Cloth	Ripstop nylon	Ripstop nylon is tougher, durable and less prone to tears
Parachute strings	Nylon ropes	Nylon ropes	Commercially available to our required length

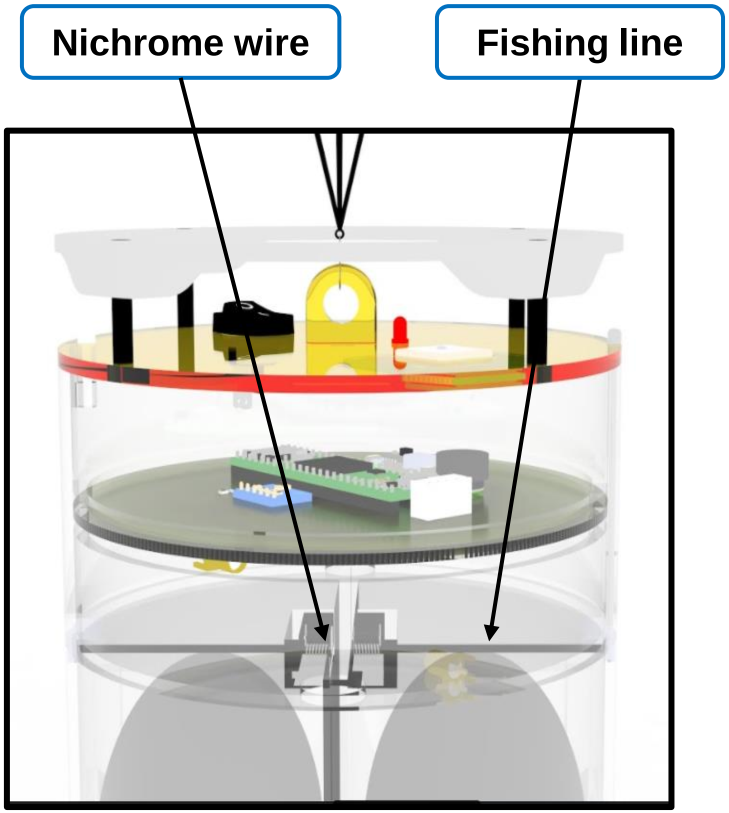
Container Mechanical Layout of Components Trade & Selection (10/10)

Structural Material Selection:

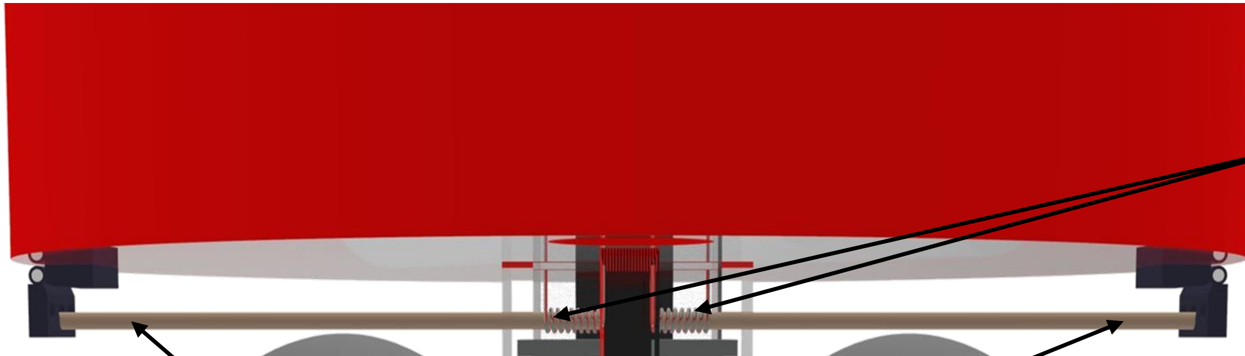


Payload Release Mechanism (1/3)

- Nichrome wire is used as the release mechanism for the payloads.
- The extrusions hold the payload intact inside the container in a position in which the seed is facing upwards to transcend in auto rotating motion faster.
- Nichrome wire is placed inside the box provided under the electronics compartment.
- Fishing line keeps each section of the container closed.
- At 500m and 400m, a current of 1.4A is supplied momentarily to the nichrome wire for each payload.
- 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.

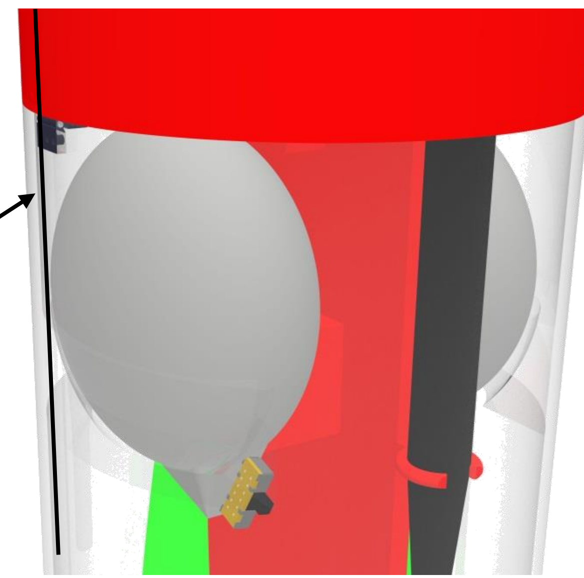


Payload Release Mechanism (2/3)



Nichrome wire burns and cuts the fishing line

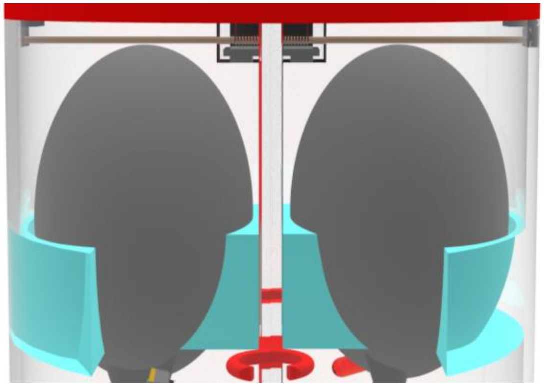
Fishing line holding the container doors



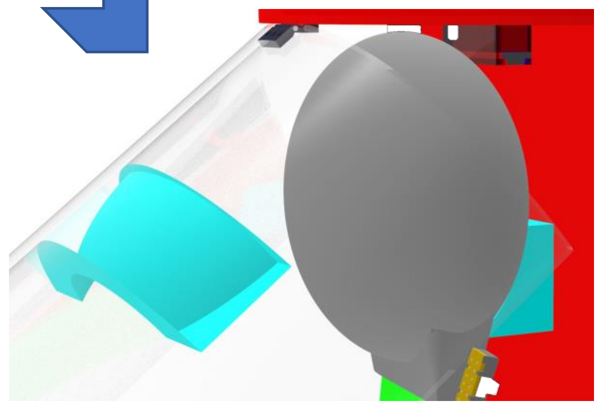
Elastic bands on the outside snap upwards, opening the container doors, once the nichrome wire burns and cuts the fishing line

Payload Release Mechanism (3/3)

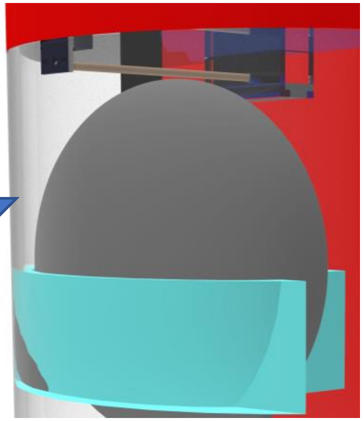
Release mechanism design:



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



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

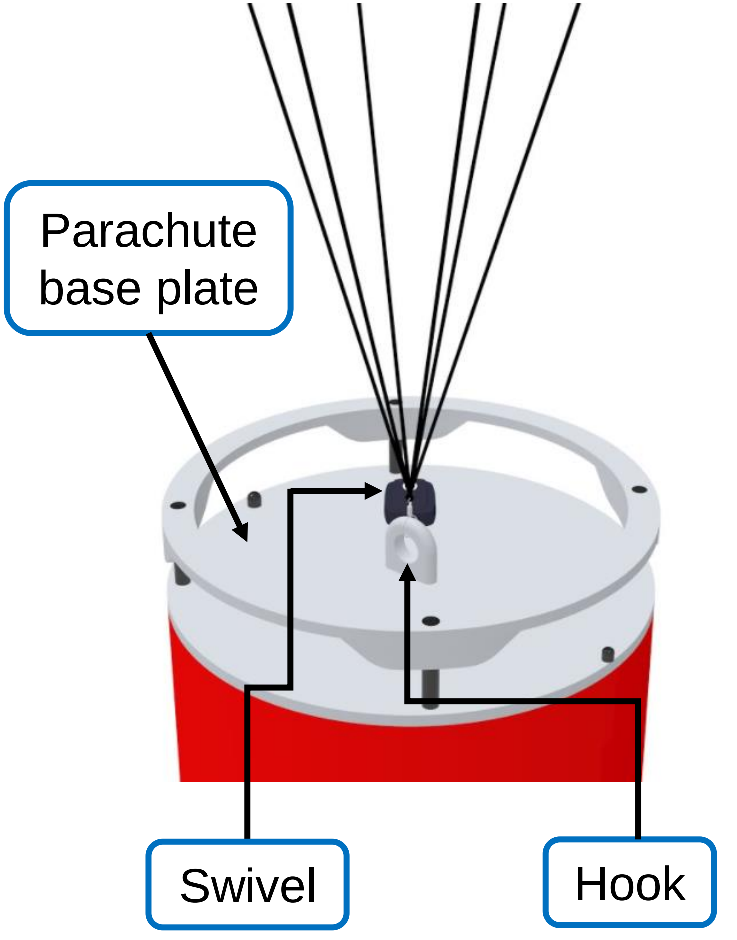


Fishing line coming out of the nichrome box holds the container doors in tension from inside.

Container Parachute Attachment Mechanism (1/2)

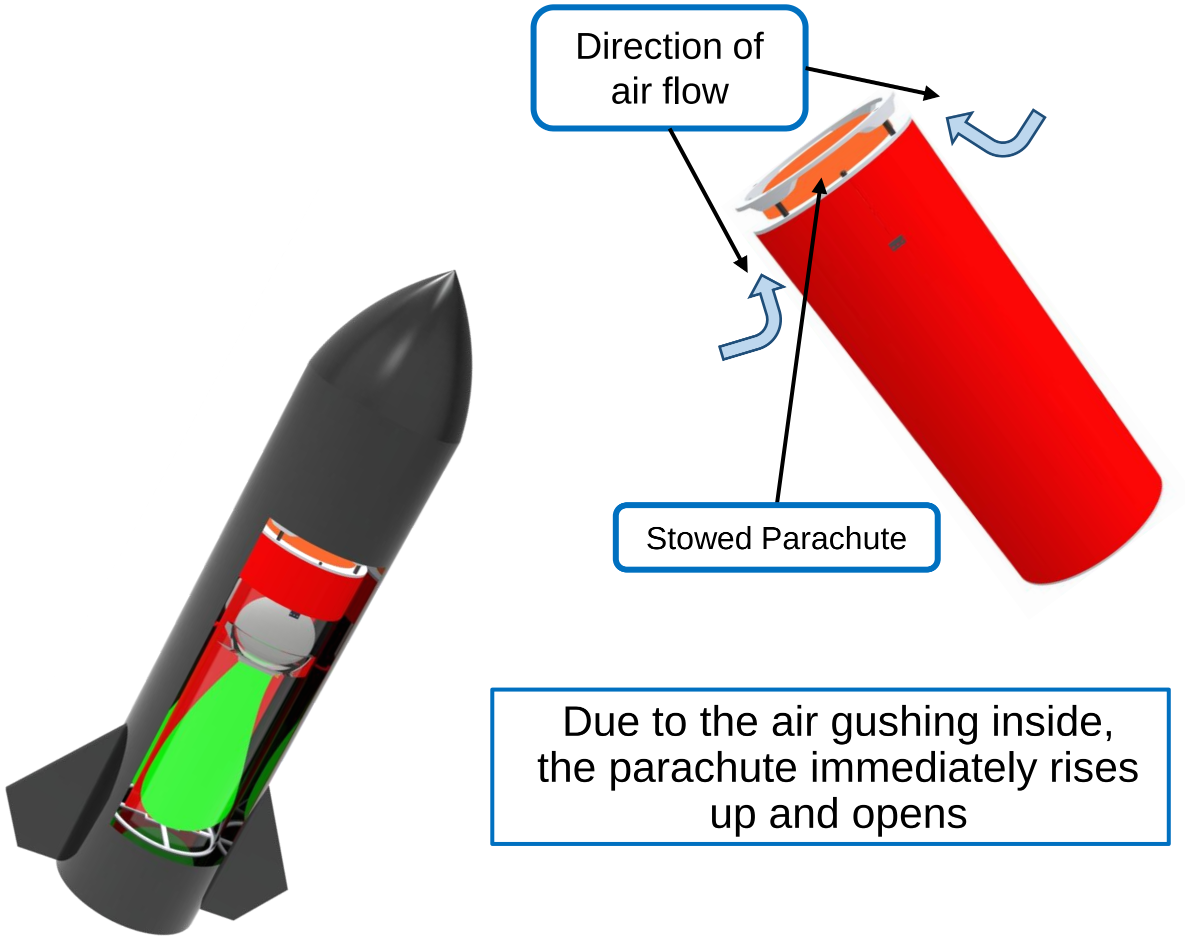
Attachment to container design:

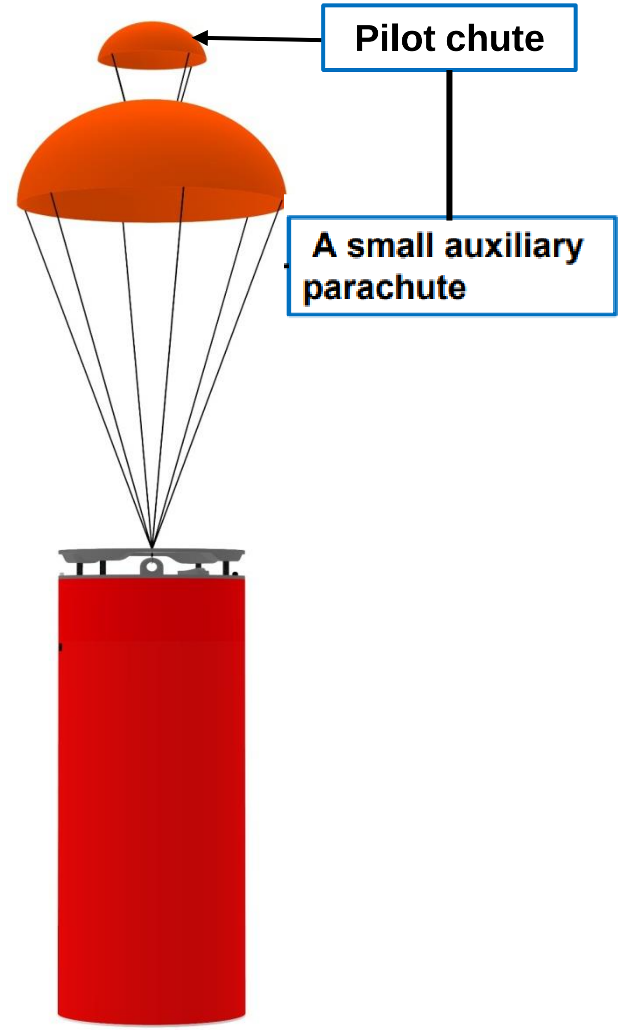
- The parachute is attached to the container with the help of nylon strings.
- The parachute strings will be tied to a swivel which is attached to a hook provided on the parachute base plate.
- Swivel ensures free rotation of the parachute about its central axis which will make sure that the tension on the strings is reduced and prevent 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.



Container Parachute Attachment Mechanism (2/2)

Release mechanism design:

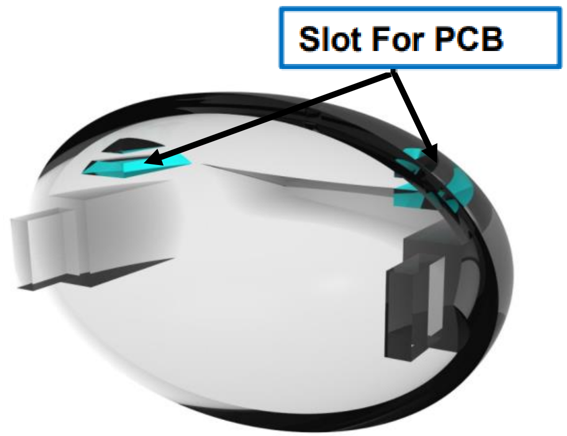




Electronics Structural Integrity (1/2)

- 3D printed slots in the seed are used to hold the PCB and its contents firmly in place, securing all the connections.
- Electronic components are enclosed in the seed made up of 3D printed PETG.
- Depending on the component, proper methods such as soldering, electric tapes and adhesives are used to secure connections.
- The antenna protrudes out of the seed to ensure uninterrupted data transmission.
- 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.

Electronics Structural Integrity (2/2)

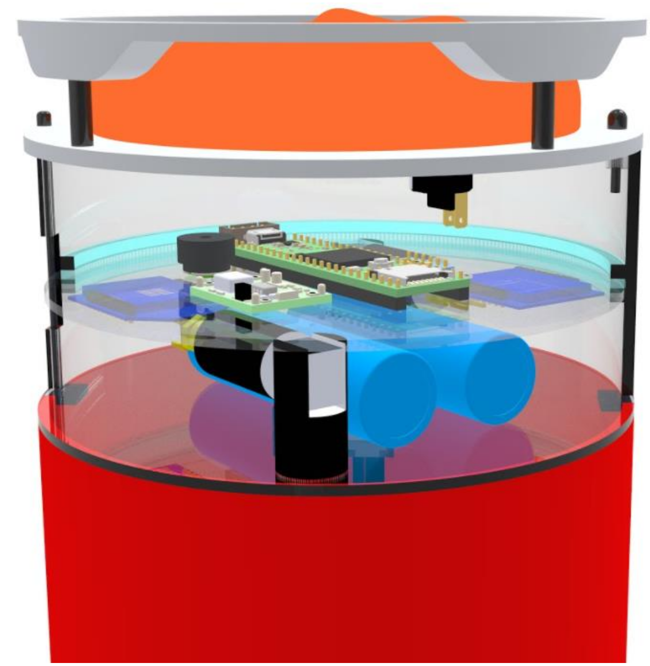
The container PCB is held in the 3D printed PCB holder located in the electronics bay to survive shock resistance.

Except for the nichrome wire mechanism there are no descent control attachments.

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

The antenna is stowed inside the payload compartment such that the telemetry occurs smoothly without any interference.

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.

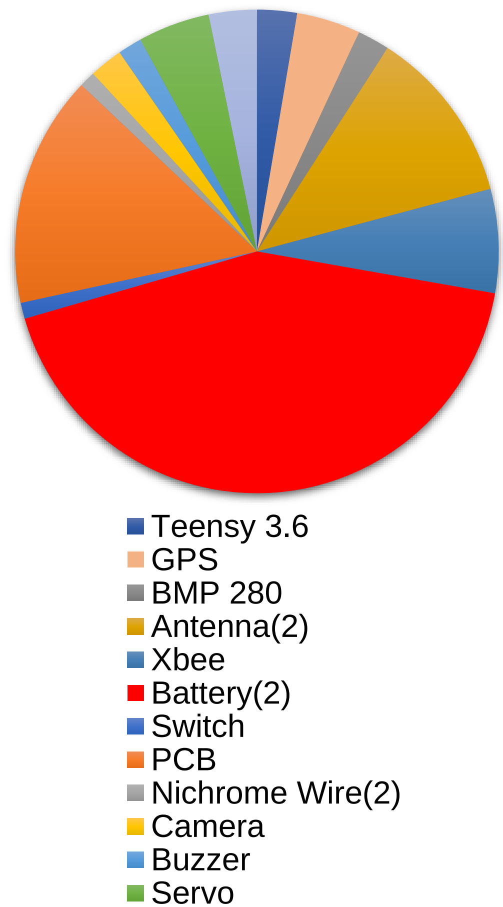


The PCB slot measures 120 mm in diameter and 4 mm in height

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)	13±0.2	Data sheet
	Battery (x2)	80±1.6	Measured
	Switch	2±0.1	Data sheet
	PCB	29±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	6±1.2	Measured
	Total	187.2±5.3gm	

Mass of Container Electronic Components



Mass Budget (2/5)

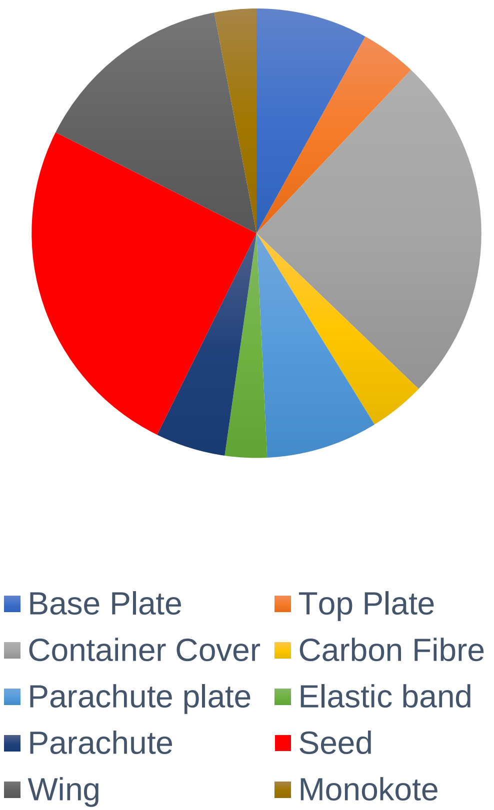
	Component	Mass per component (gm)	Source
Payload (x2)	10DoF	3±0.1	Data Sheet
	XBEE	6.5±0.1	Data Sheet
	Arduino Pro Mini	2±0.1	Data Sheet
	Battery	40±0.8	Measured
	Switch	2±0.1	Measured
	LED	1±0.1	Measured
	Total	54.5±1.3gm	

Mass of Payload Electronic Components

Mass Budget (3/5)

	Component	Mass per item (gm)	Source
Container	Base Plate	16±0.6	Measured
	Top ring	8±0.2	Measured
	Container Cover(Balsa + Fiberglass composite)	50±1.2	Measured
	Carbon fiber rods	8±0.1	Data Sheet
	Parachute plate	16±0.8	Measured
	Elastic band	6±0.2	Data Sheet
	Parachute	10±0.2	Measured
	Total	114±3.3gm	
Payload (x2)	Seed	50±1	Measured
	Wing	29±0.5	Measured
	Carbon fiber rods	8±0.2	Data Sheet
	Monokote	6±0.1	Measured
	Total	93±1.8gm	

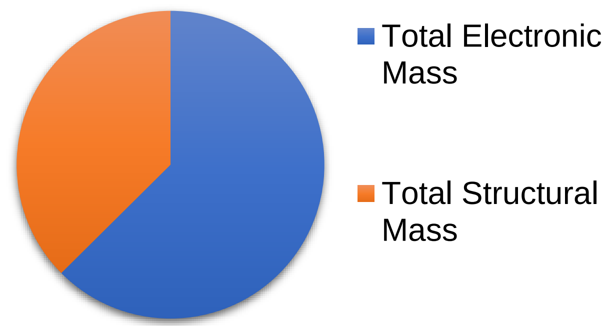
Mass of CanSat structural components



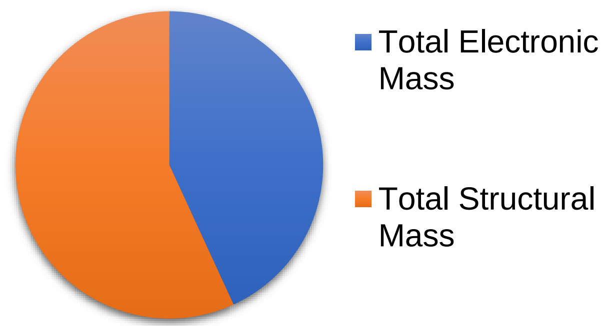
Mass Budget (4/5)

Container		Payload (x2)	
Total Electronic Mass	187.2±5.3gm	Total Electronic Mass	109±2.6gm
Total Structural Mass	114±3.3gm	Total Structural Mass	186±3.6gm
Total Mass	301.2±8.6gm	Total Mass	295±6.2gm
Total Mass of CanSat		596.2±14.8gm	

Container



Payload



Mass Budget (5/5)

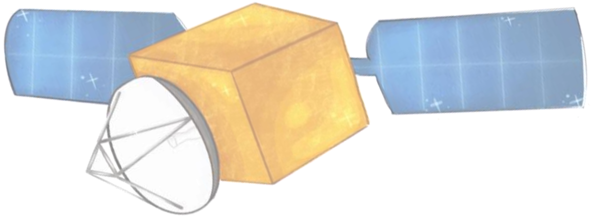
Total Mass of CanSat	596.2gm

- **Total Mass Margin of CanSat = $|600 - 596.2|$ = 3.8gm**

Correction method

- 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.

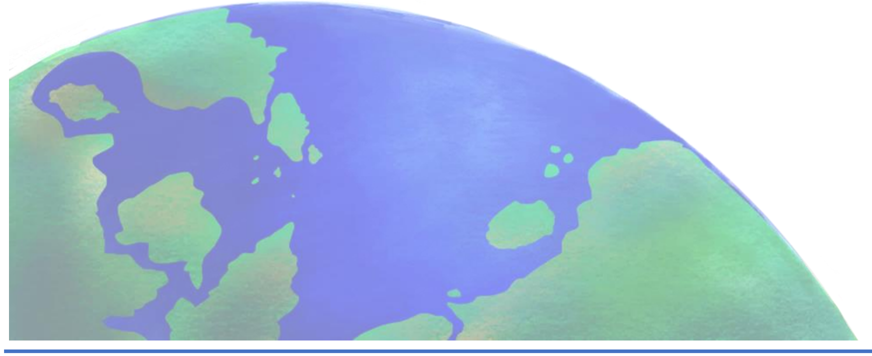
This will ensure that the total mass of CanSat is 600 ± 10gm and the competition requirement is fulfilled.



