CanSat 2018

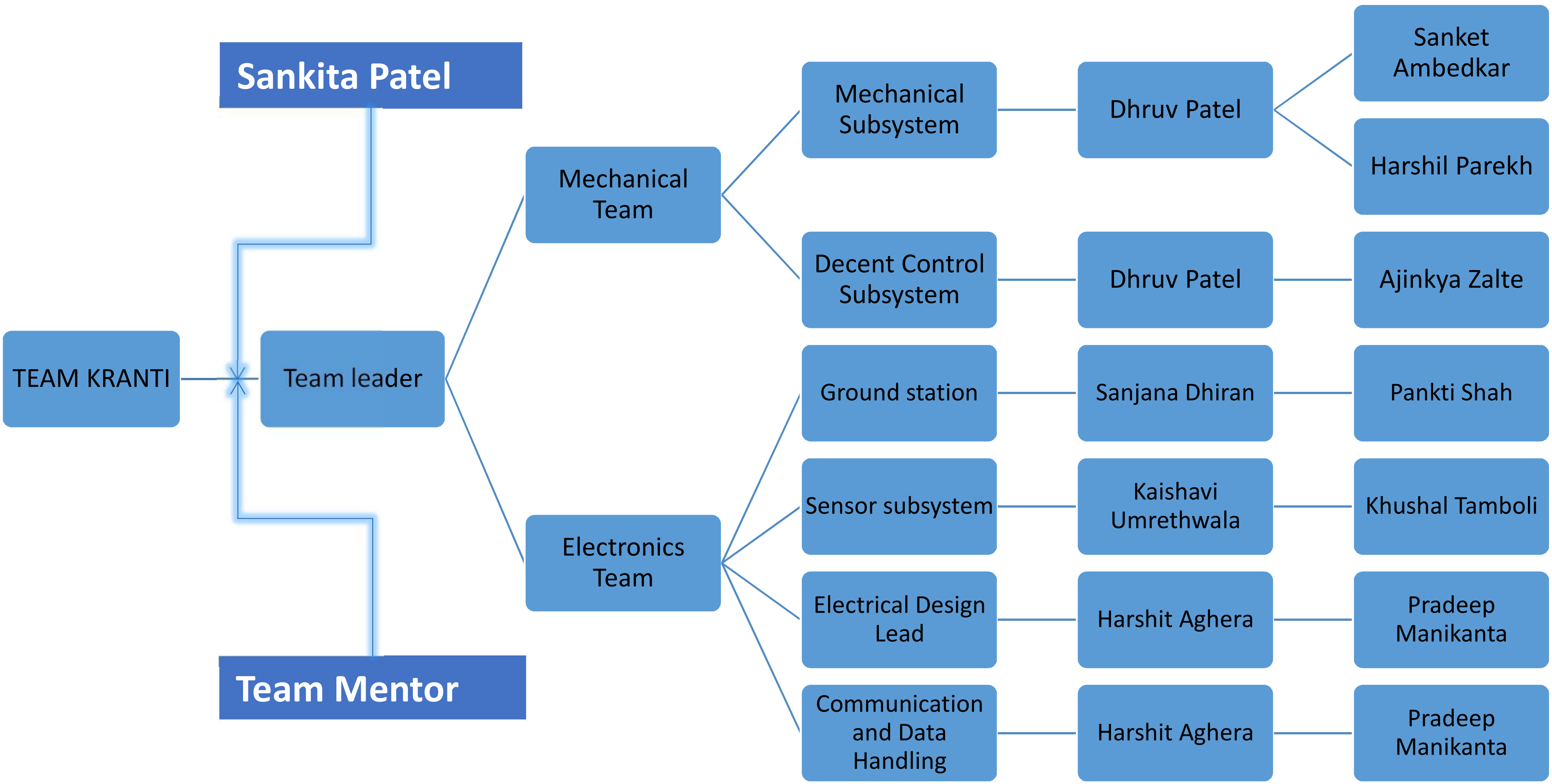
Preliminary Design Review (PDR)