Communication and Data Handling (CDH) Subsystem Design

Presenter's Name:

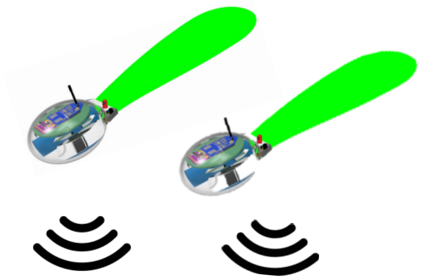
Shweta Chavan



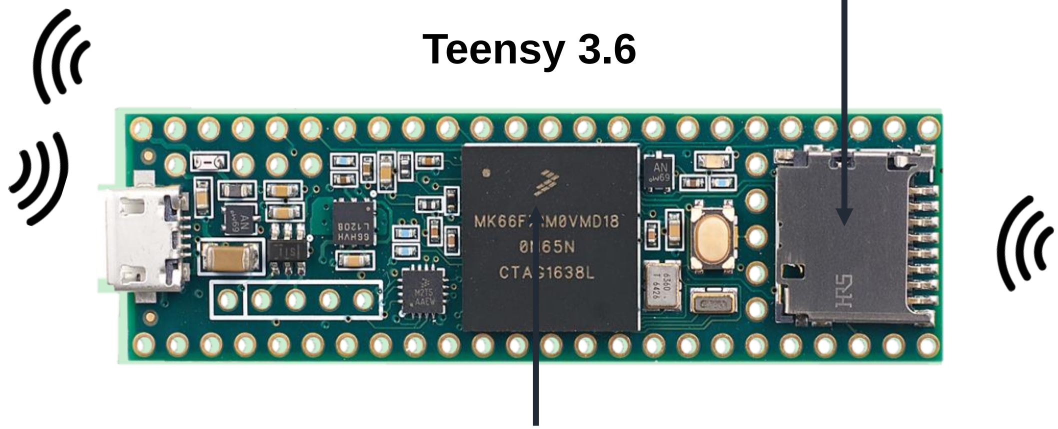
Container Command Data Handler(CDH) Overview

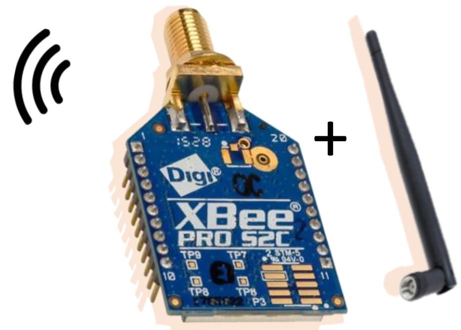
Built-In RTC:
Helps in keeping track of total mission time

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



Teensy 3.6





The most essential part, i.e. collection and processing of data takes place here

Transmission of data from Container to XBEE at Ground Station

Transmission of data from XBEE in Payloads to Container XBEE

Container CDH Requirements (1/3)

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		✓		
#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	✓		✓	✓

Container CDH Requirements (2/3)

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	√	√	√	

Container CDH Requirements (3/3)

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 Trade & Selection (1/3)

Microcontroller	Supply Voltage (V)	Processor Speed/ Boot time	Pins (GPIO)	Memory	Data Interfaces	Cost (₹)
Teensy 3.6	**3.6-6**	**180 MHz/ 1s**	**62**	**256KB - Flash 1MB -RAM 4KB – EEPROM**	**UART- 6 SPI- 3 I2C- 4**	**2900**
Teensy 4.0	3.6-5.5	600 MHz/ 20ms	40	2MB - Flash 1MB - RAM 64KB – EEPROM	UART- 7 SPI- 3 I2C- 3	3000
Arduino Nano	6-12	16 MHz/ 4.84s	23	32KB - Flash 2KB - RAM 1KB – EEPROM	UART- 1 SPI- 1 I2C- 1	400

Container Processor Memory Trade & Selection (2/3)

Selected Microcontroller : Teensy 3.6
• Contains an on-board SD card slot which is not present in Teensy 4.0 • Fulfils the mission requirements • Compact in size • Possess built-in real-time clock which is used to calculate total time of the mission • Better processing speed than Arduino nano • Light in weight • Extensive compatibility with Arduino IDE and ease of programming • **It has 22 PWM pins, 25 analog input pins, 2 analog output pins and 62 digital pins**

Overall it fulfils the application and is advantageous over other microcontrollers because of its light weight, simplicity of programming and high processor speed

Container Processor Memory Trade & Selection (3/3)

Component Name	Data transfer rate	Storage	Cost (₹)
SanDisk Micro SD Card	**98 Mbps**	**16 GB**	**350**
SDHC Card	12.5 Mbps	4 GB	300

Selected Memory : SanDisk Micro SD Card

- Fulfils the mission requirements
- High data transfer rates

Container Real-Time Clock

Component Name	Error (ppm)	Current	Hardware/ Software	Interface	Cost (₹)
DS1302	±40	300mA	Hardware	3 Wire - Interface	150
DS3231	±2	300µA	Hardware	I2C	120
Teensy 3.6 Internal RTC	**-**	**-**	**Software**	**-**	**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

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

Container Antenna Trade & Selection (1/2)

Model	Gain (dBi)	Dimensions (mm)	Range (Km)	Interface	Cost (₹)
A24-HASM-450	2.1	Height: 114.3	1.2	RP – SMA	387
2.4GHz Male Omni Antenna	**5**	**Height: 210**	**1.75**	**RP – SMA**	**550**
TL-ANT2408CL	2	Height: 294	1	RP – SMA	720

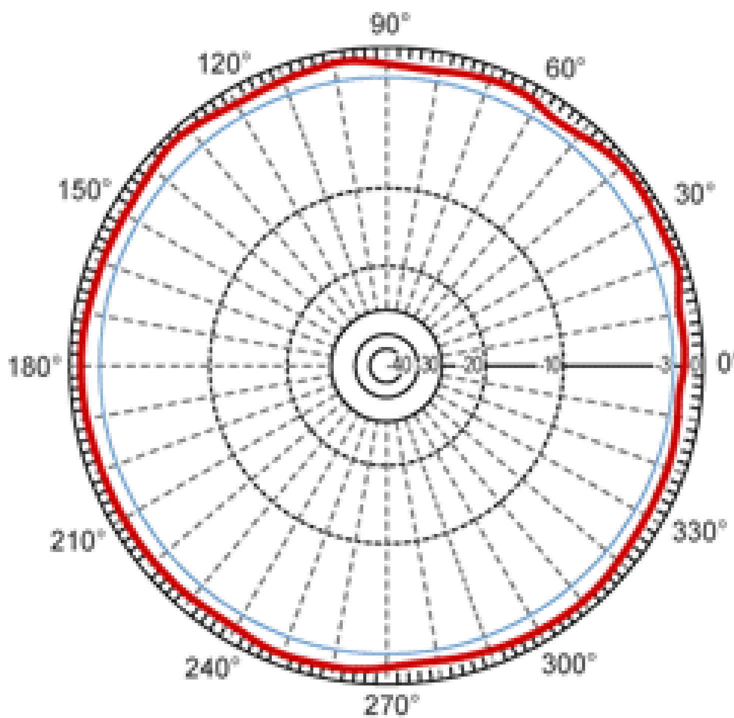
Selected Antenna: 2.4GHz Male Omni Antenna

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

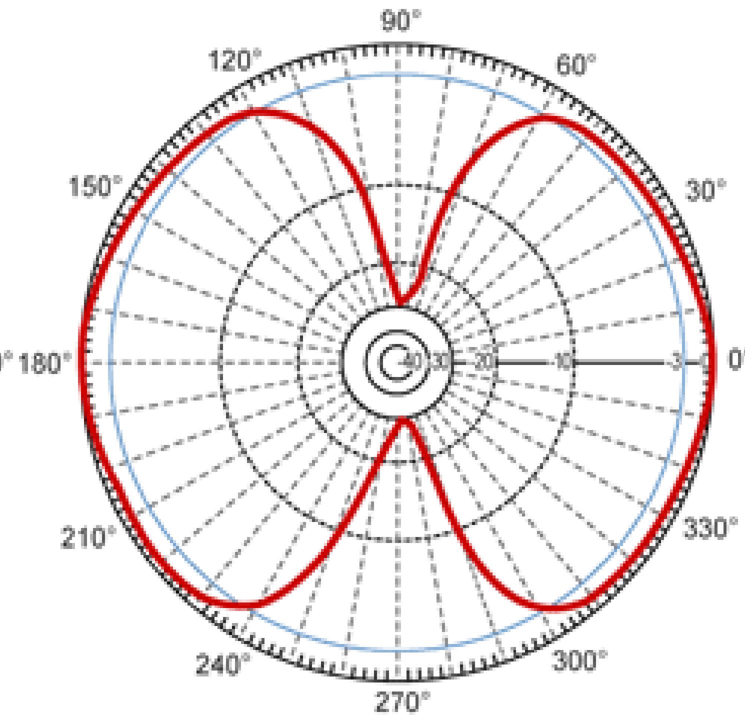
The selected Antenna is used for both the Container-to-Ground link and Container-to-Payload link

Container Antenna Trade & Selection (2/2)

Radiation pattern of 2.4GHz Male Omni Antenna



Azimuthal



Elevation

Container Radio Configuration (1/3)

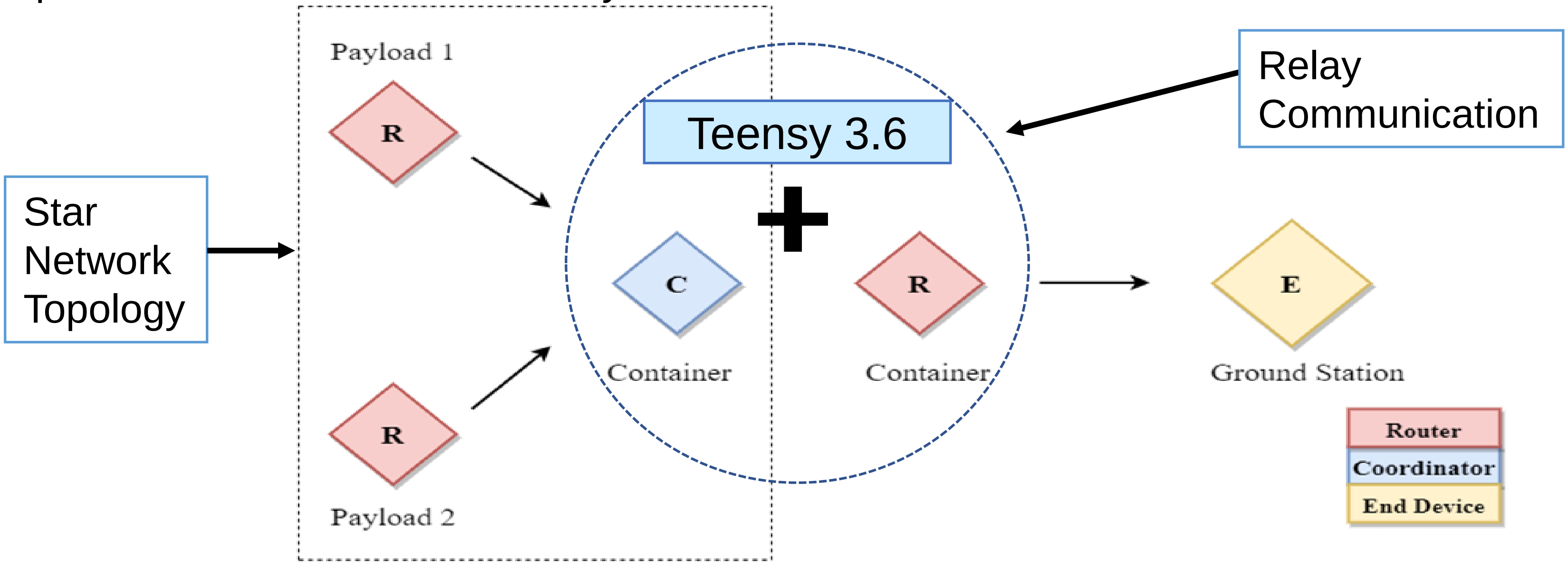
Model	Operating Frequency	Supply Voltage (V)	Range (Km)	RF Data Rate (Kbps)	Transmit Power (mW)	Sensitivity (dBm)	Cost (₹)
XBEE-Pro 900HP	900 MHz	2.4-3.6	15.5	200	250	-101	3200
Digi XBEE3 PRO	2.4 GHz	2.1-3.6	3.2	250	79.4	-103	3499
XBEE- Pro S2C	**2.4 GHz**	**2.7-3.6**	**3.2**	**250**	**63**	**-101**	**2150**

Selected Sensor: XBEE Pro S2C

- Lower transmit current (120 mA)
- Sufficient transmit power
- Low cost and easily available
- Easy to configure
- Reliable experience
- The XBEE Pro S2C variant selected has an RP-SMA antenna connector

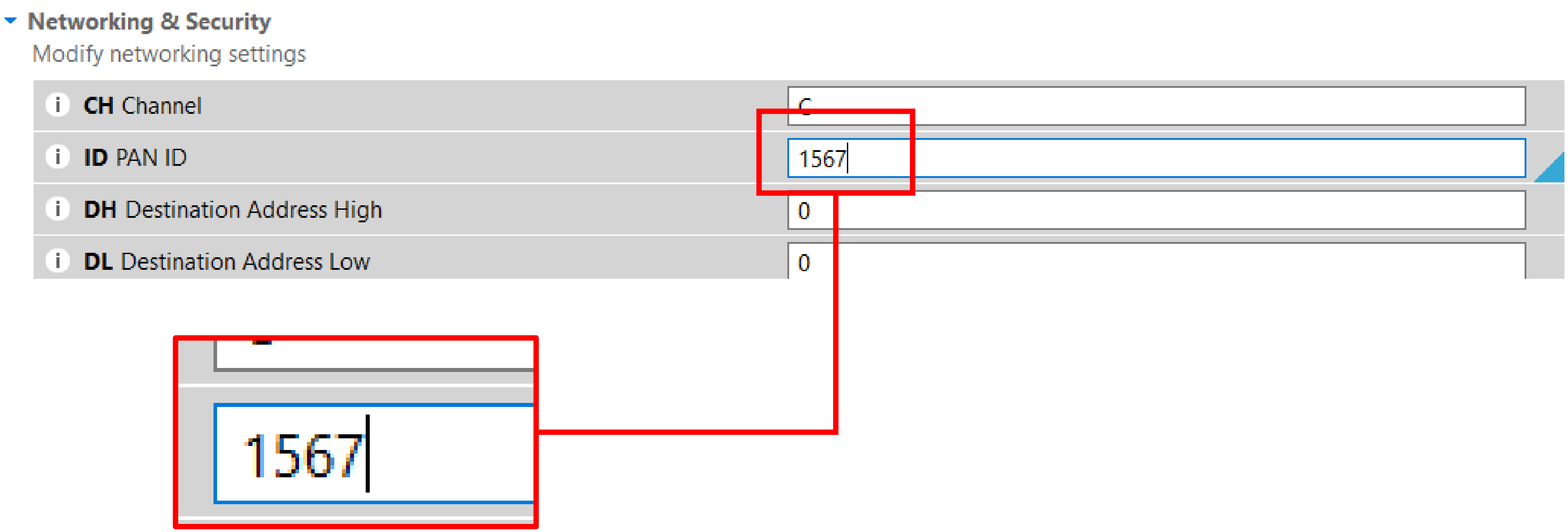
The selected radio is used for both the Container-to-Ground link and Container-to-Payload link

- The relay communication in the container takes place with the help of two XBEEs and microcontroller (Teensy 3.6).
- The two **Router** XBEEs of 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 XBEE 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.**



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	0.01 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 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>, <22>, <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>, <22>, <23>, <S1>, <362.13>, <23.42>, <32> (For Payload1)

  <1567>, <22>, <12>, <S2>, <322.12>, <23.41>, <21> (For Payload 2)

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

Container Command Formats

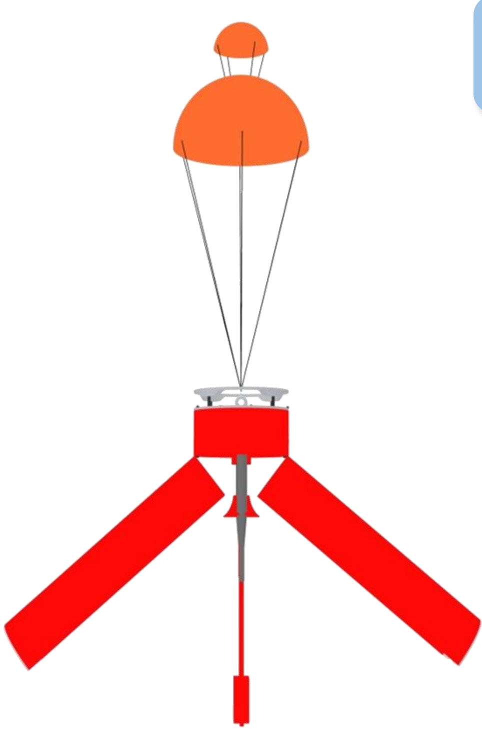
Command	Example	Description
CMD,<TEAM_ID>,CX,<ON_OFF>	CMD,1567,CX,ON	Container Telemetry ON
	CMD,1567,CX,OFF	Container Telemetry OFF
CMD,<TEAM_ID>,ST,<UTC_TIME>	CMD,1567,ST,13:10:50	Sets the mission time
CMD,<TEAM_ID>,SP1X,<ON_OFF>	CMD,1567,SP1X,ON	Triggers Container to relay Payload 1 telemetry data
	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

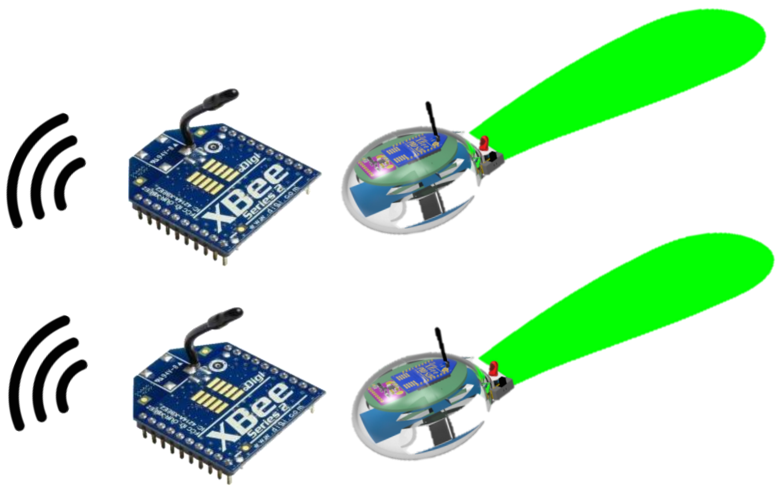
- All the Container Commands match the mission requirements

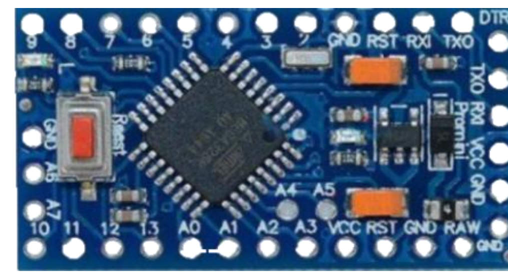
Payload CDH Overview

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 activates the XBEE to send the payload sensor data

Payload CDH 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		√		
#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	√		√	√

Payload CDH Requirements (2/2)

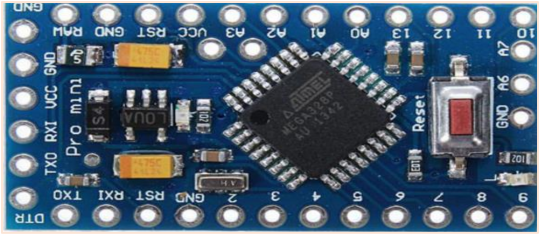
Req ID	Requirement	Rationale	Priority	VM			
				A	I	T	D
#CR27	The science payload shall measure rotation rate as it descends.	Req	Very High	√		√	√
#CR28	The science payload shall transmit all sensor data once per second.	Req	Very High	√		√	√
#CR29	The science payload telemetry shall be transmitted to the container only.	Req	Very High		√	√	√
#CR60	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Req	Very High		√		

Payload Processor & Memory Trade and Selection

Microcontroller	Supply Voltage (V)	Processor Speed/ Boot time	Pins (GPIO)	Memory	Data Interfaces	Cost (₹)
Arduino Pro Mini	**5-12**	**16 MHz/4.84s**	**14**	**32KB - Flash 2KB - RAM 1KB – EEPROM**	**UART- 2 SPI- 1 I2C- 1**	**200**
Arduino Nano	6-12	16 MHz/4.84s	23	32KB - Flash 2KB - RAM 1KB – EEPROM	UART- 1 SPI- 1 I2C- 1	350
Beetle	5	16 MHz/4.84s	10	32KB - Flash 2.5KB - RAM 1KB - EEPROM	UART-1 SPI-1 I2C-1	900

Selected Microcontroller: Arduino Pro Mini

- Better placement of headers, compared to Beetle, leading to sturdier connections
- Fulfils the mission requirements
- Compact in size and cheaper in cost
- **6 analog pins with 10 bit resolution and 14 digital pins**



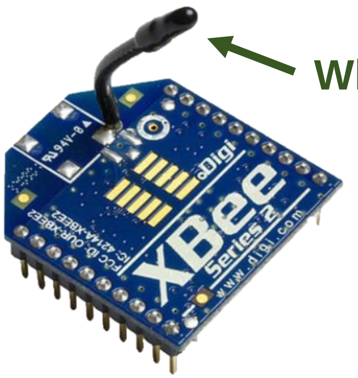
There is no memory card used in the payload

Payload Antenna Trade & Selection (1/2)

Model	Gain (dBi)	Dimensions (mm)	Range (Km)	Interface	Cost (₹)
Integrated whip antenna	**1.5**	**Height : 25**	**1**	**Integrated**	**Free**
2.4GHz Male Omni Antenna	5	Height: 210	1.75	RP – SMA	550
TL-ANT2408CL	2	Height: 294	1	RP – SMA	720

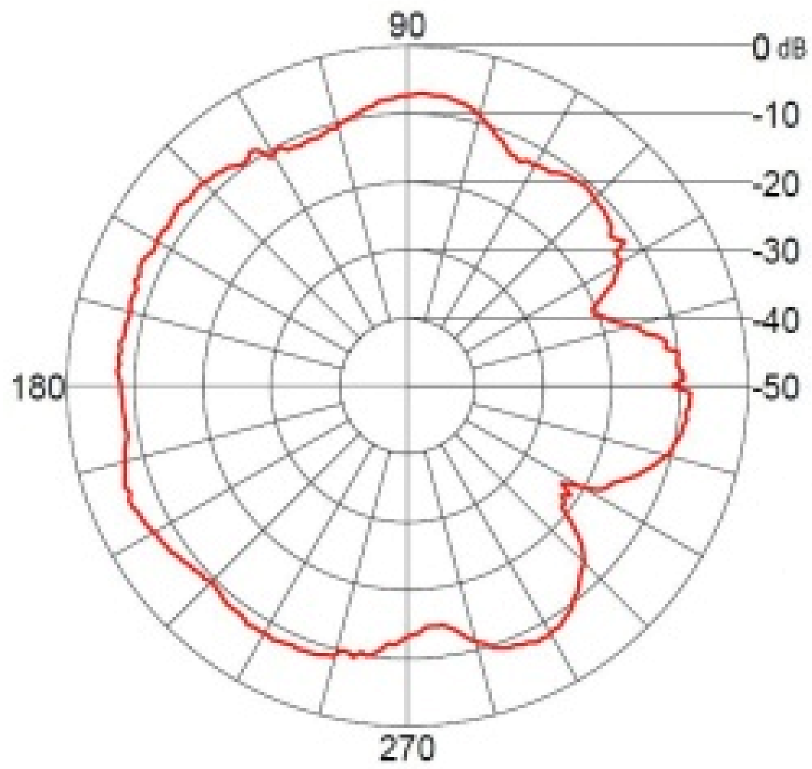
Selected Antenna : Integrated whip antenna

- Interface compatible with XBEE
- Suitable radiation pattern
- Satisfies space constrains (Pre-soldered with XBEE)
- Fulfils all mission requirements
- Free of cost



Whip Antenna

Radiation pattern of Integrated Whip Antenna



Payload Radio Configuration (1/2)

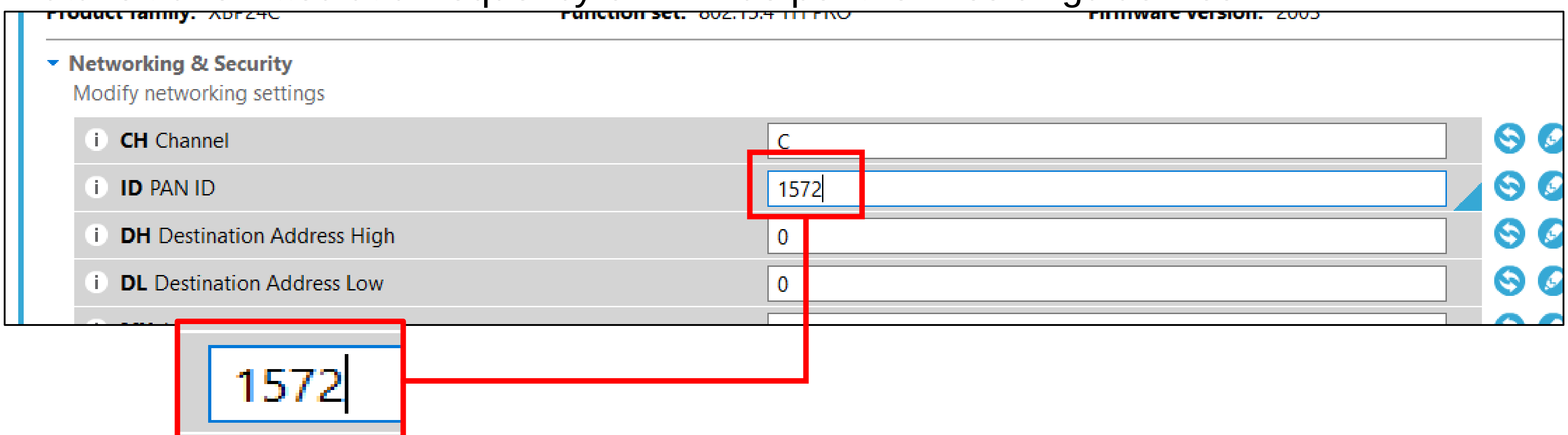
Model	Operating Frequency	Supply Voltage (V)	Range (Km)	RF Data Rate (Kbps)	Transmit Power (mW)	Sensitivity (dBm)	Cost (₹)
XBEE- Pro 900HP	900 MHz	2.4-3.6	15.5	200	250mW	-101	3200
Digi XBEE3 PRO	2.4 GHz	2.1-3.6	3.2	250	79.4mW	-103	3499
XBEE-Pro S2C	**2.4 GHz**	**2.7-3.6**	**3.2**	**250**	**63mW**	**-101**	**2150**

Selected Sensor : XBEE Pro S2C

- Lower transmit current (120 mA)
- Sufficient transmit power
- Low cost and easily available
- Easy to configure
- Reliable experience
- The XBEE Pro S2C variant selected has an integrated Whip-Antenna

Payload Radio Configuration (2/2)

- The XBEE 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 XBEE 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)

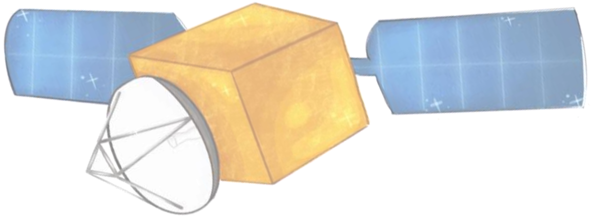
- Science Payloads shall transmit telemetry data to the Container from which it is relayed to the ground station
- The telemetry data file for payloads will be named as **Flight_1567__S1.csv**, and **Flight_1567_S2.csv** where **1567** is our **Team ID**
- Data will be transmitted at the rate of **1Hz** 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>,<22>,<23>,<S1>,<362.13>,<23.42>,<32>

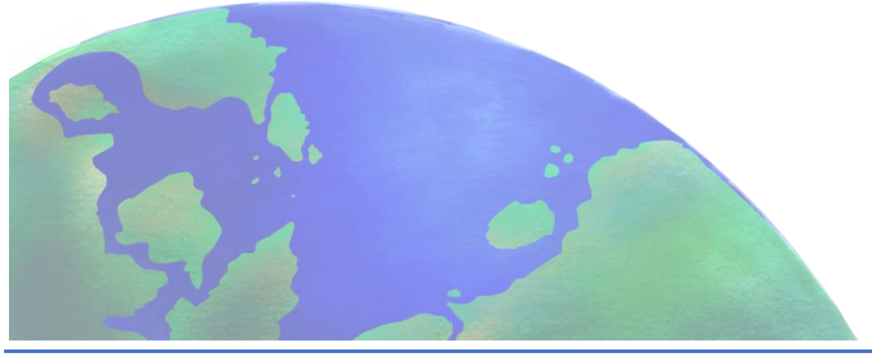
Eg. (Payload2): <1567>,<22>,<12>,<S2>,<322.12>,<23.41>,<21>

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



Electrical Power Subsystem(EPS) Design

Presenter's Name:
Shweta Chavan



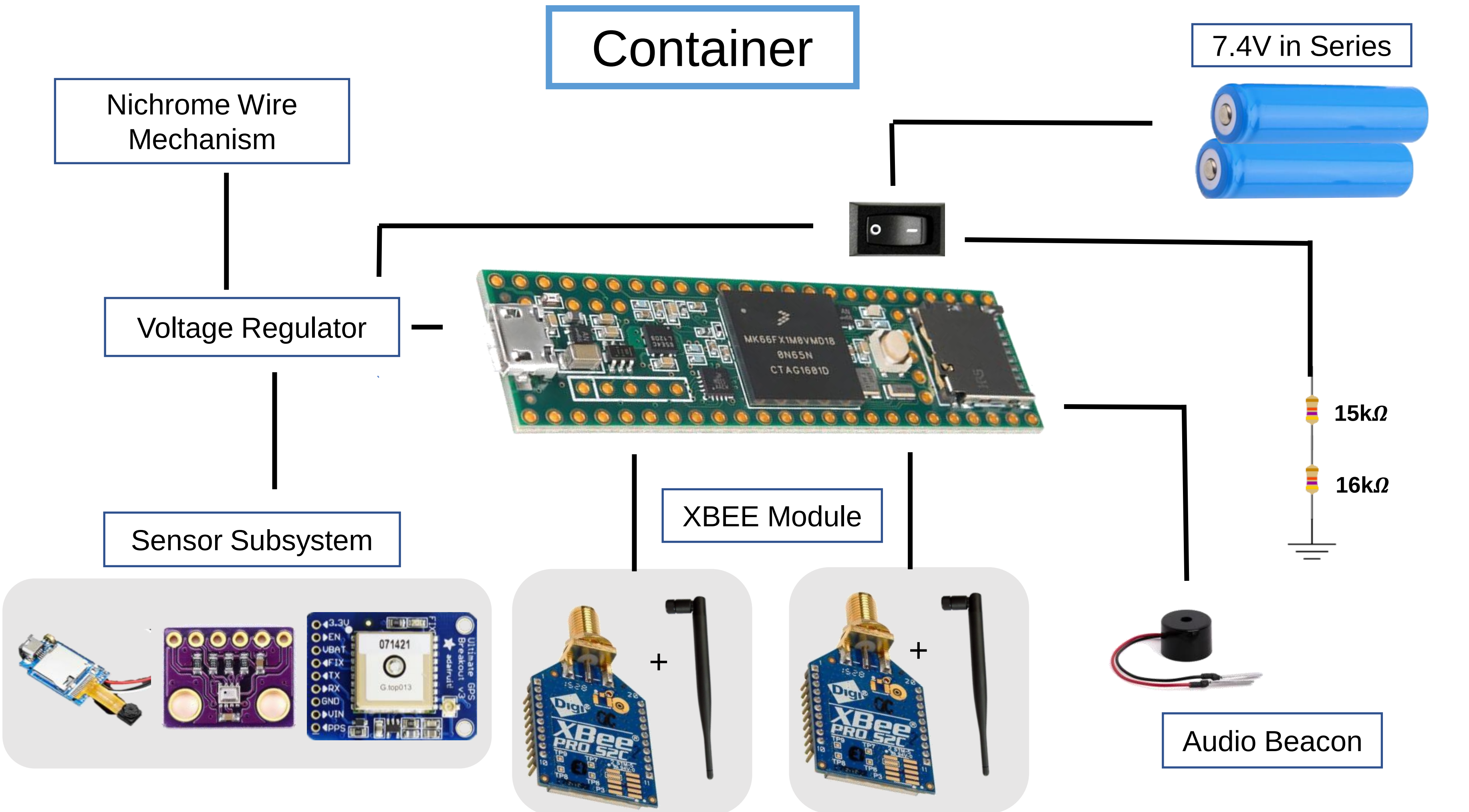
EPS Overview (1/4)

Component	Purpose	Voltage
Power Switch	To manually switch on/off the circuit	-
Lithium-ion Battery	Power Source	3.7V
BMP-280	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

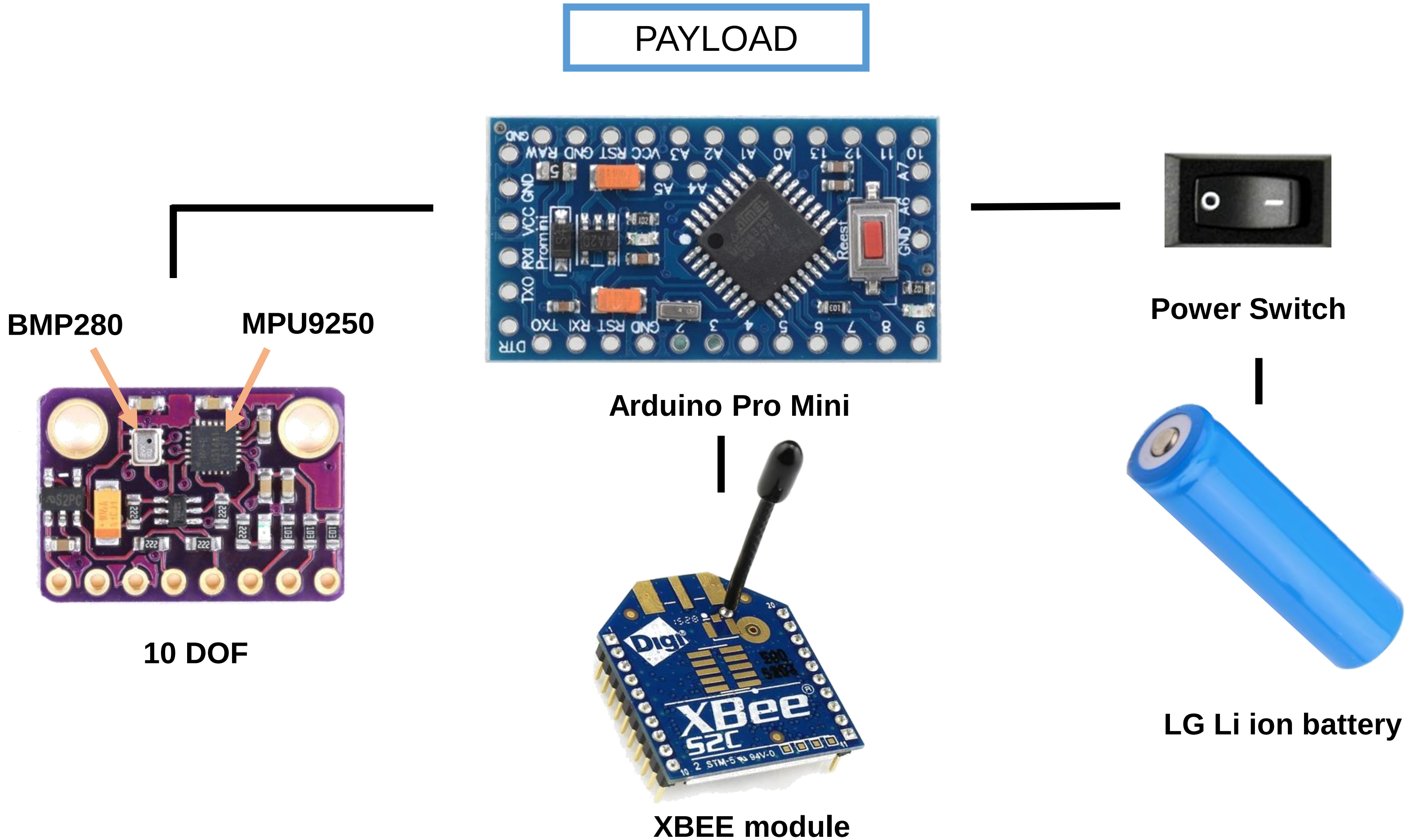
EPS Overview (2/4)

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	5V
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)



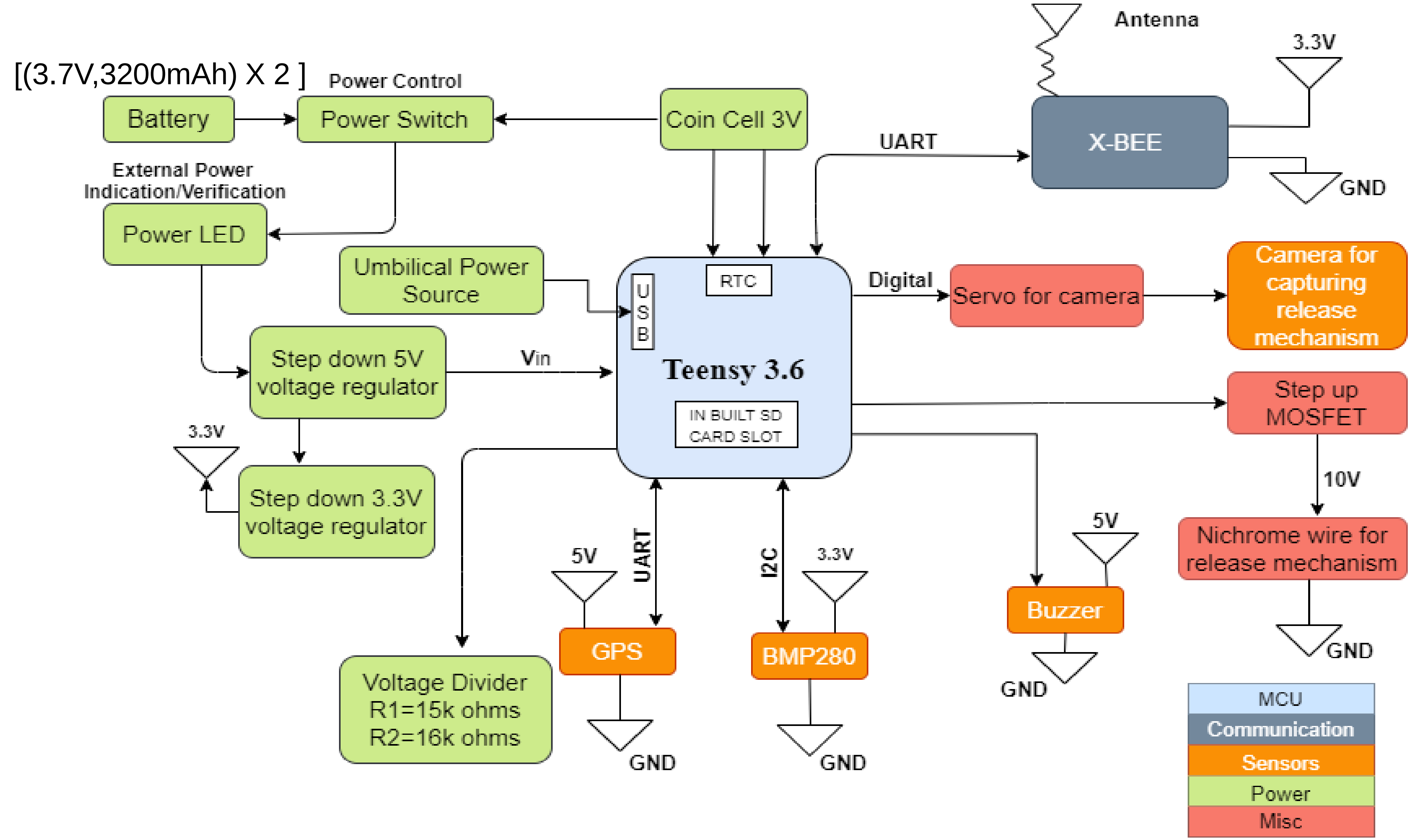
EPS Requirements (1/2)

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



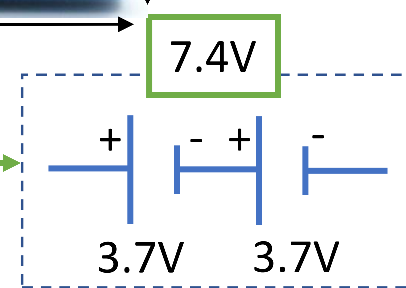
Container Power Trade & Selection

Component Name	Weight (gm)	Voltage (V)	Current (A)	Power (mWh)	Capacity (mAh)	Operating Temperature	Quantity	Cost (₹)
LG MH1 Li-ion Battery	**40**	**3.7**	**10**	**11744**	**3200**	**−20℃ to 60℃**	**2**	**490**
Samsung ICR18650	47	3.7	5.2	9620	2600	-20℃ to 45℃	2	300
Samsung 30Q	45	3.7	15	11100	3000	−20℃ to 55℃	2	560

Selected Component : LG MH1 Li-ion Battery

- Lightweight & small size
- Discharge current up to 10A
- Appropriate power/weight ratio
- High performance and capacity
- High power density

Batteries in Series configuration



The batteries are fixed in the electronics bay without any spring contacts.

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 1400	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

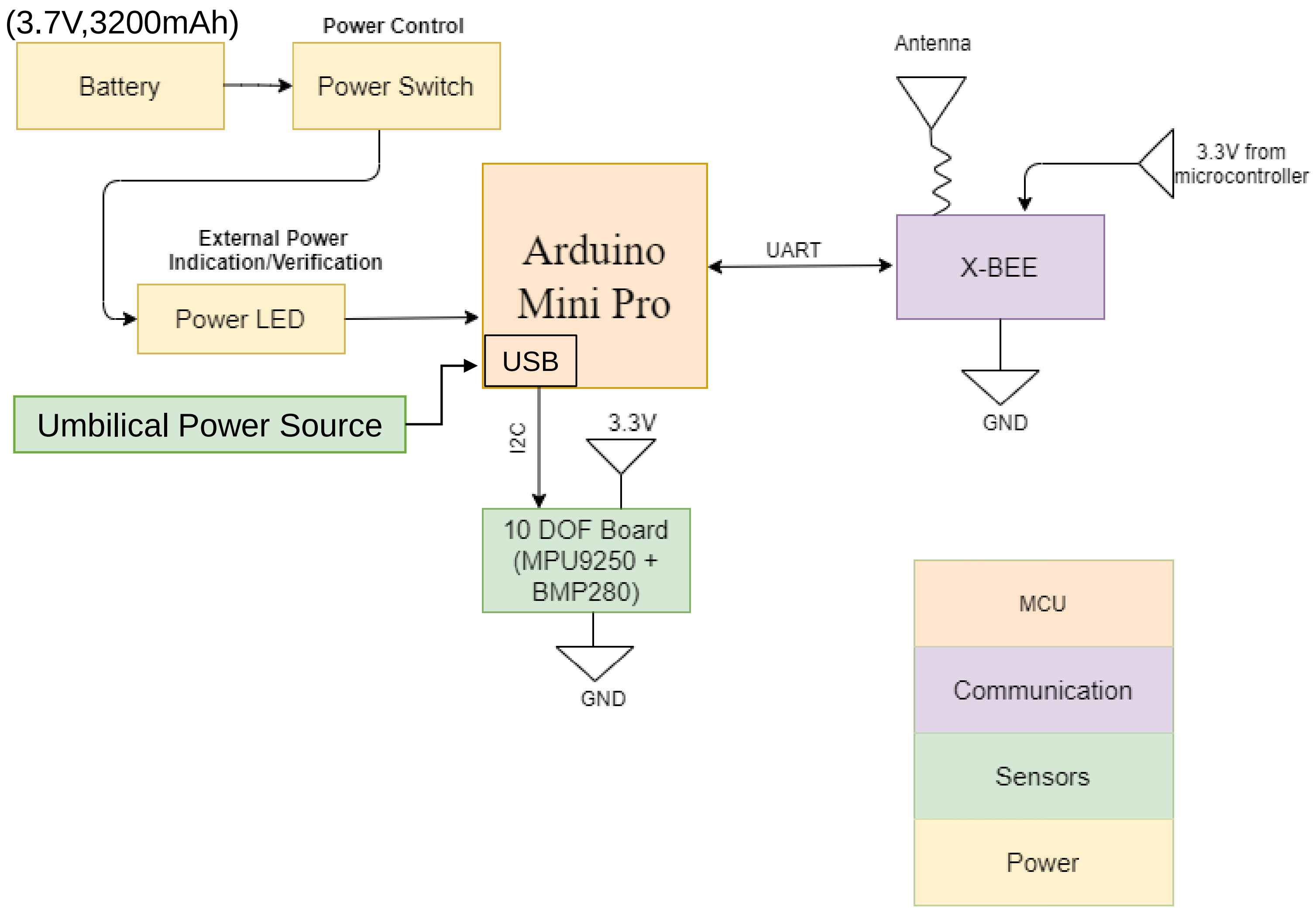
Available Power - Total Power Consumption = Power Margin

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

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

- The whole system will be powered by two LG MH1 Li-ion batteries 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 being released
- The system will work more than two hours as per the requirement

Payload Electrical Block Diagram



Payload Power Trade & Selection

Component Name	Weight (gm)	Voltage (V)	Current (A)	Power (mWh)	Capacity (mAh)	Operating Temperature	Quantity	Cost (₹)
LG MH1 Li-ion Battery	**40**	**3.7**	**10**	**11744**	**3200**	**−20℃ to 60℃**	**1**	**490**
Samsung ICR18650	47	3.7	5.2	9620	2600	-20℃ to 45℃	1	300
Samsung 30Q	45	3.7	15	11100	3000	−20℃ to 55℃	1	560

Selected Component : LG MH1 Li-ion Battery

- Lightweight & small size
- Discharge current up to 10A
- Appropriate power/weight ratio
- High power density which is sufficient for our payloads
- No configuration since only a single battery is used
- The selected battery is in series with the whole sub-system

The battery is fixed in the payload (seed) without any spring contacts.

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)

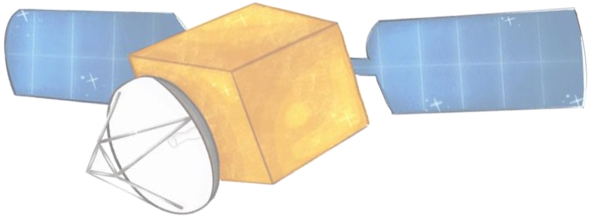
Available Power	**11.74Wh**
Total Power Consumption	**1.54Wh**
Power Margin	**10.2Wh**

Available Power - Total Power Consumption = Power Margin

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

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

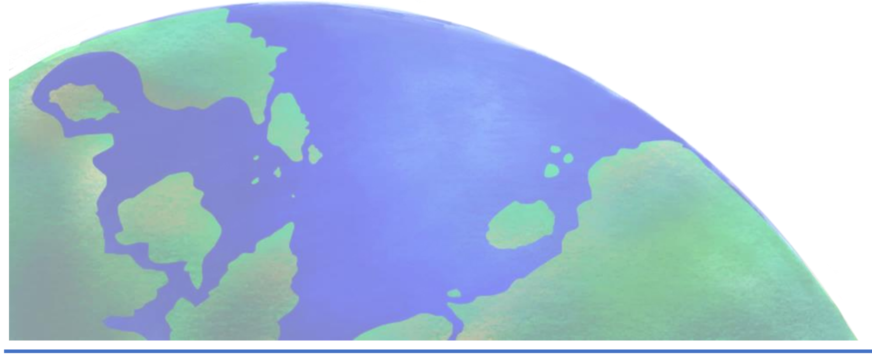
- The Power Margin is kept sufficiently large to avoid any system failures and so the system will run effectively for more than two hours.
- The whole system will be powered by the battery controlled by a power switch.
- The whole system will be powered by two LG MH1 Li-ion batteries controlled by a power switch.



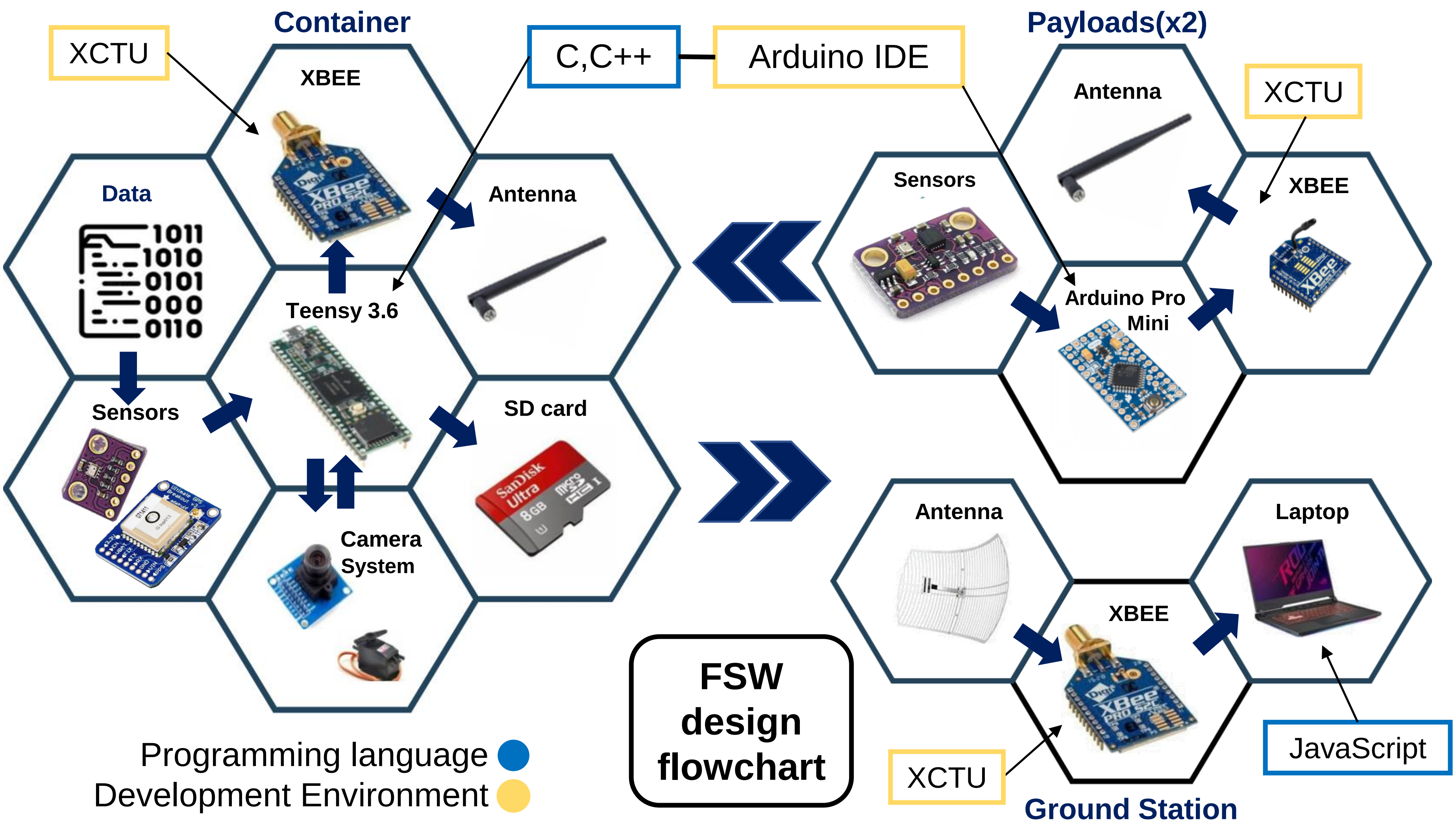
Flight Software(FSW) Design

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 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 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	√		√	√

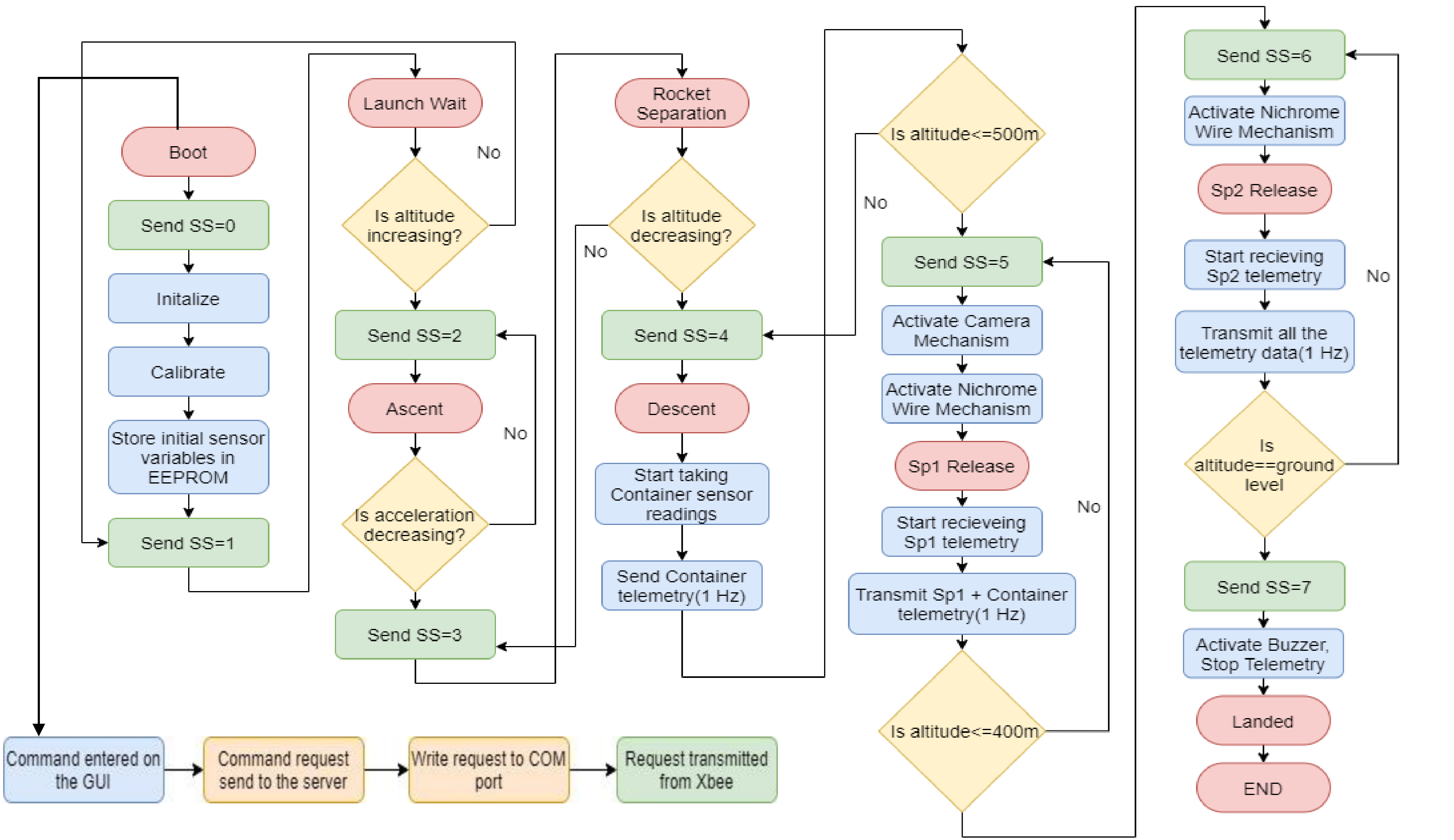
FSW Requirements (4/5)

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 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 FSW State Diagram (1/3)



Container 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(±5).
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 FSW State Diagram (3/3)

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

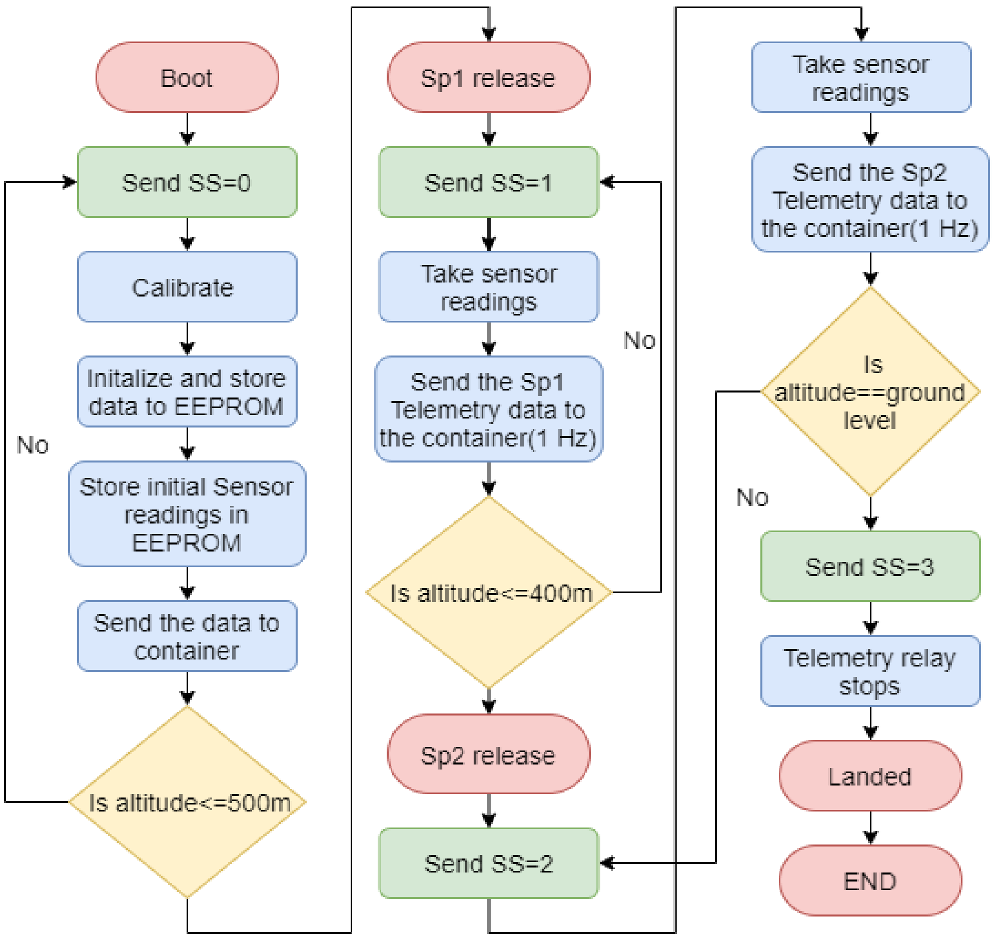
- **EEPROM variables (Remain unchanged after RESET)**

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 FSW State Diagram



- The FSW Diagram is same for both the payloads.
- 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

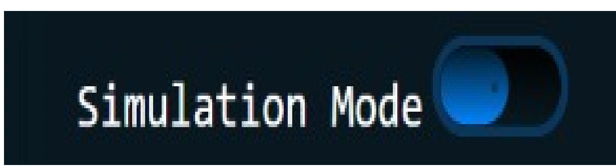
- The Ground station software reads the simulated csv file of the pressure sensor data and transmits the pressure data at a rate of 1 Hz to container.
- For this purpose the ground station XBEE will be set as **COORDINATOR.**
- If the CanSat container operates in the flight mode, the container operates 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 sensor data. No change in data from 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.