TEAM KRANTI

TEAM#2610

SARDAR VALLABHBHAI NATIONAL INSTITUTE OF TECHNOLOGY

Team Organization



Acronyms

A	Analysis
AoA	Angle of attack
ALT	Altitude
API	Application Programme Interface
ADC	Analog to Digital Convertor
CONOP	Critical Design Report
CDR	Concept Of Operation
D	Demonstrate
DCS	Descent Control System
EEPROM	Electrically Erasable Programmable Read Only Memory
FPS	Frames Per Second
FIFO	First In First Out
FSW	Flight software
GCS	Ground Control System
GUI	Graphical User Interface
GCB	General Circuit Board
GPS	Global Positioning System
HS	Heat Shield

Acronyms

Hz	Hertz
I	Inspection
IC	Integrated Circuit
I2C	Inter-Integrated Circuit
IMU	Inertial Measurement Unit
MCU	Microcontroller Unit
PCB	Printed Circuit Board
PoS	Parameter of Selection
PDR	Preliminary Design Report
PO	Primary Objective
PD	Payload design
RTC	Real Time Clock
SV	Science Vehicle
SPI	Serial Peripheral Interface
T	Test
UTC	Universal Time Clock

Systems Overview

DHRUV PATEL

Mission Summary

MISSION OBJECTIVES

- To simulate a space probe (CanSat) entering a planetary atmosphere.
- CanSat contains detachable heat shield, parachute, electronics, egg which survive all portions of flight.
- Probe deployed from 670 meters to 725 meters of altitude.
- Probe is protected by aero-braking heatshield maintaining decent rate 10 to 30 meters/sec.
- At an altitude of 300 meters, the probe shall release the aero-braking heat shield and simultaneously deploy a parachute to reduce the decent rate of 5 meters/sec.
- Probe shall include sensors for tracking altitude, external temperature, battery voltage, GPS position and tilt sensor for stability verification.

BONUS OBJECTIVE

- A camera shall capture deployment of heat shield and ground

EXTERNAL OBJECTIVE

- Drop test using solidworks
- Setup of Current measuring system aiming to provide fail safe ability to Electronics subsystem.
- Storing Software state in external storage device and read from it at every system boot to increase software robustness.

System Requirement Summary

ID	REQIREMENT	RATIONALE	PRIORITY	CHILD	VM			
					A	I	T	D
SRS-01	Total mass of CanSat shall be 500 grams +/- grams	Mission Requirement	High	DSC-01, MSR-01	✓	✓		
SRS-02	CanSat shall fit in cylindrical envelop of 125mm x 310 mm	Mission Requirement	High	DSC-02, MSR-02	✓	✓		
SRS-03	Probe shall not tumble during any portion of decent for the verification tilt sensor is used.	Mission Requirement	High	SSR-04	✓	✓		
SRS-04	Probe shall maintain heat shield orientation in decent	Mission Requirement	High	DSC-03	✓	✓		
SRS-05	Heat shield shall not contain any sharp edges and openings	To facilitate deployment	High	DSC-07, MSR-03, MSR-14	✓	✓		✓
SRS-06	Probe shall protect egg until landing	Mission Requirement	High	MSR-08	✓	✓	✓	

System Requirement Summary

ID	REQUIREMENT	RATIONALE	PRIORITY	CHILD	VM			
					A	I	T	D
SRS-07	The rocket airframe shall not be used as part of the CanSat	Mission Requirement	High		✓		✓	
SRS-08	Aero-braking heat shall of florescent colour; pink or orange	To see it from long distance	High		✓	✓		
SRS-09	The CanSat, probe with heat shield attached shall deploy from the rocket payload section	Mission Requirement	High		✓	✓		
SRS-10	The aero-braking heat shield shall be released and deploy a parachute from the probe at 300 Meters	Mission Requirement	High	DSC-08, MSR-09, MSR-16	✓	✓		
SRS-11	No lasers allowed	Mission Requirement	High		✓	✓		

System Requirement Summary

ID	REQIREMENT	RATIONALE	PRIORITY	CHILD	VM			
					A	I	T	D
SRS-12	All descent control device attachment and decent control components shall survive 30 Gs of shock.	Mission Requirement	High	DSC-04, MSR-10, MSR-15	✓	✓		
SRS-13	Spring contacts shall not be used for making electrical connections to batteries	Mission Requirement	High		✓	✓		
SRS-14	All electronic components shall be enclosed and shielded from the environment	Mission Requirement	High	SSR-10	✓	✓		
SRS-15	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost	Cost effectiveness	High		✓	✓		