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

← The commands which are required to begin Simulation Mode

CMD,1567,SIMP,101325

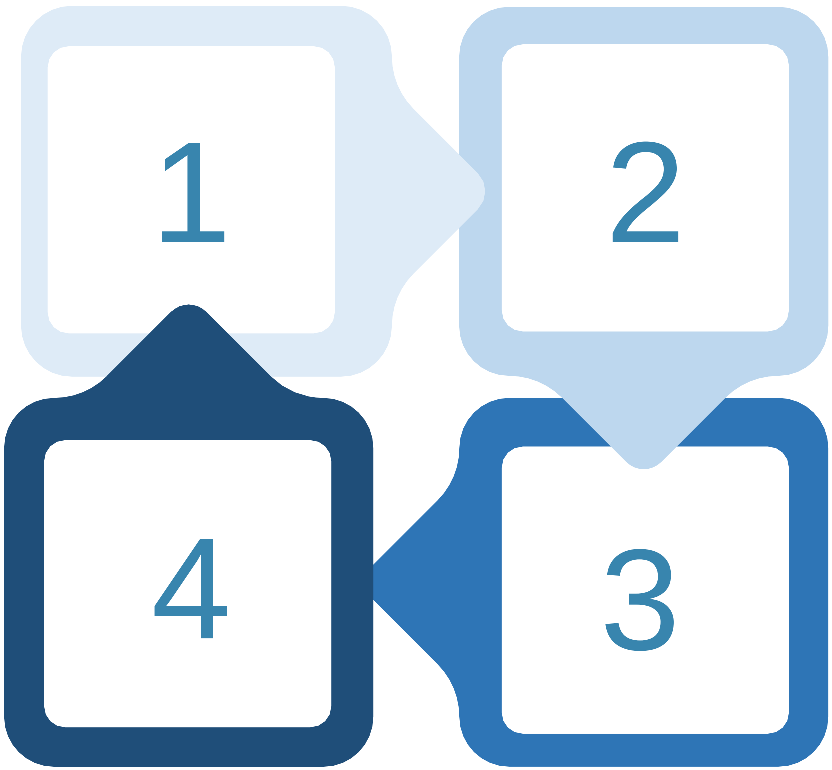
← The command which provides simulation mode pressure data



← Simulation mode activation in Ground station GUI

Software Development Plan (1/3)

Test Methodology

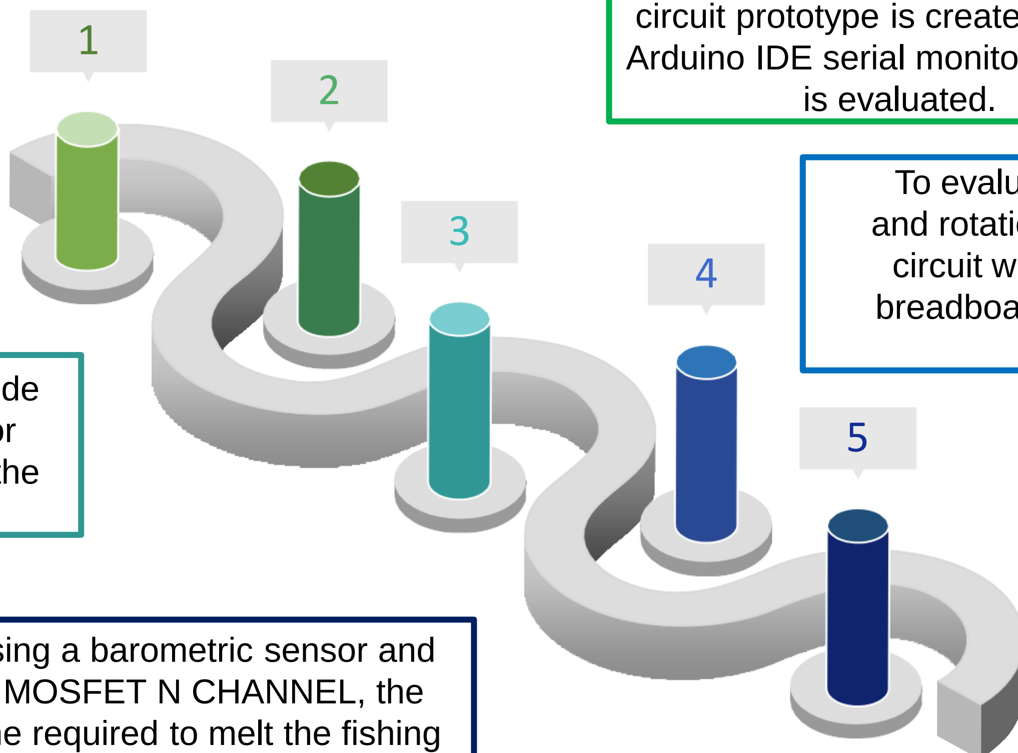


1. Testing of each sensor module with different algorithms. Algorithm finalization and subsystem code compilation.
2. By inserting and checking codes, meeting mission requirement.
3. Code debugging and finalization of acceptable telemetry format compatible code.
4. Testing of the entire CanSat system.

Prototyping and Prototyping Environments

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

By supplying the necessary power 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.



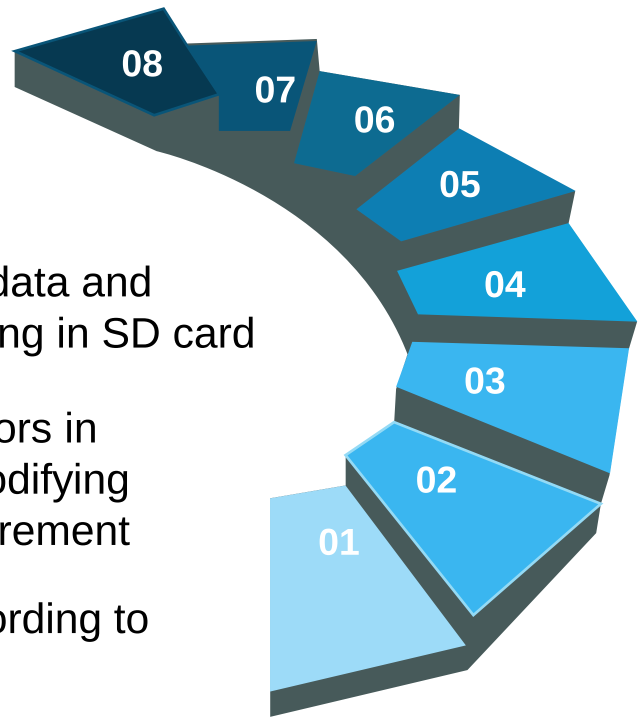
Uploading the blink code to the microprocessor tests the boot time of the microprocessor.

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

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

Software Development Plan (3/3)

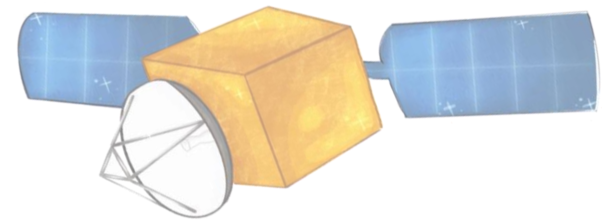
Software Subsystem Development Sequence



- **01** Sensor selection according to mission requirements
- **02** Library research, code modification and testing of each sensor
- **03** Integration of all sensors in a unified code and modifying according to the requirement
- **04** Using EEPROM for mission time recovery, packet count and FSW data (SS)
- **05** Storage of telemetry data and Camera video recording in SD card
- **06** Designing and testing PCB and checking the software compatibility
- **07** Assembling the components of the whole subsystem
- **08** Testing wireless communication with the ground station

Software Development Team:

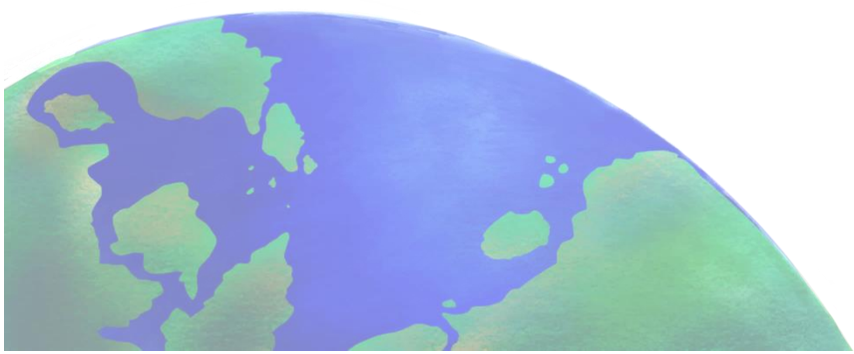
- Nisarg Shah
- Khyati Morparia



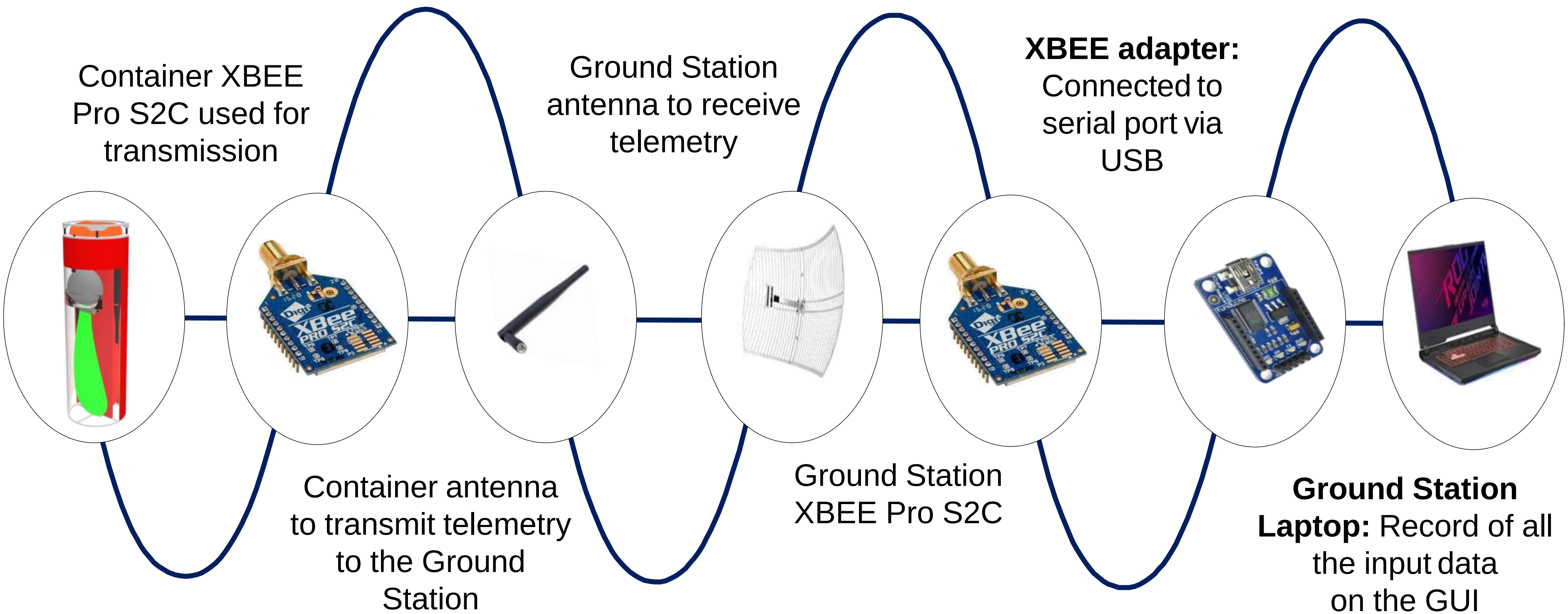
Ground Control System (GCS) Design

Presenter’s Name:

Khyati Morparia



GCS Overview



GCS Requirements (1/2)

Req ID	Requirement	Rationale	Priority	VM A	VM I	VM T	VM 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

Hand held antenna

Antenna connected to XBEE with N type to RPSMA connector

XBEE Module

XBEE module will be connected to XBEE adaptor with 2.54mm headers

XBEE Adapter

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

Ground Station Laptop

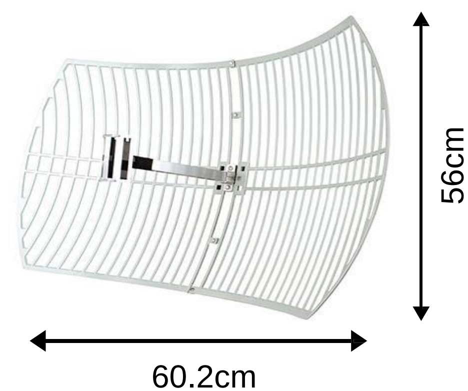
Specifications	
Battery Life of laptop	4 hours of battery life
Overheating Mitigation	External cooler under the laptop Sun shielding umbrella
Auto Update Mitigation	Auto update will be disabled, internet connection will be disabled
Portability	The Entire GCS is completely portable

GCS Antenna Trade and Selection (1/3)

Antenna Name	Type	Frequency Range (GHz)	Gain (dBi)	VSWR	Polarisation	Connector	Cost (₹)
TLANT2415 D	Omni-directional	2.4	15	≤2.0:1	Vertical	N Jack	4000
TLANT2424 B	**Parabolic Grid-directional**	**2.4**	**24**	**≤1.5**	**Vertical, horizontal**	**N Female**	**3200**
ANT-2YAG16-S MA	Yagi-directional	2.4	16	≤2.0:1	Vertical, horizontal	SMA (M)	4300

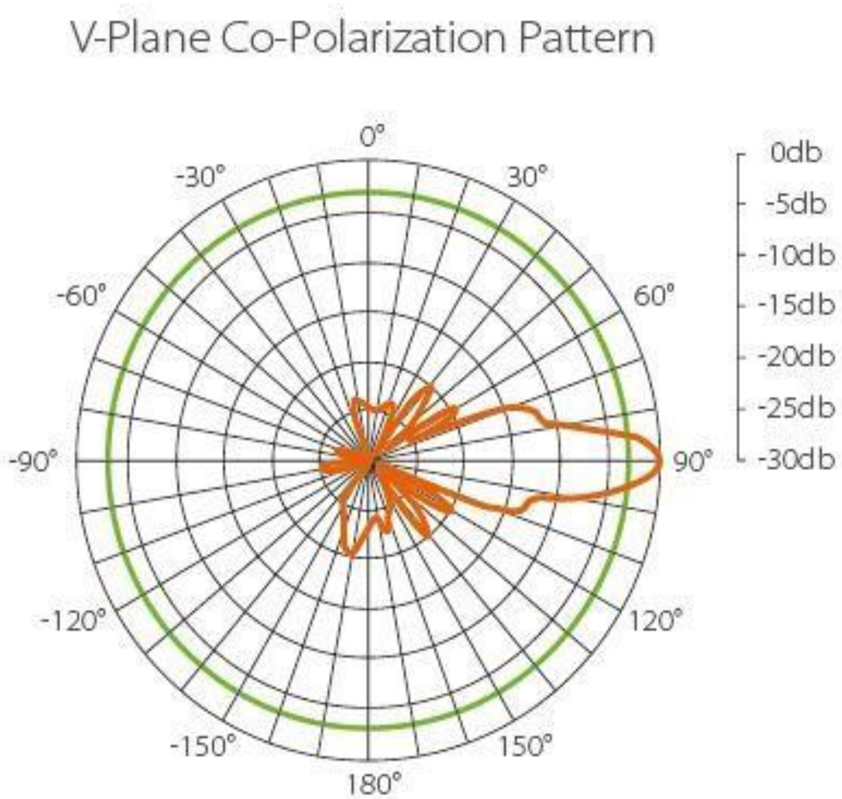
Selected Antenna: TLANT2424 B

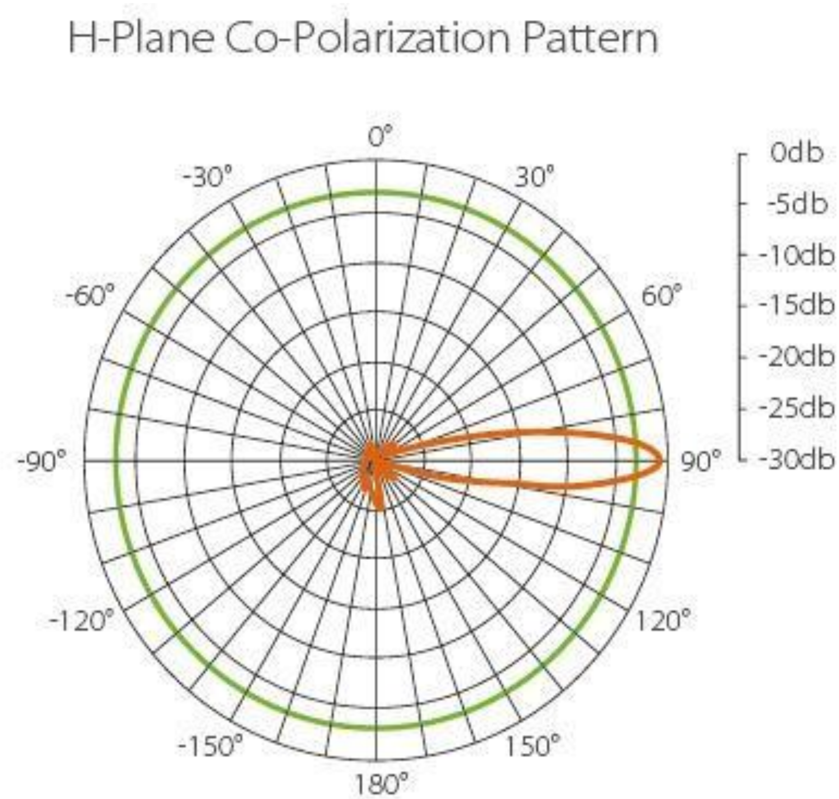
- Since it is hand-held, we can direct it easily
- 24dBi directional operation and covers long range (56km)
- Weatherproof design, suitable for all weather conditions
- Simple installation and implementation with XBEE



GCS Antenna Trade and Selection (2/3)

Radiation pattern of TP-LINK TLANT2424 B





GCS Antenna Trade and Selection (3/3)

Tripod Stand	Handheld
	
Set orientation would not match polarization, causing the signal intensity to decrease.	Beam like wave pattern, so we can adjust the orientation for optimum signal reception.
High chances of weak signal on account of the unreliable movement of payload.	Small and easy to carry.
Holding the antenna is not required since it is mounted on the stand.	Cost Effective.

Selected Design: Handheld

- The antenna is highly directional, so portability is necessary to target payload
- Cost effective

GCS Software (1/8)

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:

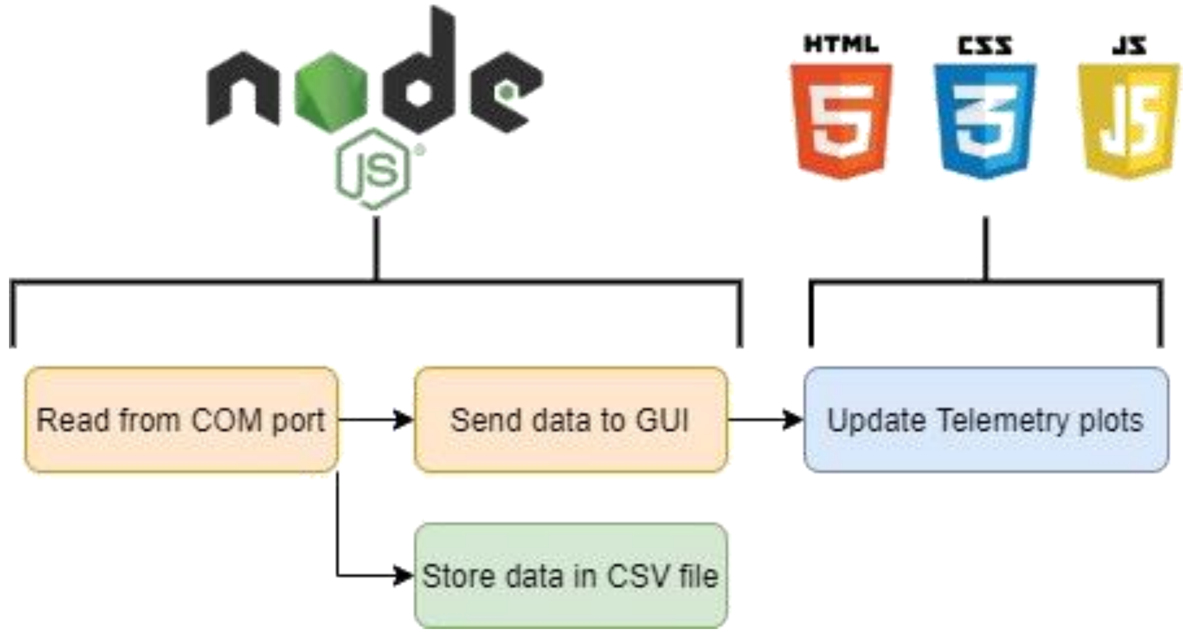
- Code for the ground station is built with visual studio code using JavaScript
- Telemetry data received will be registered right after being read in the ground station XBEE Module in a .csv format
- The data received would then be presented on real time plots displayed in engineering units.
- Telemetry 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

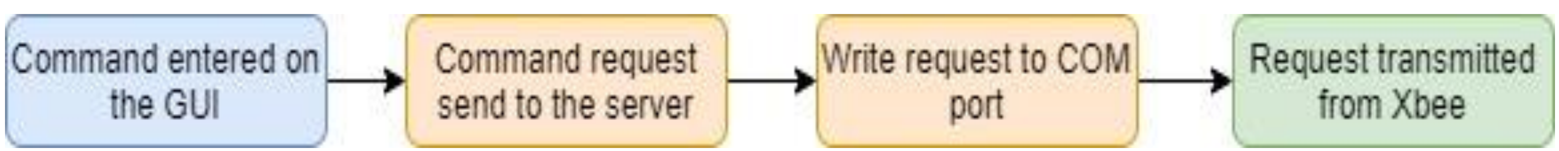
Commercial off the shelf (COTS) software packages:

- XCTU (XBEE Program Software)
- Visual studio code
- Arduino IDE

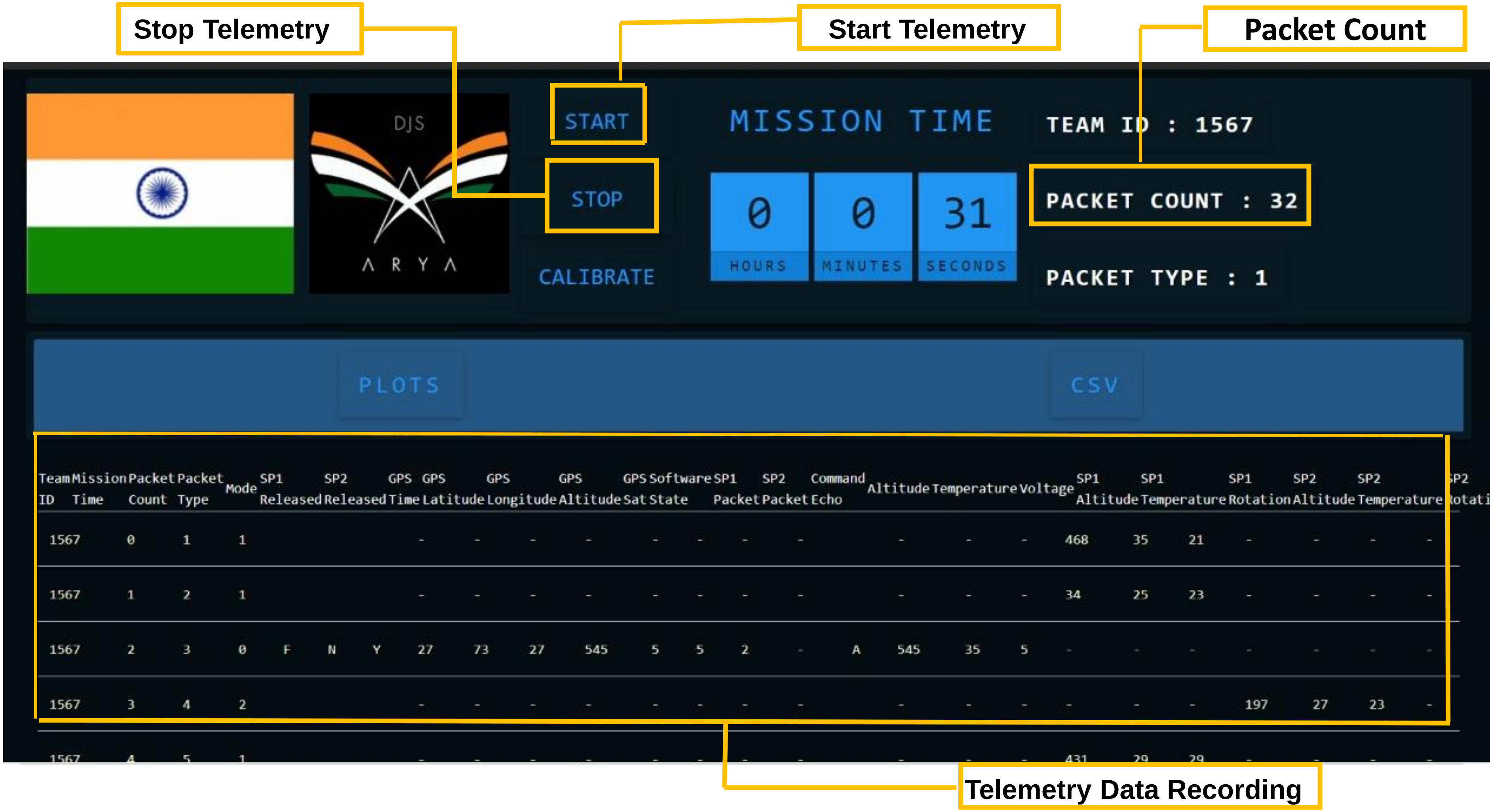
Server side:

- Node.js
- Socket.io

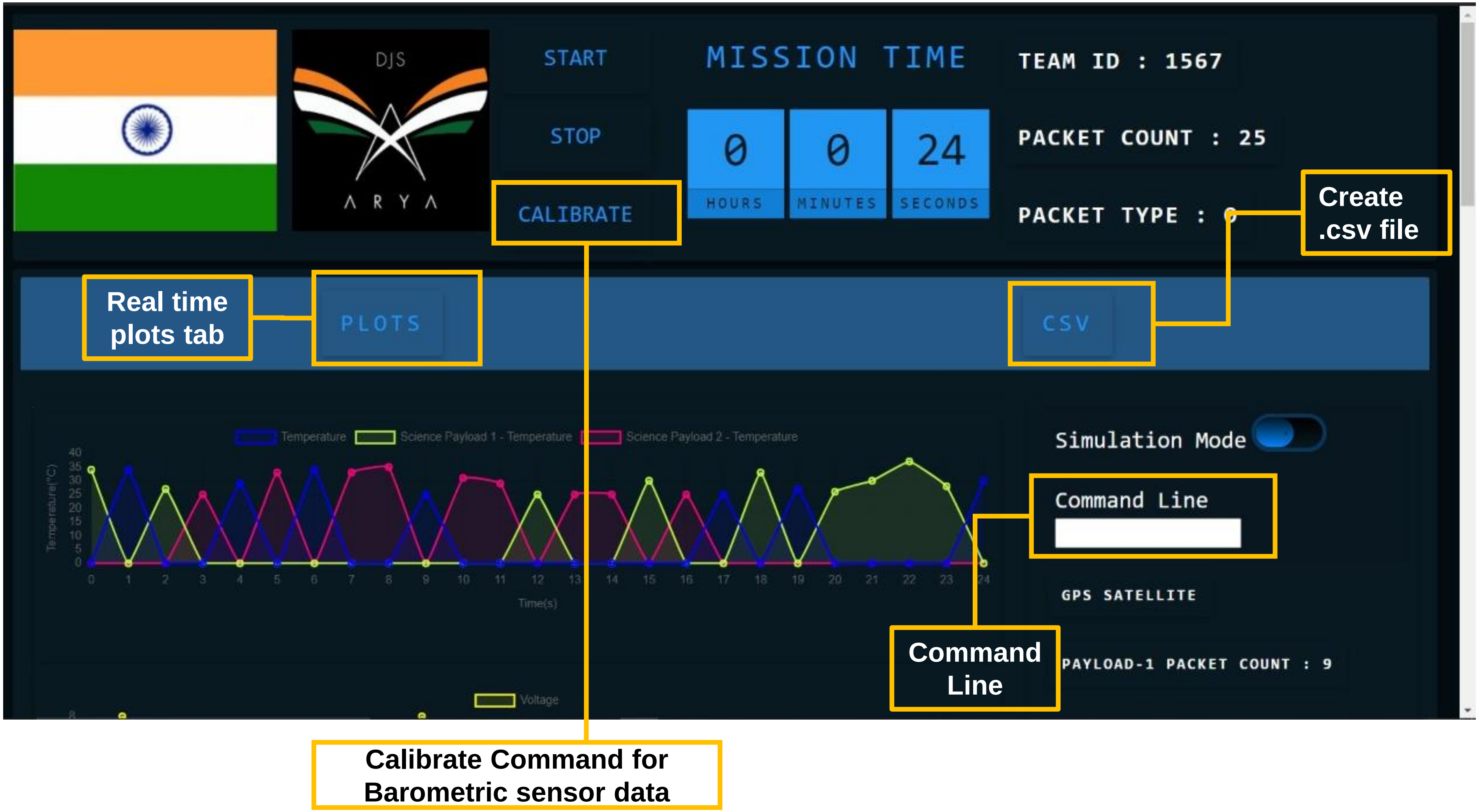




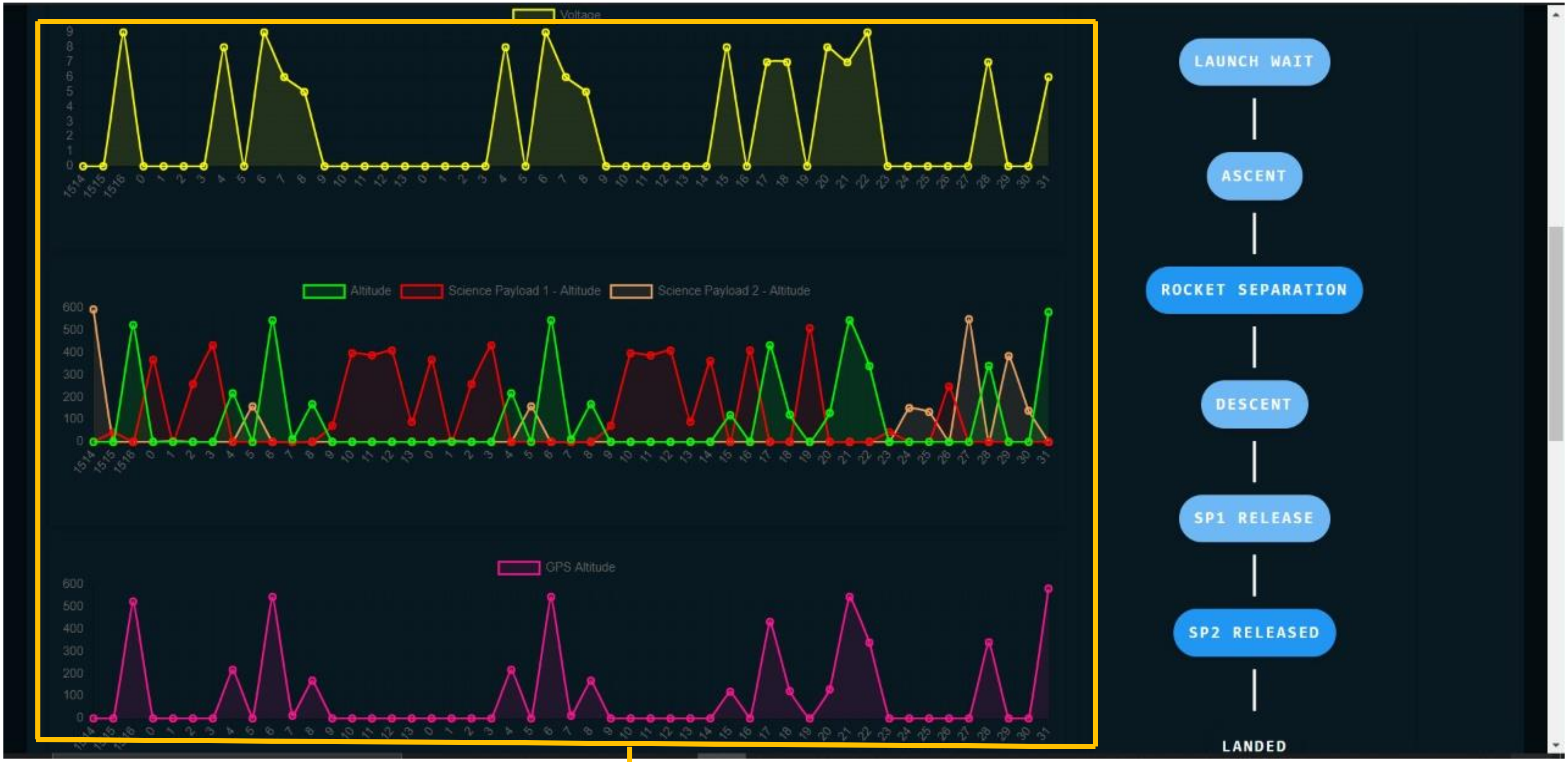
GCS Software (3/8)



GCS Software (4/8)

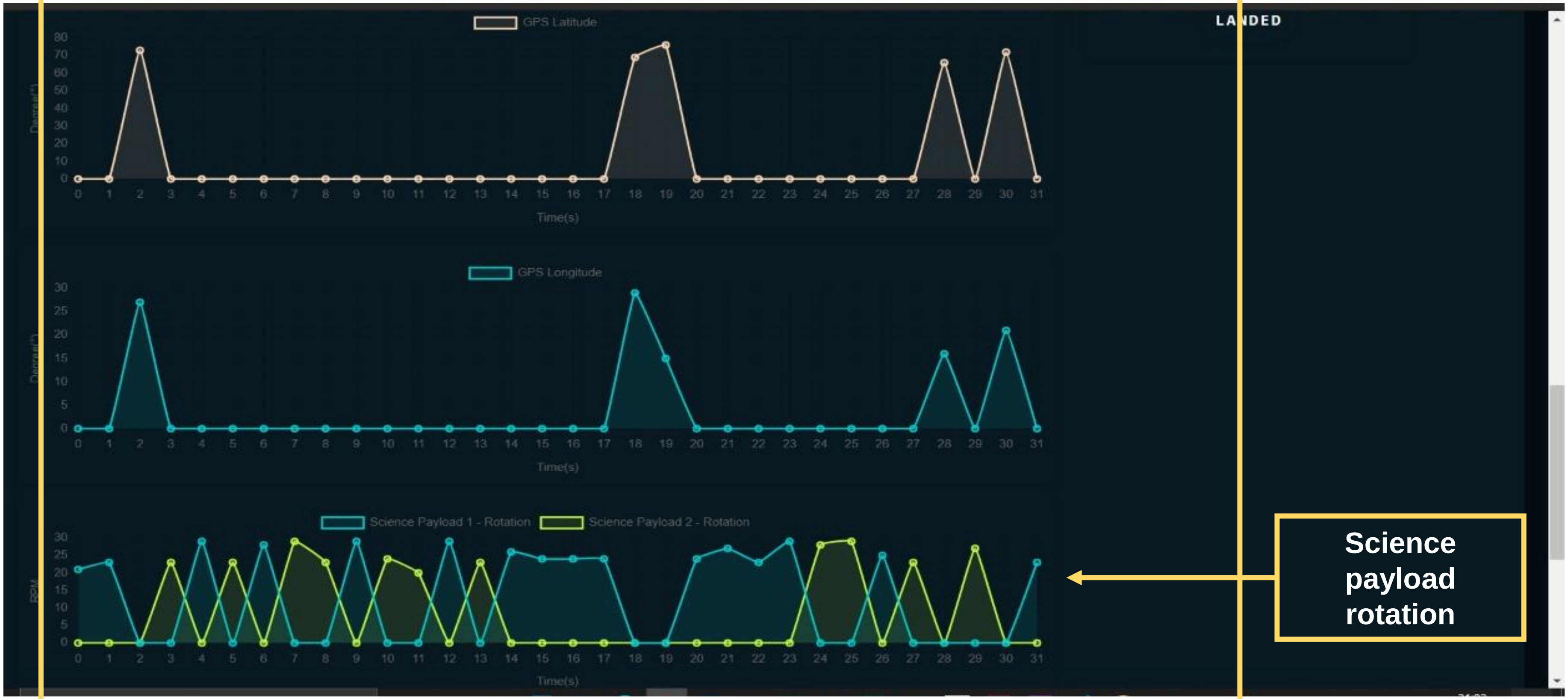


GCS Software (5/8)



Real Time Plotting

GCS Software (6/8)

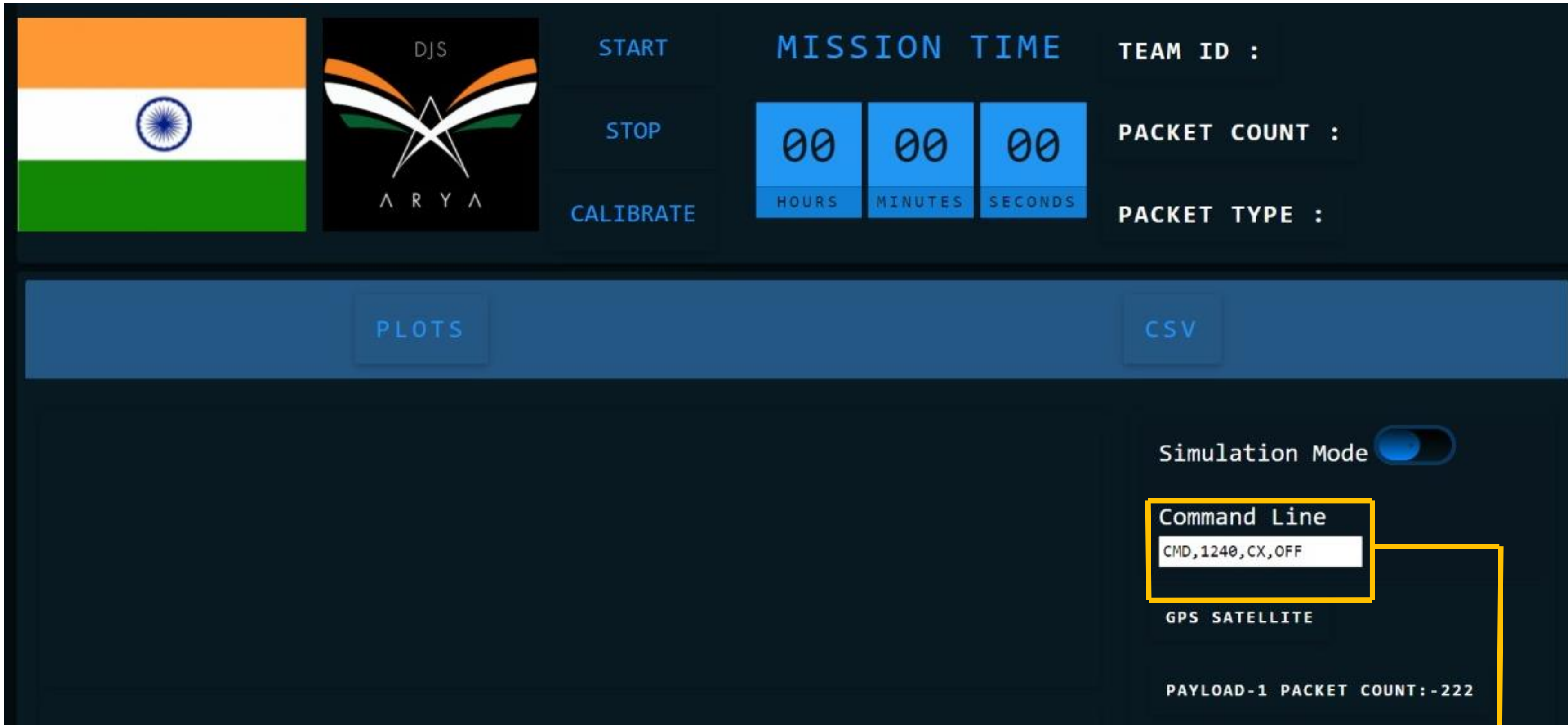


Science payload rotation

Telemetry data displayed in engineering units

Real Time Plotting

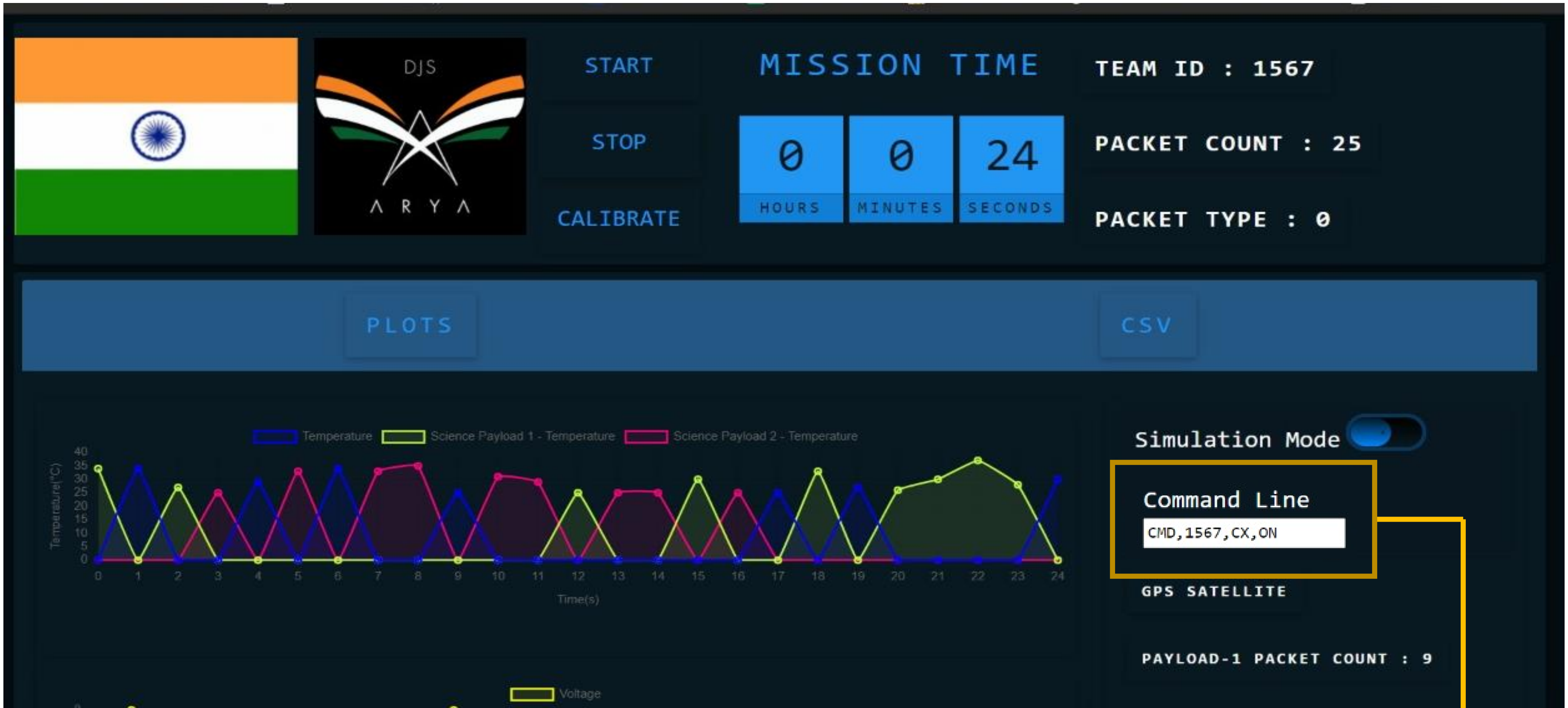
GCS Software (7/8)



Container Command OFF

The telemetry data of the container is not plotted since the telemetry transmissions are deactivated on receiving the respective command from the ground station.

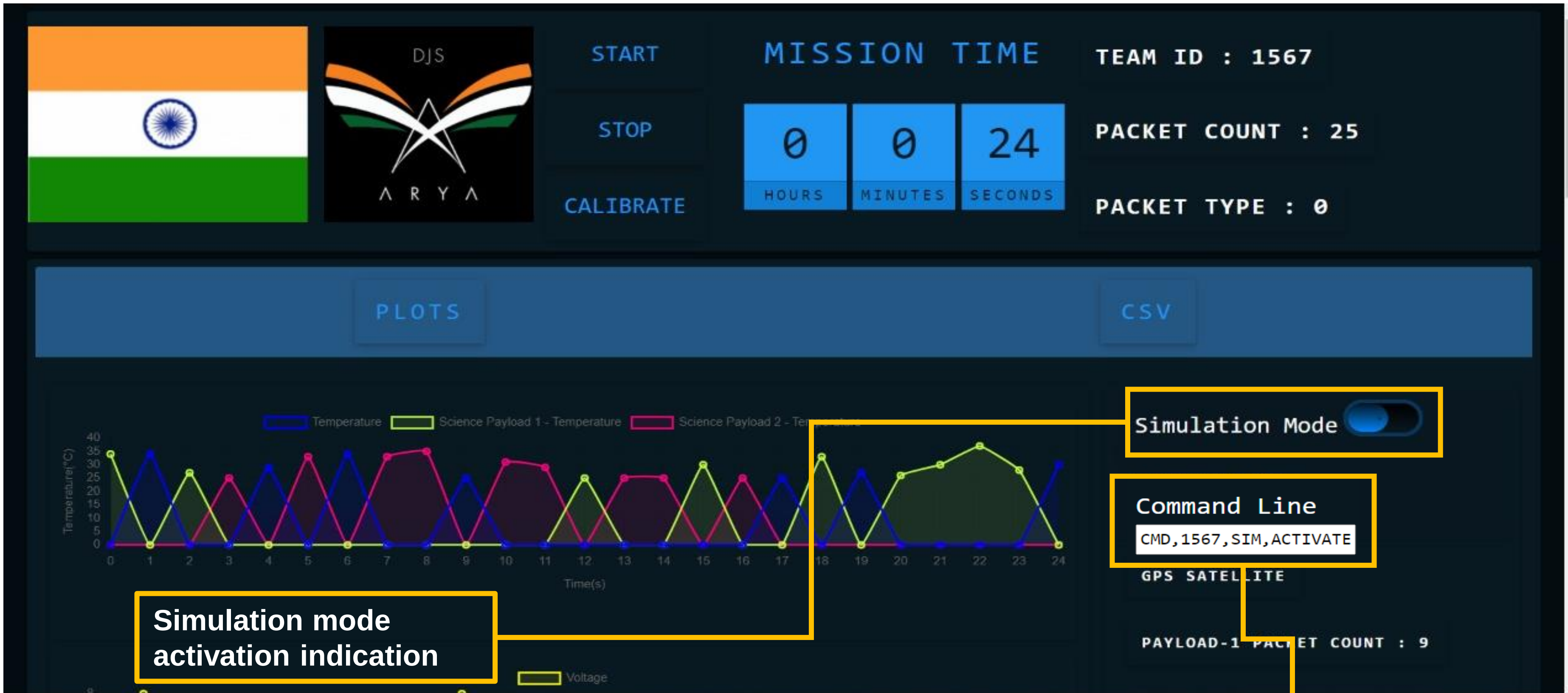
GCS Software (8/8)



Container Command ON

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

Simulation Mode Description



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

MQTT Integration

➢ MQTT Integration

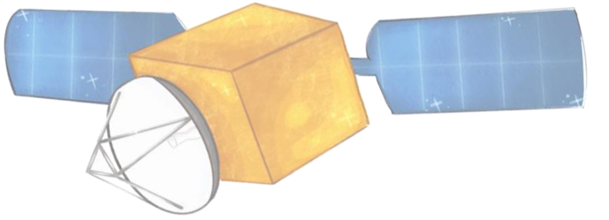
- MQTT is a publishing and subscription-based messaging system that has been used for remote viewing of the telemetry data and for which we use **MQTT.js package**.
- For this method, the languages we use are **JavaScript and Node.JS framework.**

➢ 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

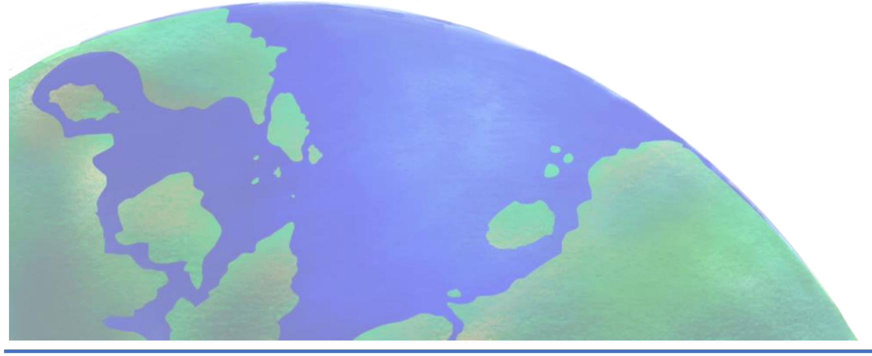
- We have used https://test.mosquitto.org/ as our client to create the instance.
- The CSV data is published by subscribing to a topic which we create and using the client to publish the data which is also displayed on the terminal.



CanSat Integration and Test

Presenter's Name:

Khyati Morparia



CanSat Integration and Test Overview (1/6)

CanSat Integration and Test

Subsystem Level Testing Plan

- Sensors
- CDH
- EPS
- Radio
- Communicat-ion
- FSW
- Mechanical
- Descent Control

Integrated Level Functional Test Plan

- Descent
- Communica-tions
- 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 (2/6)

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

SUBSYSTEM LEVEL TEST PLAN

Sensors

Each sensors is individually tested and calibrated. Later, all the sensors are integrated together and a unified code is produced.

CDH

Communication between XBEEs via antennae is tested by sending and receiving of sample data in telemetry format.

EPS

The whole system (with release mechanism) is powered using batteries and is tested to validate the power requirements.

Radio Communication

XBEEs are setup in star network with PANID set to our TEAM ID and range test will be performed to validate the selected antenna.

SUBSYSTEM LEVEL TEST PLAN

FSW

Entire flight software, GUI and flow of software states is tested by varying the altitude levels using lift elevators.

Mechanical

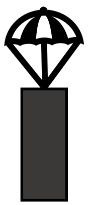
All parts will be thoroughly checked, and quality test will be done for dimensions and damage, simulations will be performed on container and payload for survivability of structure under 30Gs shock force.

Descent Control

Wing at different angle of incidences were tested in SolidWorks to gain the required lift. Parachute was drop tested for the iteration of the spill hole. Payload was drop tested at different wing angles to acquire the required angle of attack.

CanSat Integration and Test Overview (4/6)

INTEGRATED LEVEL FUNCTIONAL TEST PLAN

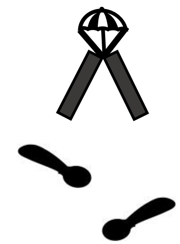


Descent Testing

Descent testing of the container and the payloads will be performed for verifying various subsystem mechanisms.

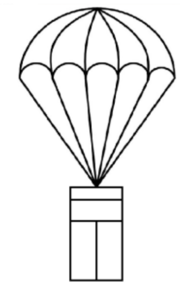
Communications

Communication test will be performed to verify lossless communication between payload-container and container-ground station.



Mechanisms

Payload release mechanism (using nichrome wire and fishing line) will be tested. The burning of the wire at different heights will also be tested.



Deployment

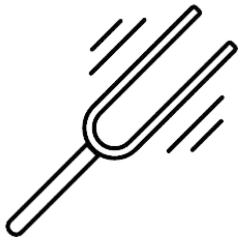
Seed and wing attachment point is tested for durability and survivability. Container parachute will be tested.

CanSat Integration and Test Overview (5/6)

ENVIRONMENTAL TEST PLAN

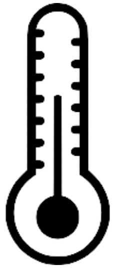
Drop test

Initially the container and the payload are individually tested. Later, drop test is performed for whole integrated system to check the structural survivability and all release mechanisms.



Vibration test

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

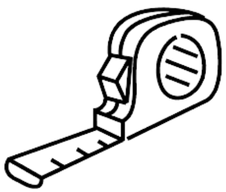


Thermal test

Temperature tolerance and sustainability of CanSat shall be tested in a heat chamber.

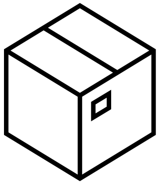
CanSat Integration and Test Overview (6/6)

ENVIRONMENTAL AND SIMULATION TEST PLAN



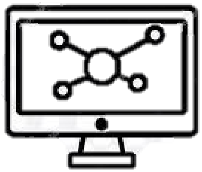
Fit Check

Dimensions of the CanSat are checked to be within the requirements. The CanSat will also be passed through a go/no go inspection to make sure its dimensions are according to the mission requirement.



Vacuum Test

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



Simulation Test

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

Subsystem Level Testing Plan (1/11)

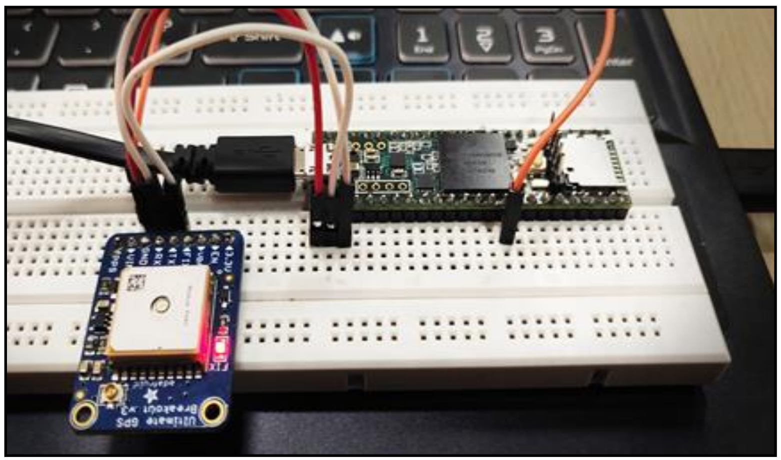
Electronics Integration & Testing Description

- 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 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.

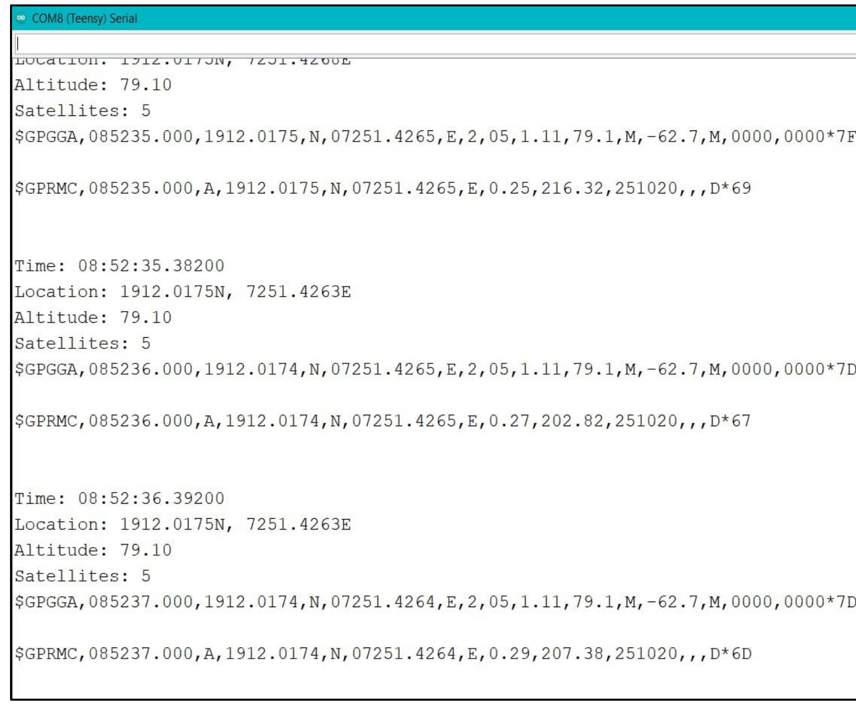
Subsystem Level Testing Plan (2/11)

Container Sensor Subsystem-Adafruit Ultimate GPS

The locking of GPS module with the Geo-stationary satellite was tested in the university premises and the co-ordinates are validated with the help of Google maps.



GPS Testing

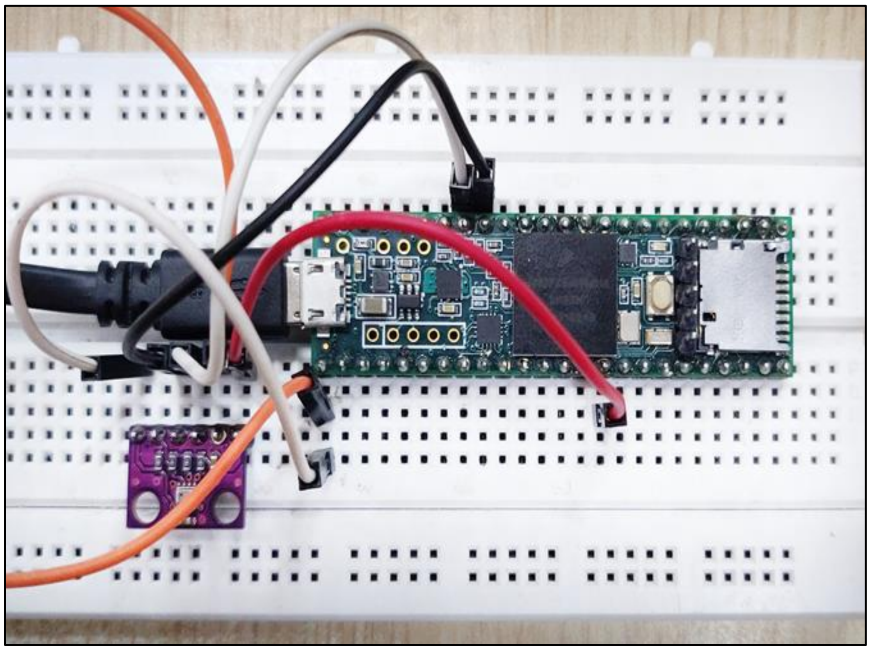


GPS after lock readings

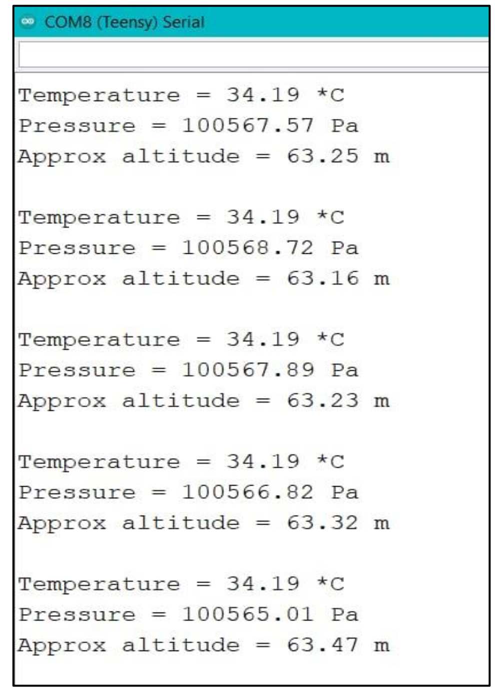
Subsystem Level Testing Plan (3/11)

Container Sensor Subsystem-BMP 280

BMP 280 is tested, and the readings are verified with local weather data online.