System Requirement Summary

ID	REQIREMENT	RATIONALE	PRIORITY	CHILD	VM			
					A	I	T	D
SRS-16	All electronics shall be hard mounted using proper mounts	Mission Requirement	High	SSR-11, MSR-07	✓	✓		
SRS-17	All mechanisms shall be capable of maintaining their states under all forces	Mission Requirement	High	MSR-04	✓	✓		
SRS-18	Mechanisms shall not use pyrotechnics or chemicals	Safety purpose	High	MSR-05	✓	✓		
SRS-19	Mechanisms that use heat shall not be exposed to the outside environment	To protect it from environment	High		✓			
SRS-20	Both the heat shield and probe shall be labelled with team contact information including email address	Mission Requirement	High	MSR-12	✓	✓		

System Requirement Summary

ID	REQIREMENT	RATIONALE	PRIORITY	CHILD	VM			
					A	I	T	D
SRS-21	During descent, the probe shall collect air pressure, outside air temperature, GPS position and battery voltage once per second and time tag the data with mission time	Mission Requirement	High	SSR-01, SSR-02, SSR-03, SSR-05, SSR-06, SSR-12, FSW-01, FSW-02			✓	
SRS-22	During descent, the probe shall transmit all telemetry	Mission Requirement	High	CDH-01, FSW-04, GCS-01, GCS-02	✓		✓	
SRS-23	XBEE radios shall have their NETID/PANID set to their team number	Mission Requirement		CDH-06		✓	✓	
SRS-24	All structures shall be built to survive 15 Gs of launch acceleration and 30 Gs of shock	Mission Requirement	High	SSR-07, MSR-06	✓	✓		

System Requirement Summary

<table>
<tr><th rowspan="2">ID</th><th rowspan="2">REQIREMENT</th><th rowspan="2">RATIONALE</th><th rowspan="2">PRIORITY</th><th rowspan="2">CHILD</th><th colspan="4">VM</th></tr>
<tr><th>A</th><th>I</th><th>T</th><th>D</th></tr>
<tr><td>SRS-25</td><td>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</td><td>Mission Requirement</td><td>High</td><td>CDH-02, FSW-05, FSW-06</td><td>✓</td><td></td><td></td><td></td></tr>
<tr><td>SRS-26</td><td>XBEE radios shall be used for telemetry. 2.4 GHz Series 1 and 2 radios are allowed. 900 MHz XBEE Pro radios are also allowed</td><td>Mission Requirement</td><td>High</td><td>GCS-02
CDH-01</td><td></td><td>✓</td><td>✓</td><td></td></tr>
<tr><td>SRS-27</td><td>Each team shall develop their own ground station portable ground station</td><td>Mission Requirement</td><td>High</td><td>GCS-03, GCS-08</td><td>✓</td><td>✓</td><td></td><td></td></tr>
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System Requirement Summary

ID	REQIREMENT	RATIONALE	PRIORITY	CHILD	VM			
					A	I	T	D
SRS-28	The ground station shall include one laptop, XBEE radio and a hand held antenna	Mission Requirement	High	GCS-07	✓			
SRS-29	The descent rate with the heat shield deployed shall be between 10 and 30 m/s and parachute deployed shall be 5 m/s	Mission Requirement	High	DSC-05, DSC-09	✓	✓		
SRS-30	An audio beacon is required for the probe. It may be powered after landing or operate continuously	Mission Requirement	High	SSR-09, MSR-11, FSW-08, EPS-08		✓		

System Requirement Summary

ID	REQIREMENT	RATIONALE	PRIORITY	CHILD	VM			
					A	I	T	D
SRS-31	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	Mission Requirement	High	FSW-03, FSW-06, FSW-07, EPS-08	✓			
SRS-32	XBEE radios shall not use broadcast mode	Mission Requirement	High	CDH-08 CDH-03	✓	✓		
SRS-33	All telemetry shall be displayed in real time during descent in engineering units	Mission Requirement	High	GCS-04, GCS-05	✓	✓		
SRS-34	Teams shall plot each telemetry data field in real time during flight	Mission Requirement	High	GCS-06	✓			

System Requirement Summary

ID	REQIREMENT	RATIONALE	PRIORITY	CHILD	VM			
					A	I	T	D
SRS-35	An easily accessible battery compartment must be included with battery source	Mission Requirement	High	EPS-06	✓	✓		
SRS-36	The probe must include an easily accessible power switch	To easy on/off	High	EPS-01	✓			
SRS-37	The probe must include a power indicator such as an LED or sound generating device	After landing to find the probe	High	EPS-02	✓			
SRS-38	SD card is to be used to store video and telemetry data	For data backup	Medium	SSR-08 CDH-11	✓	✓	✓	
SRS-39	Camera shall take a video at the time of releasing heat shield	Bonus objective	High	CDH-12 FSW-09	✓	✓		

System Level CanSat Configuration Trade & Selection

CONFIGURATION 1:

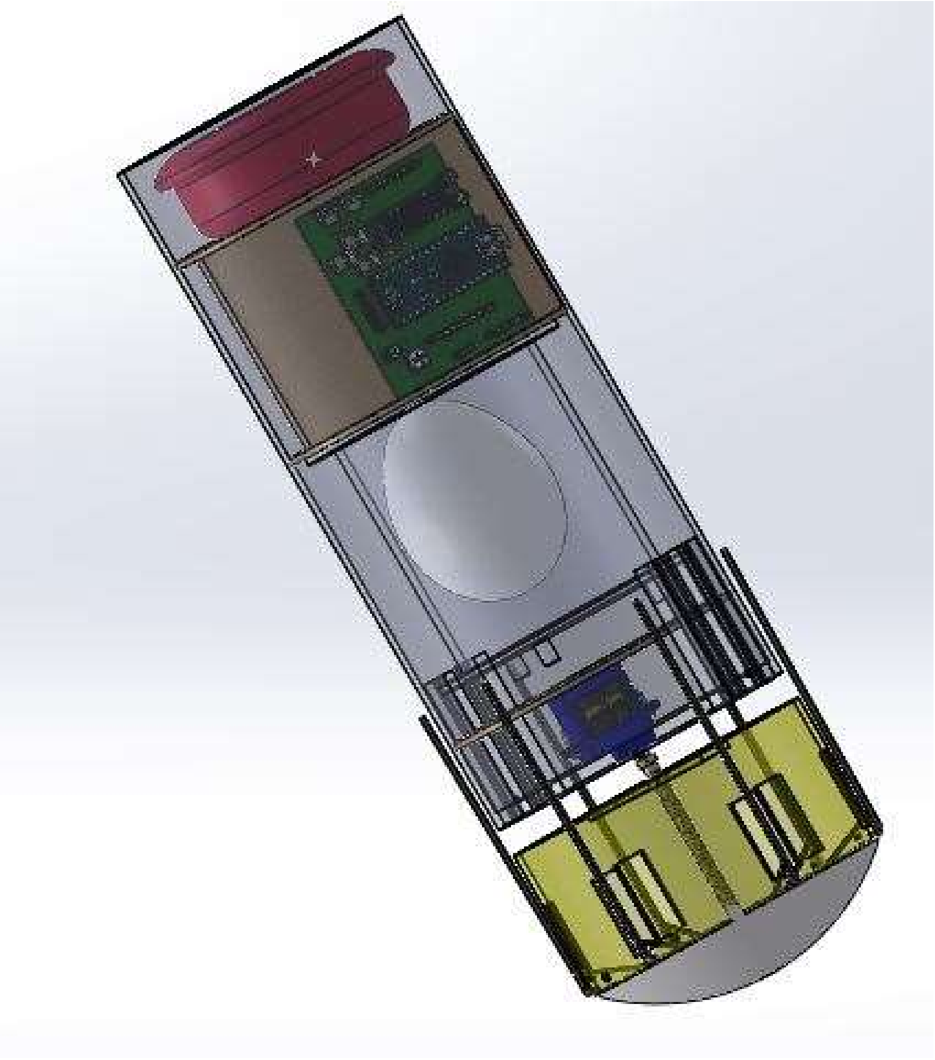
- To develop the Heat-Shield, lead screw mechanism is used, as the servo motor is actuated the lead screw rotates pushing the module to open the rods to form the required structure.