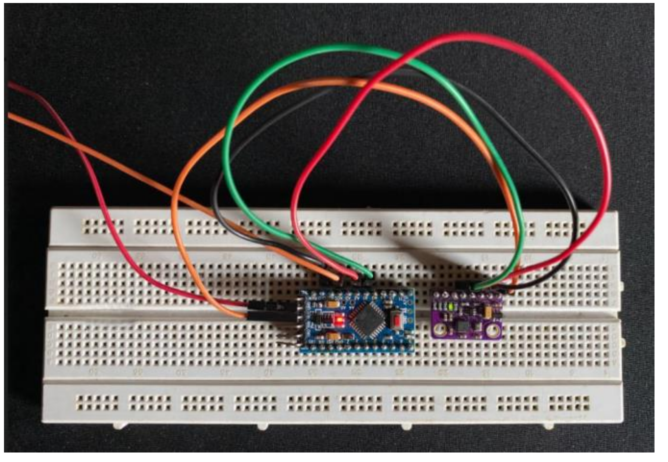
BMP 280 Testing



Temperature, Pressure & Altitude readings

Payload Sensor Subsystem-10 DoF sensor module

The sensors on the 10 DoF are tested. The data obtained from BMP 280 was verified with local weather data online. The readings of the MPU 9250 were also verified with smart phones accelerometer.



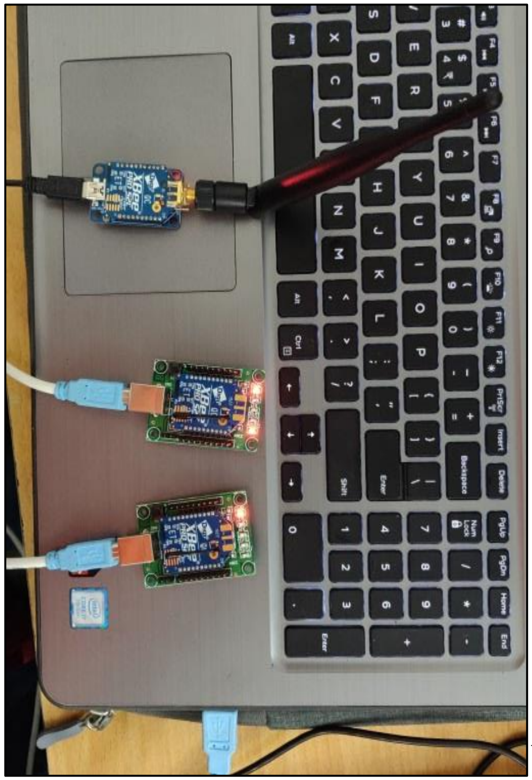
10 DoF board testing

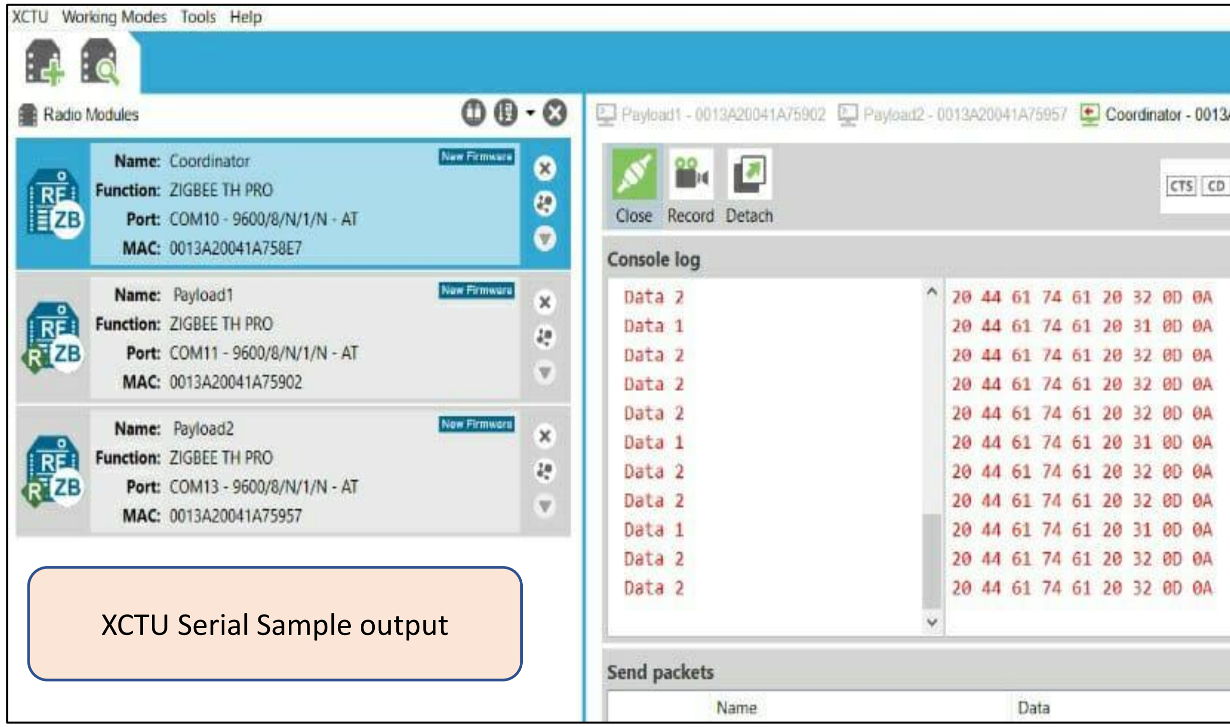
```
Temperature = 28.44 *C
Pressure = 1009.69 hPa
Approx altitude = 13 m
RPM:11.98
```

Temperature, Pressure and RPM reading

Communication and Data Handling Subsystem

The sensors are integrated together to verify efficient code in compliance with the mission telemetry format & analyze noise in the data with 1Hz sampling rate. The star network topology between container XBEE and Payload XBEE is tested.





XCTU Serial Sample output

The three XBEEs are in star network topology.

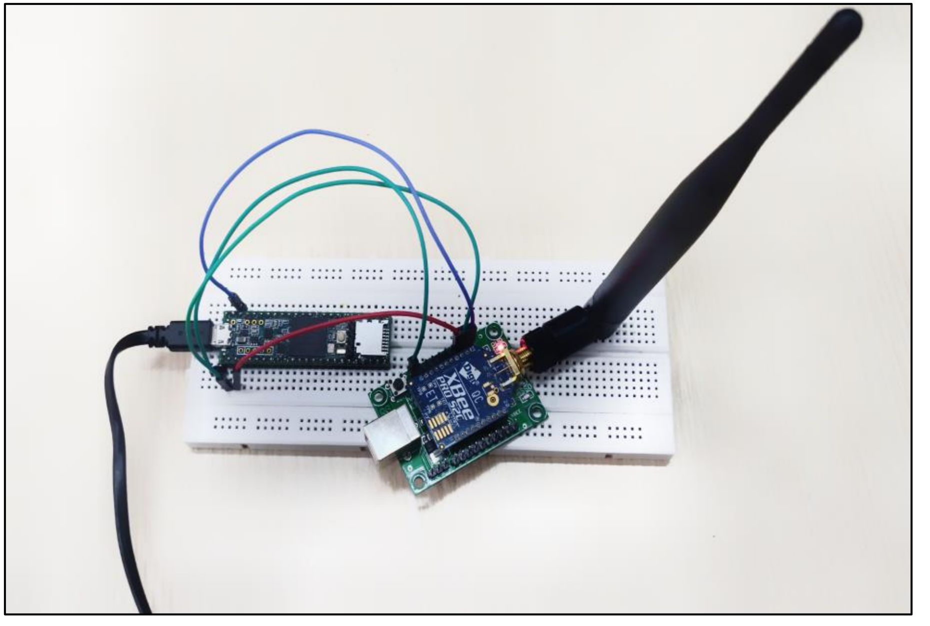
Subsystem Level Testing Plan (6/11)

Communication and Data Handling Subsystem

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 is tested.

Ground Station Antenna

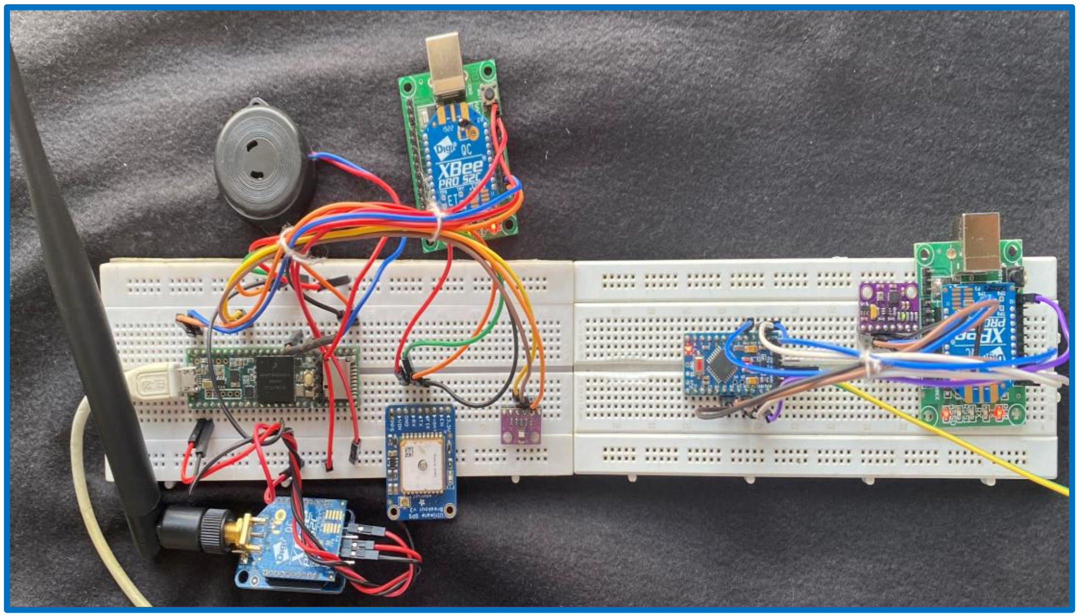


Container Antenna

Subsystem Level Testing Plan (7/11)

Electrical Power Subsystem

- The battery will operate for more than 2 hours in both the payload and the container.
- The entire test has been carried out without any power issues

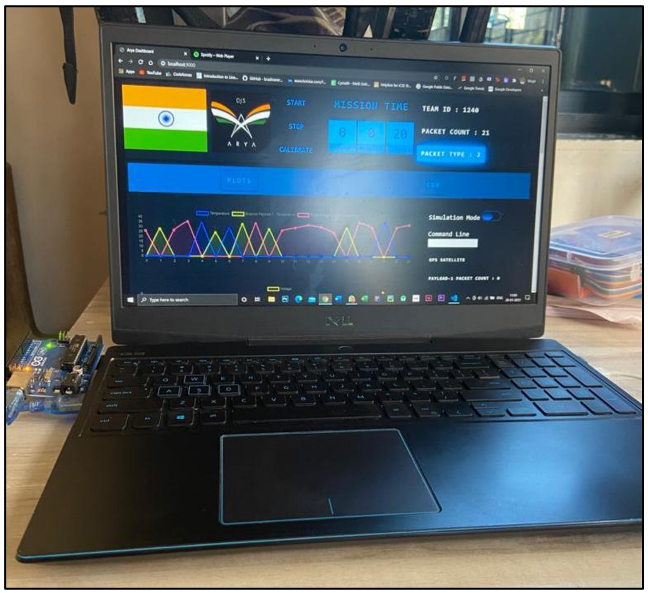


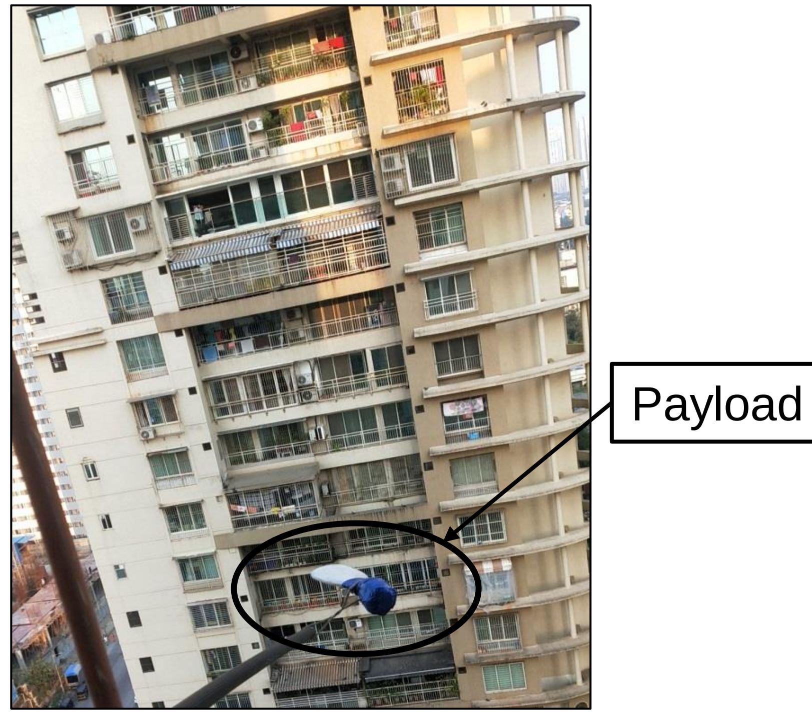
Electronics subsystem testing on Breadboard

Flight Software Subsystem

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

All telemetry and FSW data successfully displayed on the GUI

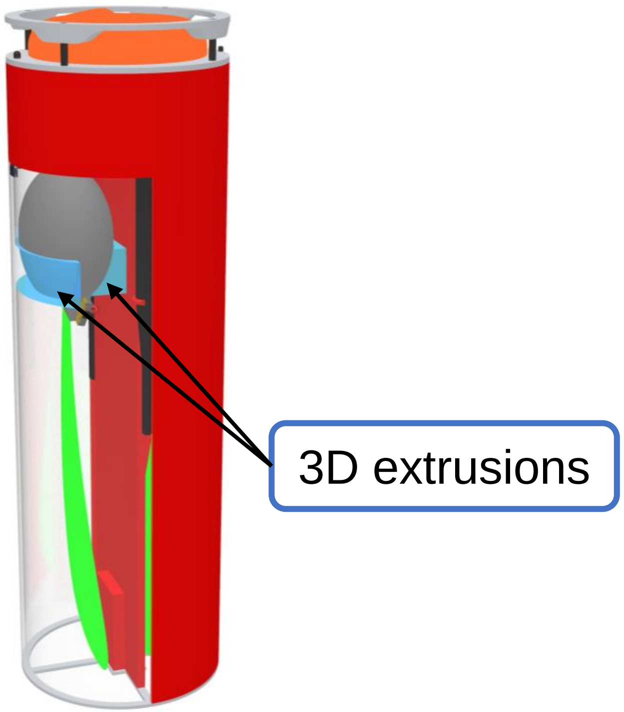


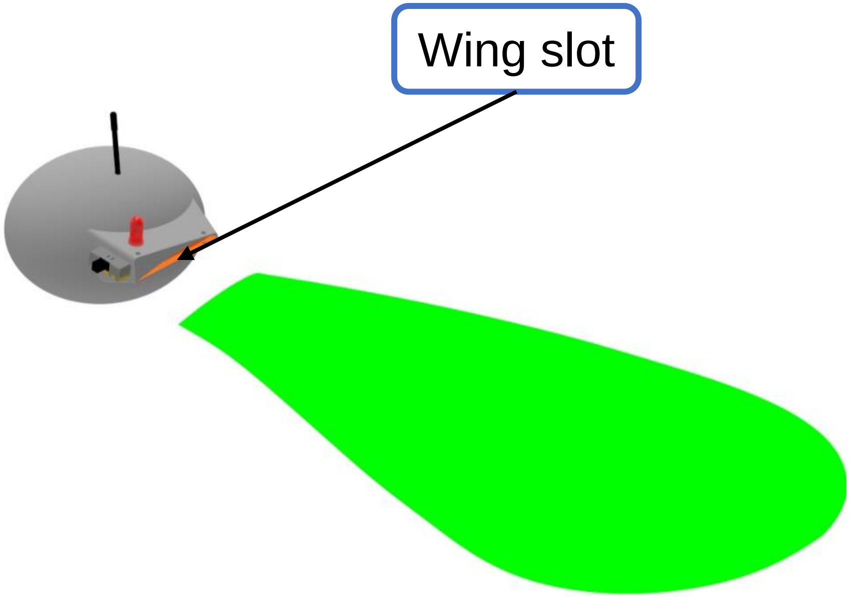


Mechanical Subsystem

- The entire mechanical assembly was designed in CAD and manufactured on industrial grade machines. All parts were thoroughly checked and quality tested for dimensions and damage.
- All structures have been built to survive 15Gs of launch acceleration.
- All components are built to survive 30 Gs of acceleration.
- A prototype of the autorotating maple seed science payload was manufactured for rigorous testing. The wings are made of Balsa with a covering of Monokote. The seed was 3D printed with PETG.
- The angle of attack of the wing of the science payload was tested for various iterations.

Mechanical Subsystem





The dimensions of 3D extrusions were verified for perfect fitting of payloads

Wing slot of each payload are made with enough clearance to accommodate wing with support pins

Descent Control

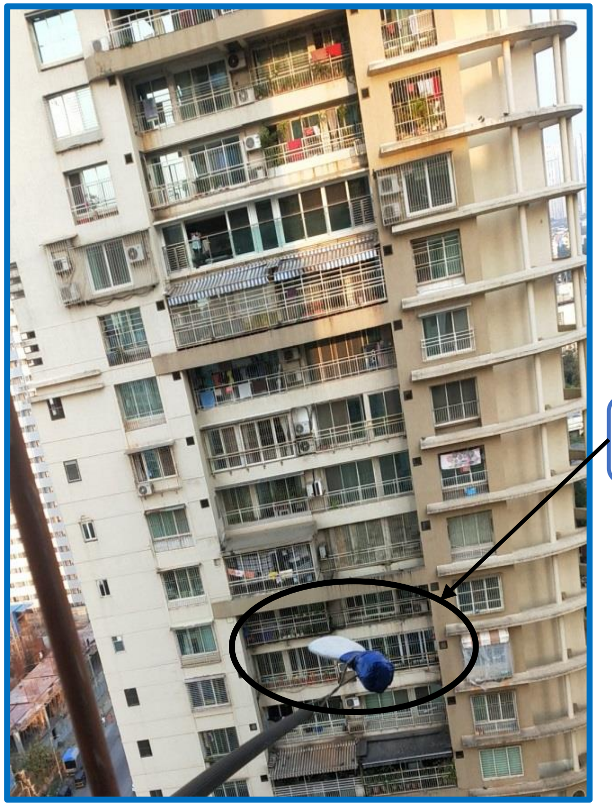
- The descent of the container and science payloads were tested for descent rate velocities to be within the restrictions mentioned in the mission guide.
- **CONTAINER**
- The calculations for the surface area of the parachute are done.
- Two mass equivalents: CanSat (600 g) and Container (300 g) are used for testing of parachute before and after the release of the science payloads.

PAYLOAD

- The autorotation of the science payload was obtained with different iterations of the centre of gravity in the seed.
- The descent observed was controlled and smooth.

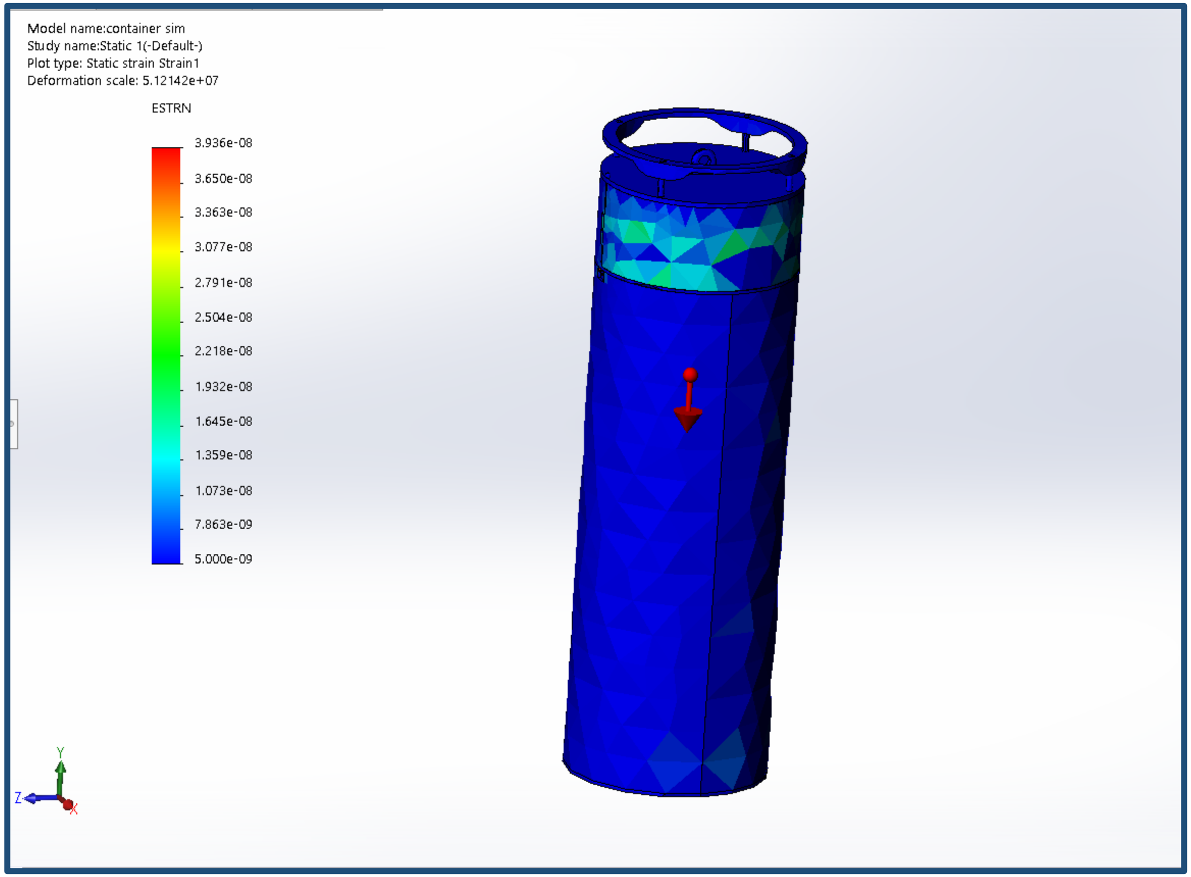
Descent testing and Communication

- Initially the container and the payload were individually dropped from a height of 100+ meters to verify the robustness and strength.
- The communication will be tested with partial electronics
- Opening of container parachute and autorotation of the maple seed payload was achieved.
- Communication between the ground station and the container XBEEs were tested successfully.



Integrated Level Functional Test Plan (2/7)

Descent Testing : Container stress analysis



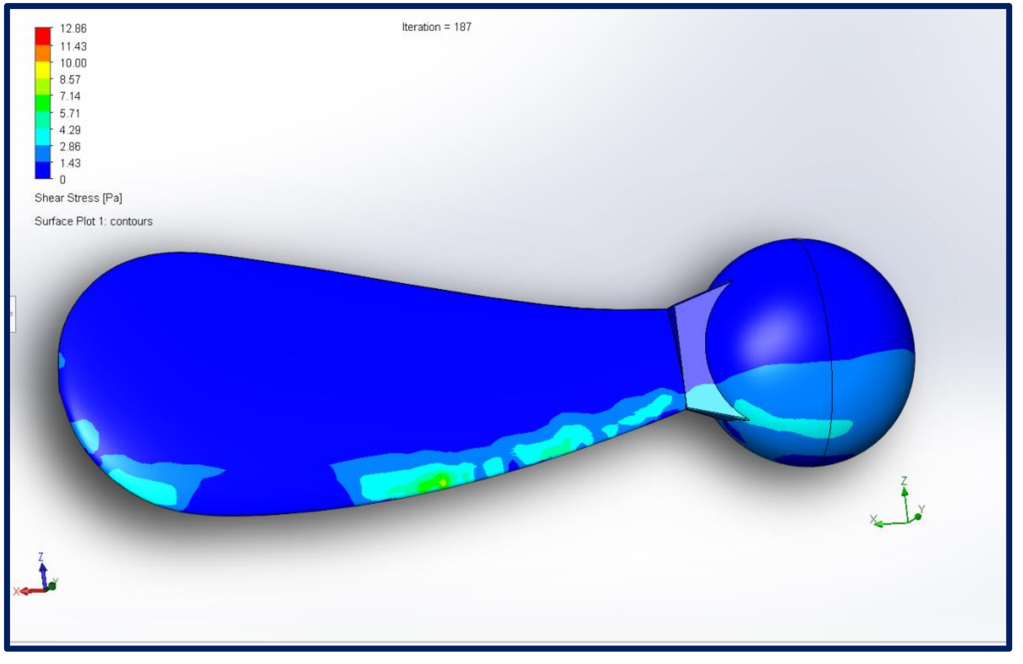
- The stress analysis is carried under shock load of 30Gs for the container.
- The colors indicate the stress on the container

Test output :

- Stress on all structural parts is studied
- Thickness of balsa-fiberglass composite has been selected accordingly
- Infill percentage of the 3D printed container parts has been selected accordingly

Integrated Level Functional Test Plan (3/7)

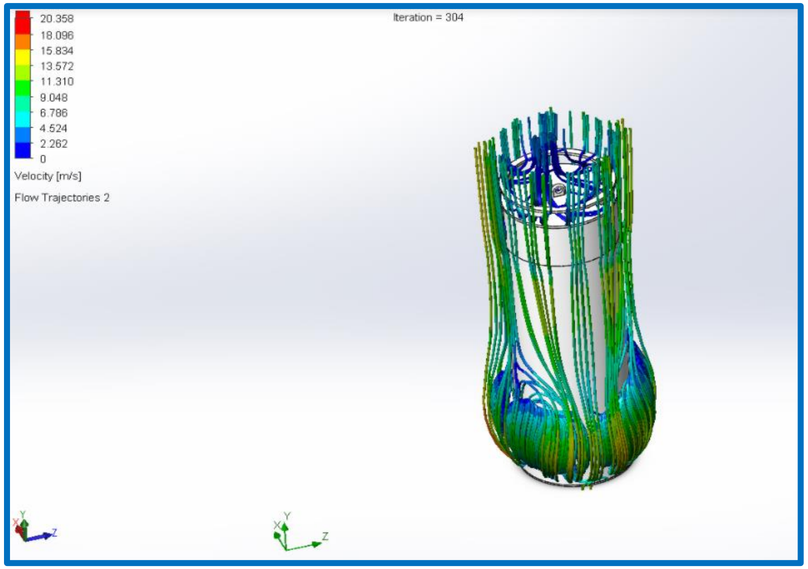
Descent Testing : Payload stress analysis



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.

Descent Testing : Flow simulation

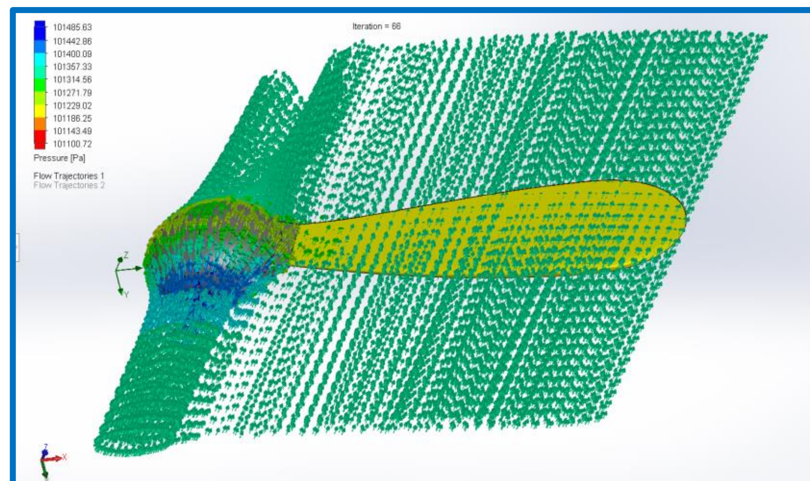


Test output (Container):

- Flow simulation done on the container shows a stable descent

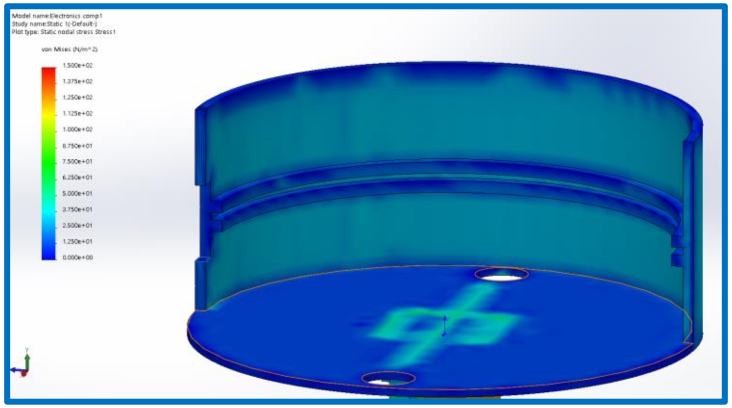
Test output (Payload):

- The Flow Simulation shows the wind speed on various sections of the payload.
- Angle of attack was chosen as 11° after various iterations.



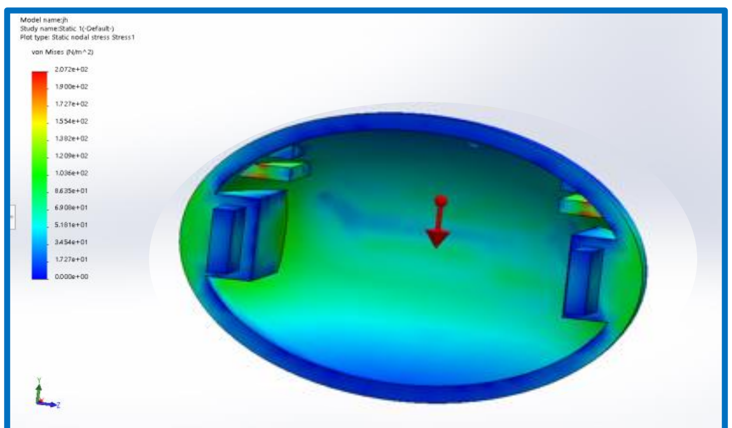
Integrated Level Functional Test Plan (5/7)

Stress analysis: PCB slots



Test output (Container):

- Stress analysis on 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.

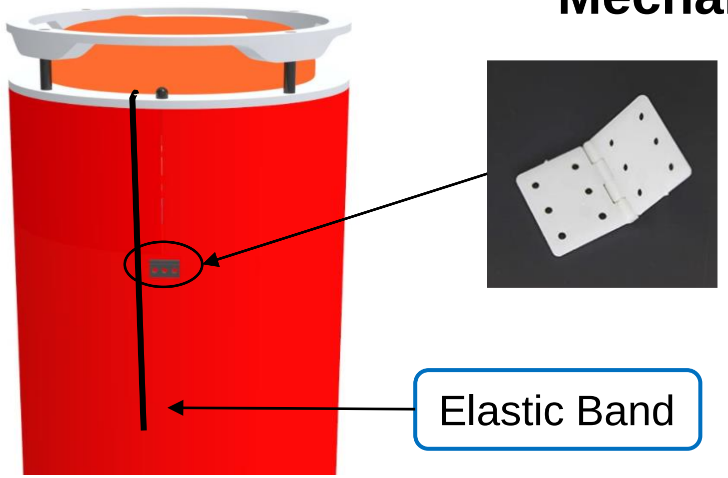


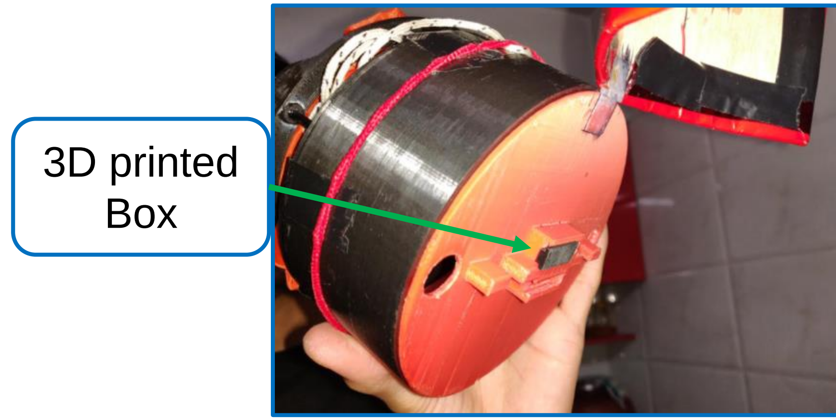
Test output (Payload):

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

Integrated Level Functional Test Plan (6/7)

Mechanisms





All release mechanisms are mechanical and heat based. **NO** pyro techniques, chemicals, lasers etc. have been used keeping safety in mind

CONTAINER:

- Nylon hinges are used to connect the electronics bay and the container doors.
- Elastic bands along with nichrome wire mechanism are used to open the container doors for the release of the science payloads at required heights.
- The nichrome wire is housed inside a 3D printed box making it easily accessible.

PAYLOAD:

- The wings of the science payloads are at a fixed calculated angle using 3D printed hollow extrusions.

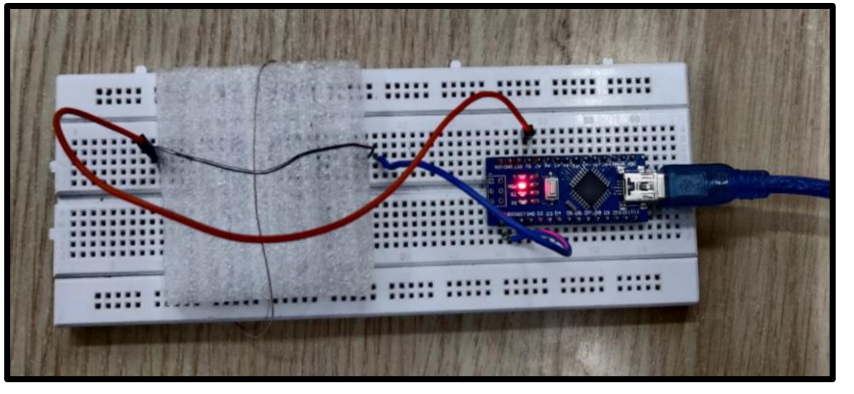
Integrated Level Functional Test Plan (7/7)

Deployment

Payload Release Mechanism Using Nichrome Wire

- The current and time required to cut the fishing line is measured
- Nichrome wires of different gauges were tested.
- Placement of the maple seeds were tested with the 3D printed extrusions.
- Deployment of the payloads at two different height will be tested.

3D printed extrusions

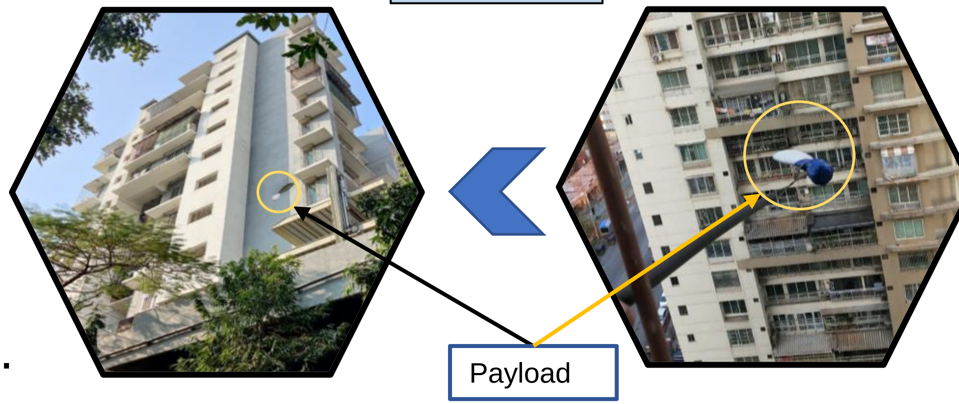


Environmental Test Plan (1/3)

Drop Test

- The payload was dropped from a height of approximately 60m to verify the survivability of the wing attachment and strength of the seed.
- Electronic components were integrated in the payload while testing.
- The payload achieved autorotation due to its structure and low CG.
- The descent time for the payload was approximately 3s.
- The container parachute was tested to ensure smooth deployment.
- Container has been manufactured and is yet to be drop tested.

Payload



Container

Environmental Test Plan (2/3)

Fit Check:

- Stowed CanSat dimensions are checked with a measuring tape.
- The length of the container was measured and found to be within 392 mm and diameter within 122 mm.
- Area of the wing is such that it fits inside the container without any hinderance.
- A compartment like the rocket CanSat section will be prepared to check the clearance of the CanSat.

Vacuum Test:

- A near deployment environment is created inside a closed chamber with the help of vacuum.
- The environment inside is monitored with the help of the telemetry received.
- As air is then allowed to enter, the payloads are deployed according to the change in the sensor values.

Environmental Test Plan (3/3)

Vibration Test:

- An orbit sander will be used. Orbit sander will operate at a fixed orbits per minute ranging from 12000 to 14000 orbits per minute.
- The CanSat will be placed along the edges of the orbit sander.
- The sander will be at full speed for 5 seconds.
- The amount of shaking generated by this sander is around 20 to 29 Gs.

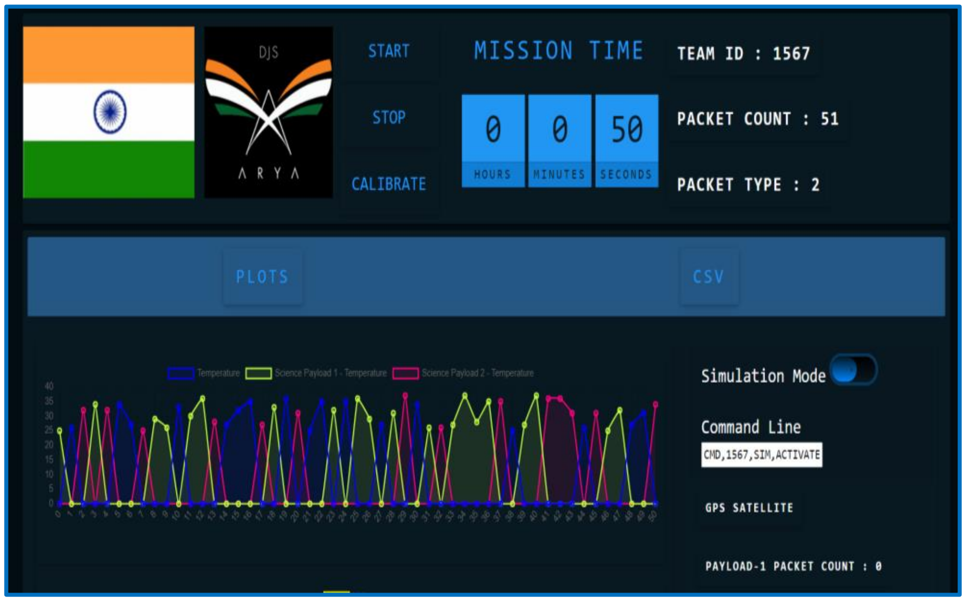
Thermal test:

- 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.
- 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.

Simulation Test Plan

Parts of CanSat getting tested during simulation

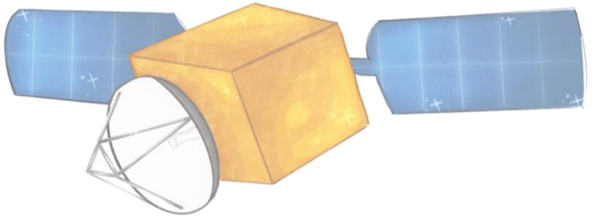
- Simulation test plan verifies the software state, release mechanism of the payloads and the telemetry received.



Simulation mode activation command

Methodology

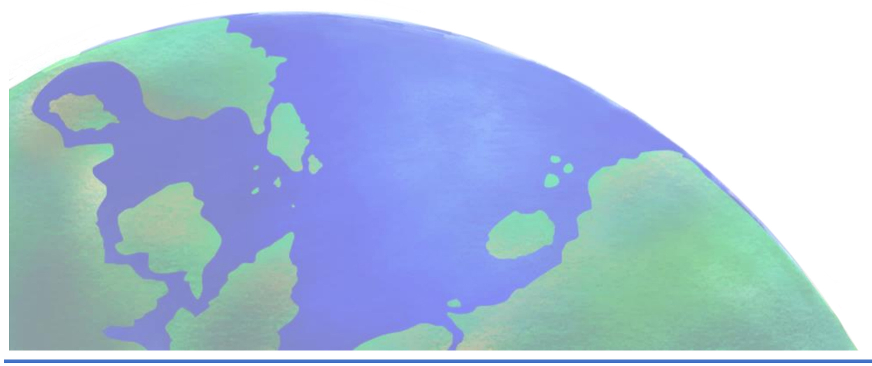
- Dummy files containing csv of air pressure are created.
- These values are then fed to Teensy 3.6.
- As the Teensy 3.6 receives the pressure values from the ground station it calculates the appropriate altitude.
- Software state of the CanSat is being verified.
- At 500 m and 400 m, the CanSat deploys both the payloads respectively.
- Release mechanism for payload release is also verified.



Mission Operation Analysis

Presenter's Name:

Anushka Kanabar



Overview of Mission Sequence of Events (1/5)

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 done
- 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 SW 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

- Integrity of CanSat shall be checked for any damage suffered during travel
- Drop test will be done

Arrival

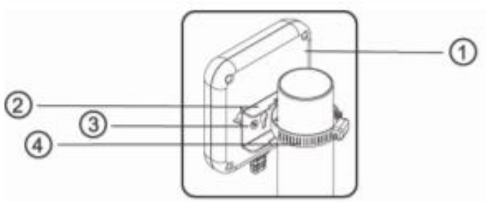
- Separation mechanism will be connected to the CanSat (fishing line)
- Parachute will be placed in parachute compartment of container
- Payload will be placed in container
- Checking the working and calibration of all sensors
- Calibrate the camera to the magnetic north of the earth
- Checking the ON/OFF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

Pre-Launch

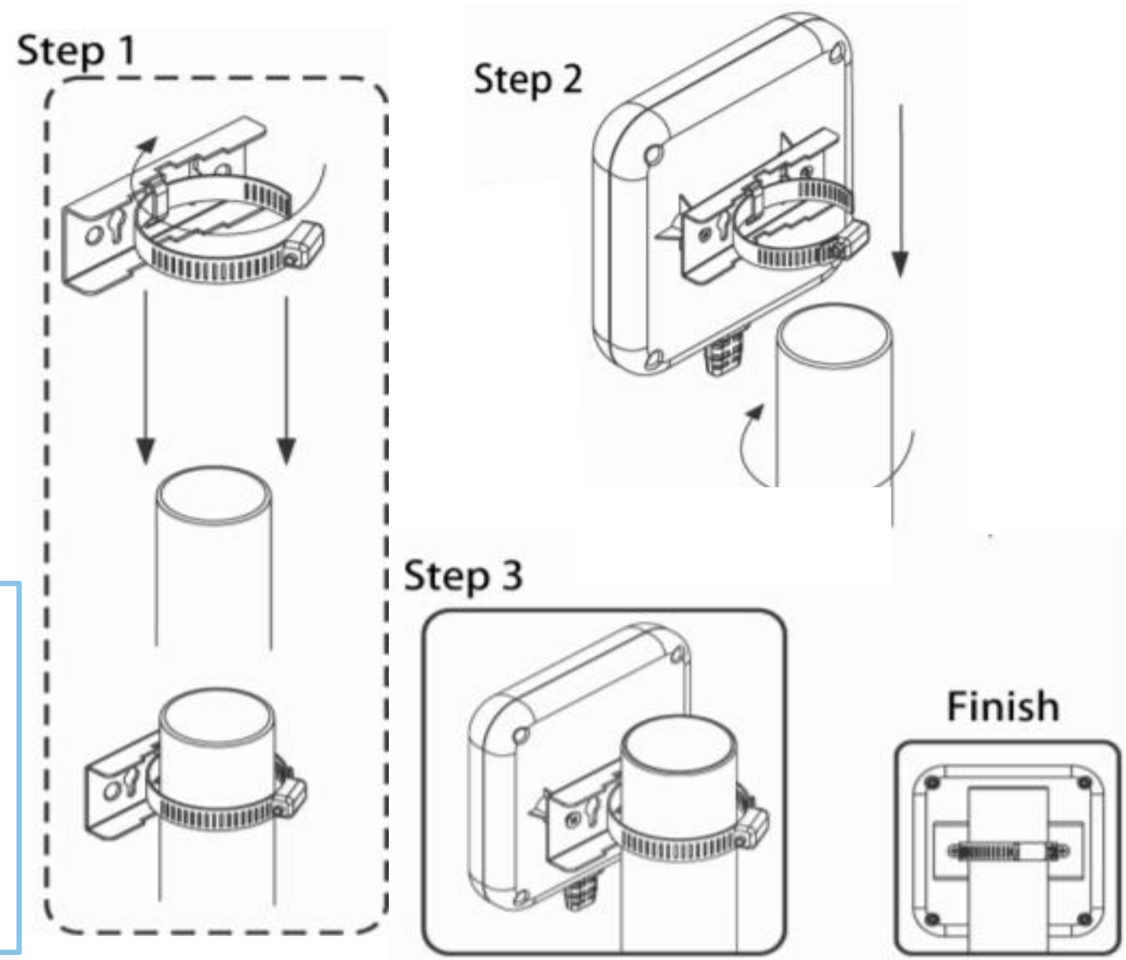
Overview of Mission Sequence of Events (3/5)

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.

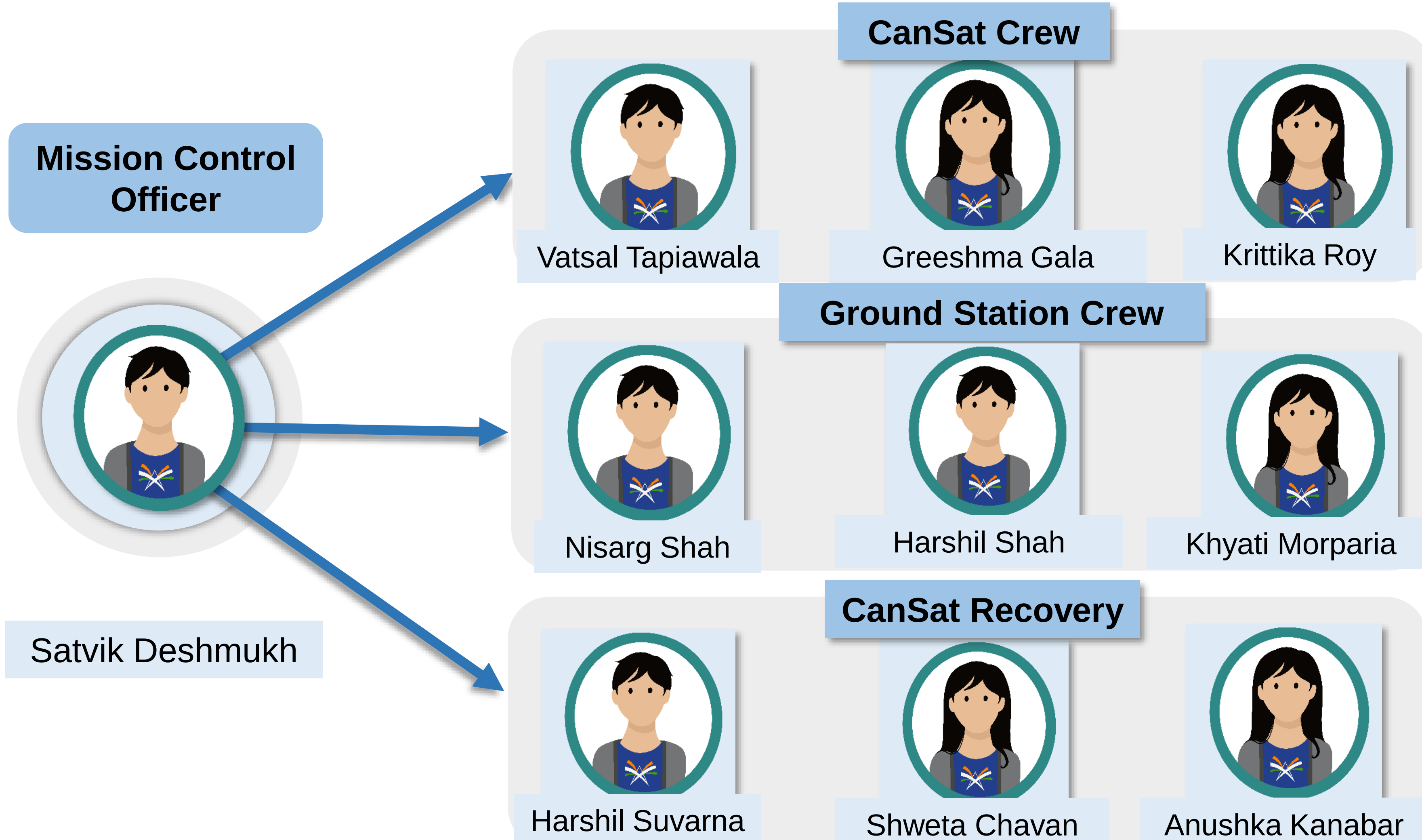
Data Analysis

- 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.

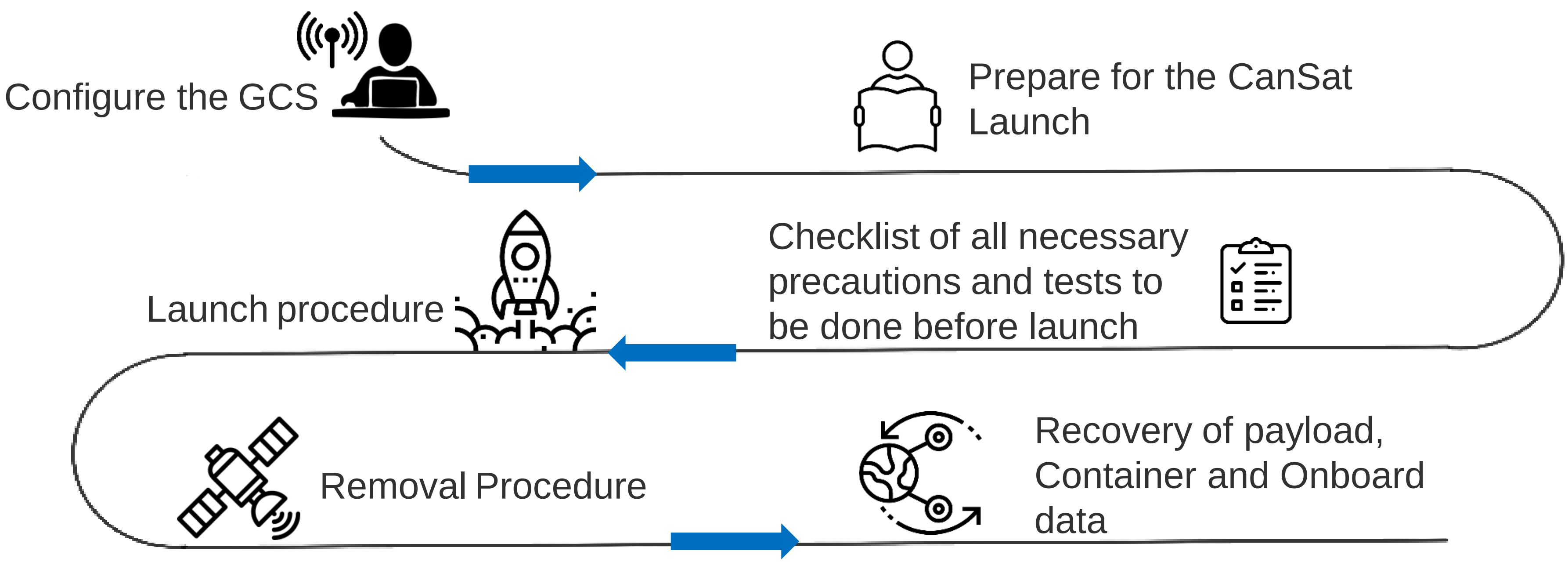
Overview of Mission Sequence of Events (5/5)



Mission Operations Manual Development Plan

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.

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.”



CanSat Location and Recovery

Container Recovery

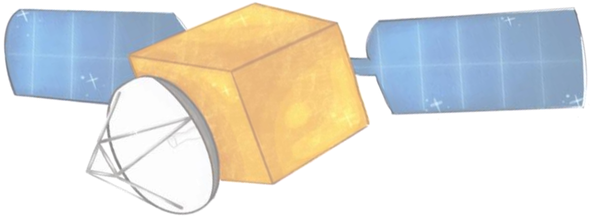
- Container color will be fluorescent red and hence easy to locate.
- The parachute will have a fluorescent orange color for the same reason.
- The audio beacon is of 95dB (which is more than 92 dB as per mission guide).
- A sticker with the team details and address will be attached to the container 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 SPACE Team
Team DJS ARYA #Team 1567
djsarya2021@gmail.com

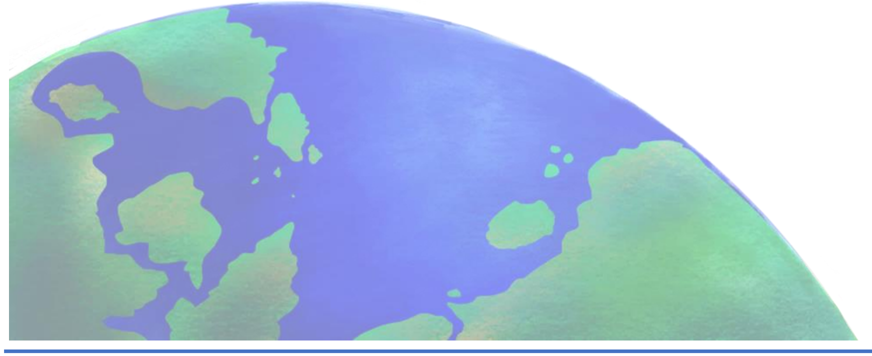
College sticker



Requirements Compliance

Presenter's Name:

Anushka Kanabar



Requirements Compliance Overview

Fully complied

- Almost 97% of the total requirements have already been complied.
- All safety features and size restrictions have been thoroughly complied.
- Every requirement complies with our design.
- Auto-rotating descent of the payload was completed.
- Management requirements are met.

Partially complied

➢ Further improvement stages until CDR

- The tables in the next slides are filled according to the requirement-based compliance which help us to see which of the mission requirements are fulfilled
- Most of the speed and altitude level mission requirements have been tested on lower heights than mentioned in the PDR, as there are height restrictions and limitations while testing these requirements from buildings. CanSat has shown sufficient performance to testify the designs requirements and verify our design.
- Appropriate camera tests were performed for the bonus mission, camera is yet to be integrated.
- All the environmental tests for this year are yet to be completed. However, the design has been made to comply with the test conditions.

➢ **The compatibility of the design with the mission requirements has been successfully tested.**

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.		118-122	Current weight is 596.2 gm (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	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	Complied
#CR4	The container shall be a fluorescent color; pink, red or orange.		82,237	Container is fluorescent red in color
#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.		106,111,117	Complied
#CR6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat		111-113	Complied
#CR7	The rocket airframe shall not be used as part of the CanSat operations		111-113	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.		114,115	Complied
#CR9	The Parachutes shall be fluorescent Pink or Orange		237	Complied
#CR10	The descent rate of the CanSat (container and science payload) shall be 15 meters/second +/- 5m/s. .		59,71,73	Tested at lower heights
#CR11	All structures shall be built to survive 15 Gs of launch acceleration.		216	Tested during drop test for 60+ meters
#CR12	All structures shall be built to survive 30 Gs of shock.		104,220-223	Tested during drop test for 60+ meter (verified using simulations)
#CR13	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high-performance adhesives.		116,117	Compiled
#CR14	All mechanisms shall be capable of maintaining their configuration or states under all forces.		104,216, 217,220-223	Verified using drop tests.
#CR15	Mechanisms shall not use pyrotechnics or chemicals.		224	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.		111,112	Compiled
#CR17	Both the container and payloads shall be labeled with team contact information including email address. .		237	Compiled
#CR18	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.		255	Cost presently approximately $539
#CR19	XBEE radios shall be used for telemetry 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.		134,148	XBEE Pro S2C used is 2.4 GHz radio
#CR20	XBEE radios shall have their NETID/PANID set to their team number		136	Complied
#CR21	XBEE radios shall not use broadcast mode.		136,149	XBEE is used in unicast mode
#CR22	The science payload shall descend spinning passively like a maple seed with no propulsion.		67,68,218, 219	Complied. Verified using drop test.

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. .		76	Tested at lower heights
#CR24	The wing of the science payload shall be colored fluorescent orange, pink or green.		237	Complied
#CR25	The science payload shall measure altitude using an air pressure sensor.		50	Complied
#CR26	The science payload shall measure air temperature.		51	Complied
#CR27	The science payload shall measure rotation rate as it descends.		52	Complied
#CR28	The science payload shall transmit all sensor data once per second.		149,178	Complied
#CR29	The science payload telemetry shall be transmitted to the container only.		135,149	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.		149	Complied
#CR31	The container shall include electronics to receive sensor payload telemetry.		132-136	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.		111-113,159	Nichrome wire mechanism is used
#CR33	The container shall include a GPS sensor to track its position.		54,237	Complied
#CR34	The container shall include a pressure sensor to measure altitude.		53,209	Complied
#CR35	The container shall measure its battery voltage.		55	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.		139,140, 149,151	Complied
#CR37	The container shall stop transmitting telemetry when it lands.		136	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.		33,34, 36,117	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.		36,107,234	Complied
#CR40	An audio beacon is required for the container. It may be powered after landing or operate continuously.		36,107, 136,175,234	Complied
#CR41	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.		237	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.		160,164	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.		107,117	Complied
#CR45	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.		117,160,164	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.		206,207, 226-228	Performed in-house
#CR47	The CanSat shall operate for a minimum of two hours when integrated into the rocket.		162,166,214	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.		177,178	Packet count is shown in GCS software
#CR49	The container must maintain mission time throughout the whole mission even with processor resets or momentary power loss.		177	Complied
#CR50	The container shall have its time set to UTC time to within one second before launch.		176	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.		179,194,195	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.		179	Complied
#CR53	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.		141,179,195	Complied
#CR54	The ground station shall command the CanSat to start transmitting telemetry prior to launch.		193	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.		194	The GUI has a “csv” button for this feature
#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.		137,177,178	GUI shows mission time with 1 second 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.		177	Complied
#CR58	Each team shall develop their own ground station.		187-198	Complied

Requirements Compliance (9/10)

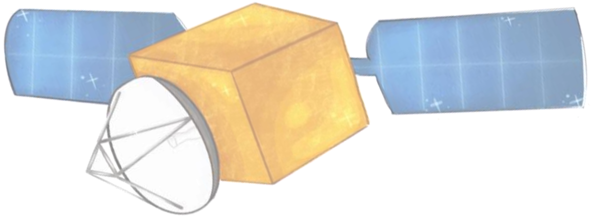
Req ID	Requirement	Compliance	Slide No.	Comments
#CR59	All telemetry shall be displayed in real time during descent on the ground station.		196	Complied and tested
#CR60	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		191	All data is plotted and displayed with proper units on the GUI
#CR61	Teams shall plot each telemetry data field in real time during flight.		193-196	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.		187,190	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.		187,190	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.		141,179,199	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.		179	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.		175,178	Complied

Bonus Objectives

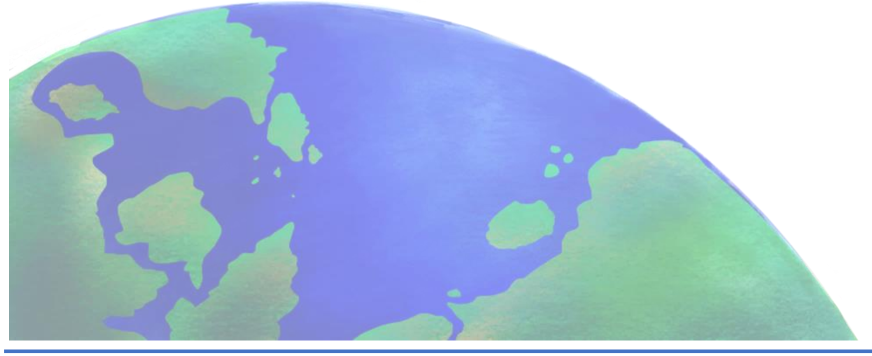
Req ID	Requirement	Compliance	Slide No.	Comments
#BNS1	A video camera shall be integrated into the container and point toward the ground. The camera shall capture the release of both science payloads and capture the descent of the science payloads. The video shall be spin stabilized with the view not 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..		45,56	Tested individually, yet to be integrated



Management

Presenter's Name:

Anushka Kanabar



CanSat Budget – Hardware (1/3)

Container Electronic Components:

Electronic Components	Model Number	Quantity	Unit Cost (₹) (Actual)	Total Cost (₹) (Actual)
Antenna	2.4GHz Male Omni Antenna	2	550.00	**1,100.00**
Atmospheric Sensor	BMP280	1	225.00	**225.00**
Battery	LG Li-ion Battery	2	490.00	**980.00**
Buzzer	Piezo 5V 95dB	1	40.00	**40.00**
Camera	Adafruit Mini Spy Camera	1	920.00	**920.00**
Coin Cell 3V	CR2032	1	85.00	**85.00**
GPS	Adafruit Ultimate GPS	1	2,900.00	**2,900.00**
Microcontroller	Teensy 3.6	1	2,900.00	**2,900.00**
Servo	MG995	1	240.00	**240.00**
Storage	SanDisk 16GB SD Card	1	350.00	**350.00**
Voltage Regulator	Pololu Voltage Regulator	1	200.00	**200.00**
XBEE	XBEE S2C Pro	2	2,150.00	**4,300.00**
Voltage Divider	Resistors in Parallel	1	10.00	**10.00**
Total Cost:				**14,250.00**

CanSat Budget – Hardware (2/3)

Payload Electronic Components:

Electronic Components	Model Number	Quantity	Unit Cost (₹) (Actual)	Total Cost (₹) (Actual)
Atmospheric Sensor + RPM Sensor	10-DoF IMU Board	1	590.00	**590.00**
Battery	LG Li-ion Battery	1	490.00	**490.00**
Microcontroller	Arduino pro mini	1	200.00	**200.00**
Voltage Regulator	Pololu Voltage Regulator	1	200.00	**200.00**
XBEE	XBEE S2C Pro with Whip Antenna	1	2,150.00	**2,150.00**
Total Cost:				**3,630.00**

There are two payloads:
Total Cost of 2 Payload's Electronic Components = 2 x 3,630.00
= ₹ 7,260.00

CanSat Budget – Hardware (3/3)

Mechanical Components:

Mechanical Components	Details	Quantity	Unit Cost (₹) (Actual)	Total Cost (₹) (Actual)
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 + Nylon hinges	4	330.00	**1,320.00**
Container Body	Fiberglass	2	1,100.00	**2,200.00**
Payload	PETG + Monokote(3m)	3 kg	1,200.00 (per kg)	**3,600.00**
Parachute Material	Ripstop Nylon (50x50 cm^2)	5	200.00	**1,000.00**
Release Mechanism	Nichrome Wire + MOSFETS + fishing line	2	50	**100.00**
Adhesives	Cyanoacrylate, Epoxy, etc.	-	-	**2,000.00**
Power tools	Drilling Machine, Hacksaw, etc.	**College Provided**		
Total Cost:				**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 used: 1 USD($) = 75.003 INR(₹)

Item	Cost (₹)	Cost ($)
Electronic Total Cost	21,510	298.73
Mechanical Total Cost	12,620	168.26
Ground Station Total Cost	5,650	75.33
Total Costs:	**39,780**	**542.32**

Total cost for making one CanSat is USD 542.32 which is less than USD 1000

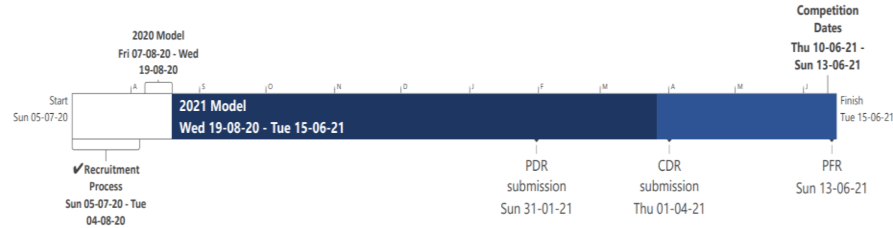
Source of income:

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

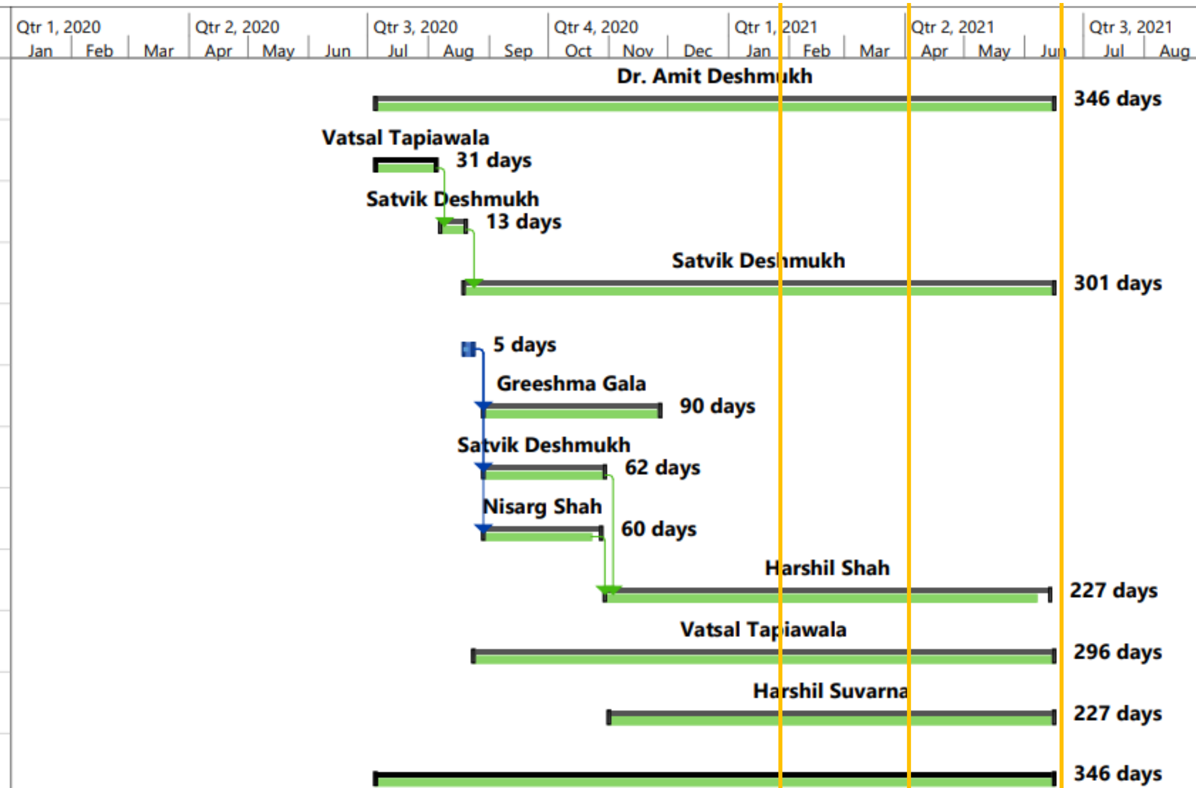
Note: Due to virtual competition, Travel expense is excluded

Program Schedule Overview

Major Milestones

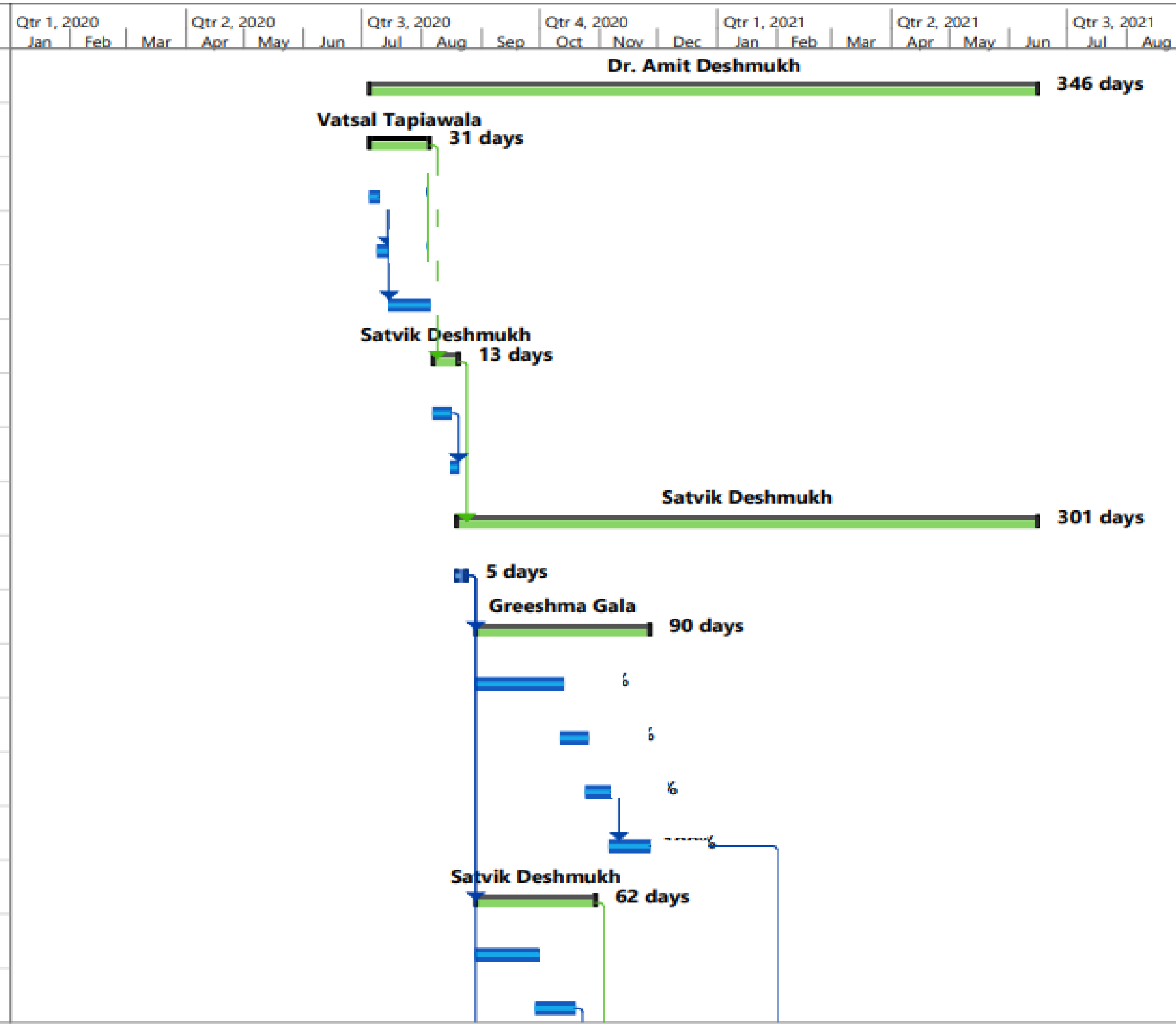


ID	Task Name	Start	Finish
1	**CanSat USA 2021**	**Sun 05-07-20**	**Tue 15-06-21**
2	**Recruitment Process**	**Sun 05-07-20**	**Tue 04-08-20**
6	**2020 Model**	**Fri 07-08-20**	**Wed 19-08-20**
9	**2021 Model**	**Wed 19-08-20**	**Tue 15-06-21**
10	Problem Statement Analysis	Wed 19-08-20	Sun 23-08-20
11	**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**



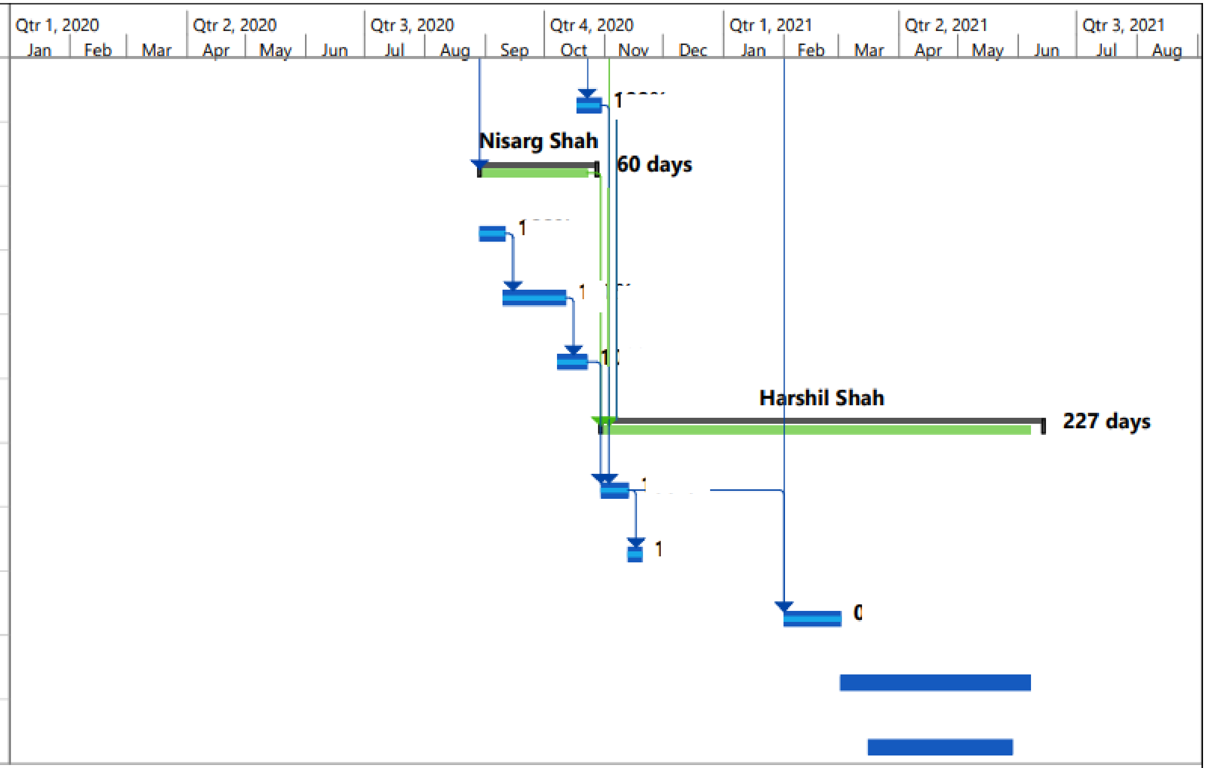
Detailed Program Schedule (1/4)

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	Mon 12-10-20	Sun 25-10-20
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	Tue 29-09-20	Sun 18-10-20



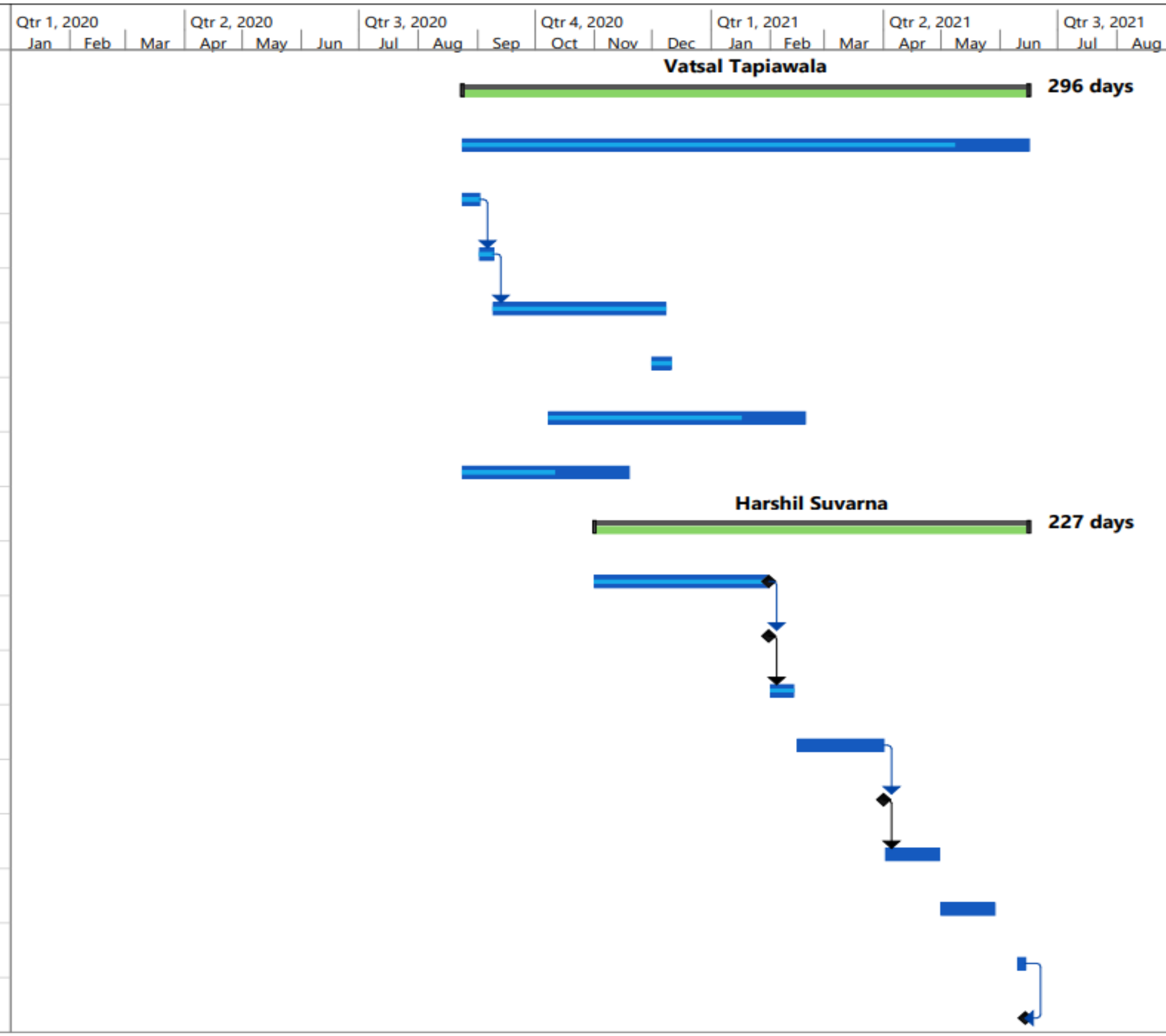
Detailed Program Schedule (2/4)

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



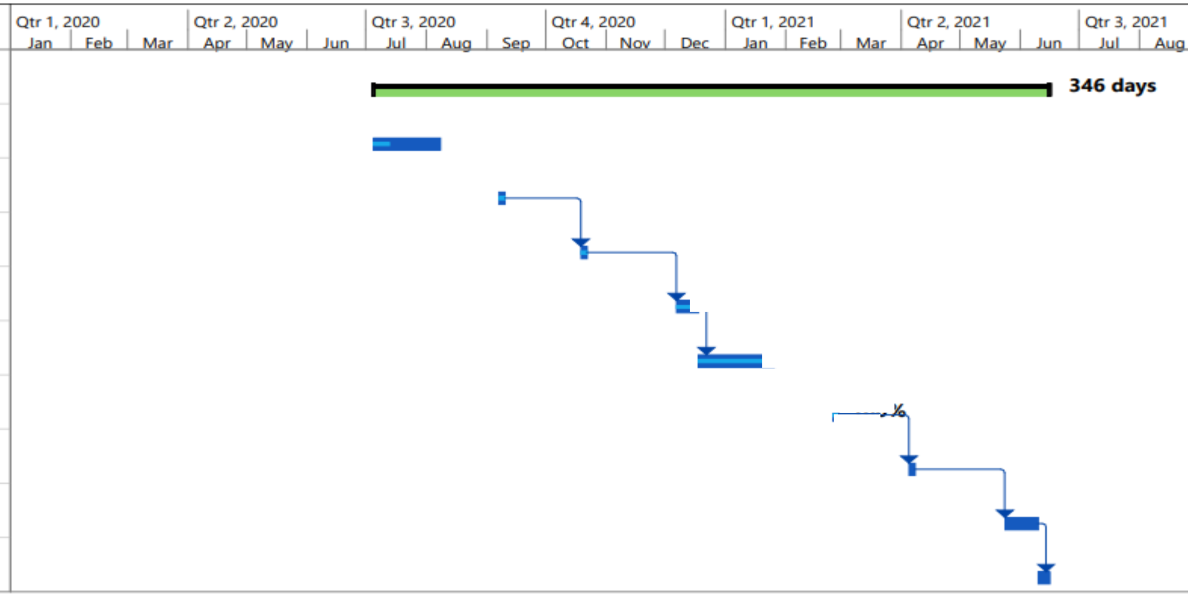
Detailed Program Schedule (3/4)

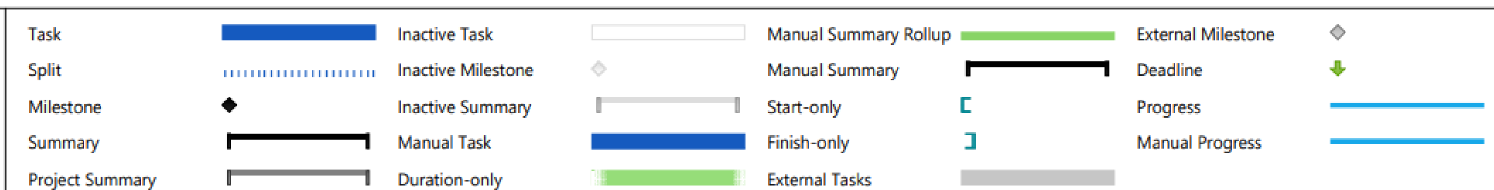
ID	Task Name	Start	Finish
30	**Marketing & Finance**	**Mon 24-08-20**	**Tue 15-06-21**
31	Social Media Updation	Mon 24-08-20	Tue 15-06-21
32	Funding Proposal for College	Mon 24-08-20	Tue 01-09-20
33	Marketing Proposal for Potential Sponsors	Wed 02-09-20	Tue 08-09-20
34	On-field Marketing	Wed 09-09-20	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





Conclusions (1/5)

Electronics and Programming

Major Accomplishments

- The flight software is 90 percent complete
- The selection, purchase and procurement of components was done
- Simulation, testing and implementation of the entire electronics system done
- GUI was intricately designed and developed

Major Unfinished Work

- Partial testing with the actual payload in real flight conditions is yet to be done. It was not possible due to the outbreak of COVID-19. 40% implementation of the MQTT protocol is yet to be finished

Conclusions (2/5)

Mechanics and Aerodynamics

Major Accomplishments

- Simulations of structural parts on various applications were cohesively used
- The positives and negatives of various structural parts were weighed out to determine the whole model.
- Various tests were successfully performed on the container as well as the payload

Major Unfinished Work

- Bonus objective still to be integrated with the full mechanical system

Conclusions (3/5)

Administration and Finance

Major Accomplishments

- Management funding proposal was verified and approved by the university
- Final draft of PDR is completed
- Various ground tests were conducted at the university, abiding by the govt rules during the pandemic
- Online workshops and seminars were conducted to increase the awareness of the competition and working of DJS Arya

Major Unfinished Work

- Monetary income is only partially secured

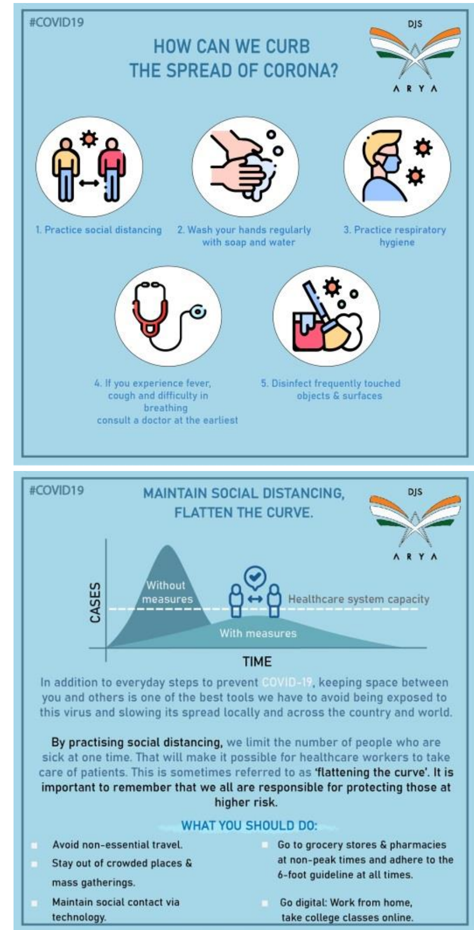
Conclusions (4/5)

Other Accomplishments

- As a team, we expand our knowledge through in-depth research and improvise our designs in order to improve our rank every year, considering the errors made in previous years
- With the help of our 3D printing sponsors, we managed to use a part of our funds to make face shields and distribute them as a precautionary measure
- We have been interviewed for our work and have gained **national recognition** for it
- A **video documentary** has been made on DJS Arya, YouTube links are given below

https://www.youtube.com/watch?v=J2QoQt2itAM
https://www.youtube.com/watch?v=4t7TsMYnec4

Unfortunately, due to the COVID-19 pandemic, the competition will be held virtually. We strongly support the decision made by the organizing team of the CanSat competition as safety and health should be the top priority.



Social media posts on COVID-19 awareness

Conclusions (5/5)

Reasons to proceed to the next stage of development:

1) Team has been on track so far in terms of:
    - Designing and manufacturing of CanSat
    - Testing and partial integration of electronics
    - Development of ground station software
2) Continued availability of virtual platforms for team activities
3) Absence of any major university level events
4) Completion of the environmental tests have been scheduled