PROS :

- Simple design
- Easier locking of the heat shield configuration

CONS :

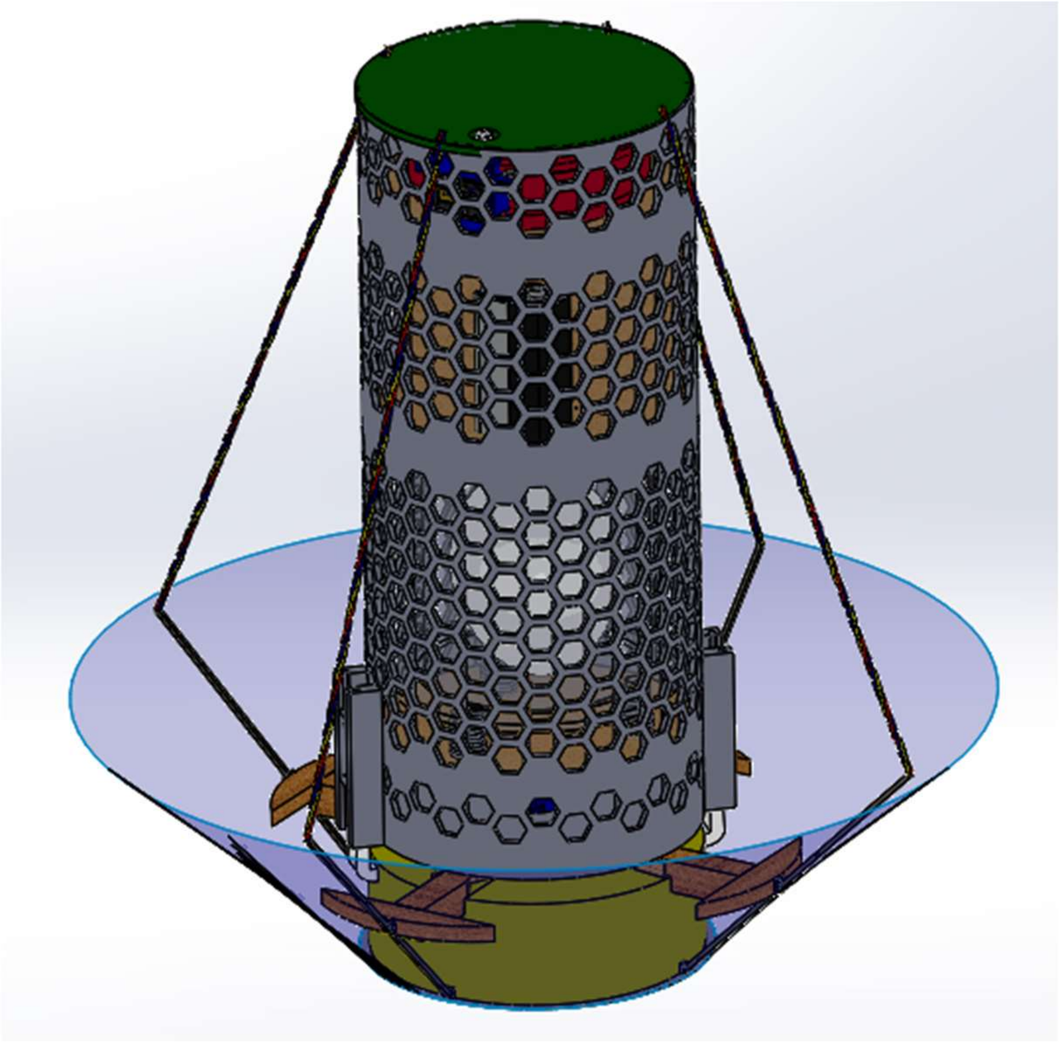
- The overall design takes up a lot of space.
- The weight of the mechanism is considerable.
- Not feasible for the deployment of heat shield



System Level CanSat Configuration Trade & Selection

CONFIGURATION 2

- Honey-comb structure is use for container.
- To open the Heat-Shield we use cam-follower mechanism
- Rope is used for stability of system
- Spring is used as shock absorber so forces are damped.



PROS

- The overall weight of the mechanism is considerably less.
- Easier deployment configuration.
- High reliability.

CONS

- Extra arrangement for locking of mechanism in one configuration.

System Level CanSat Configuration Trade & Selection

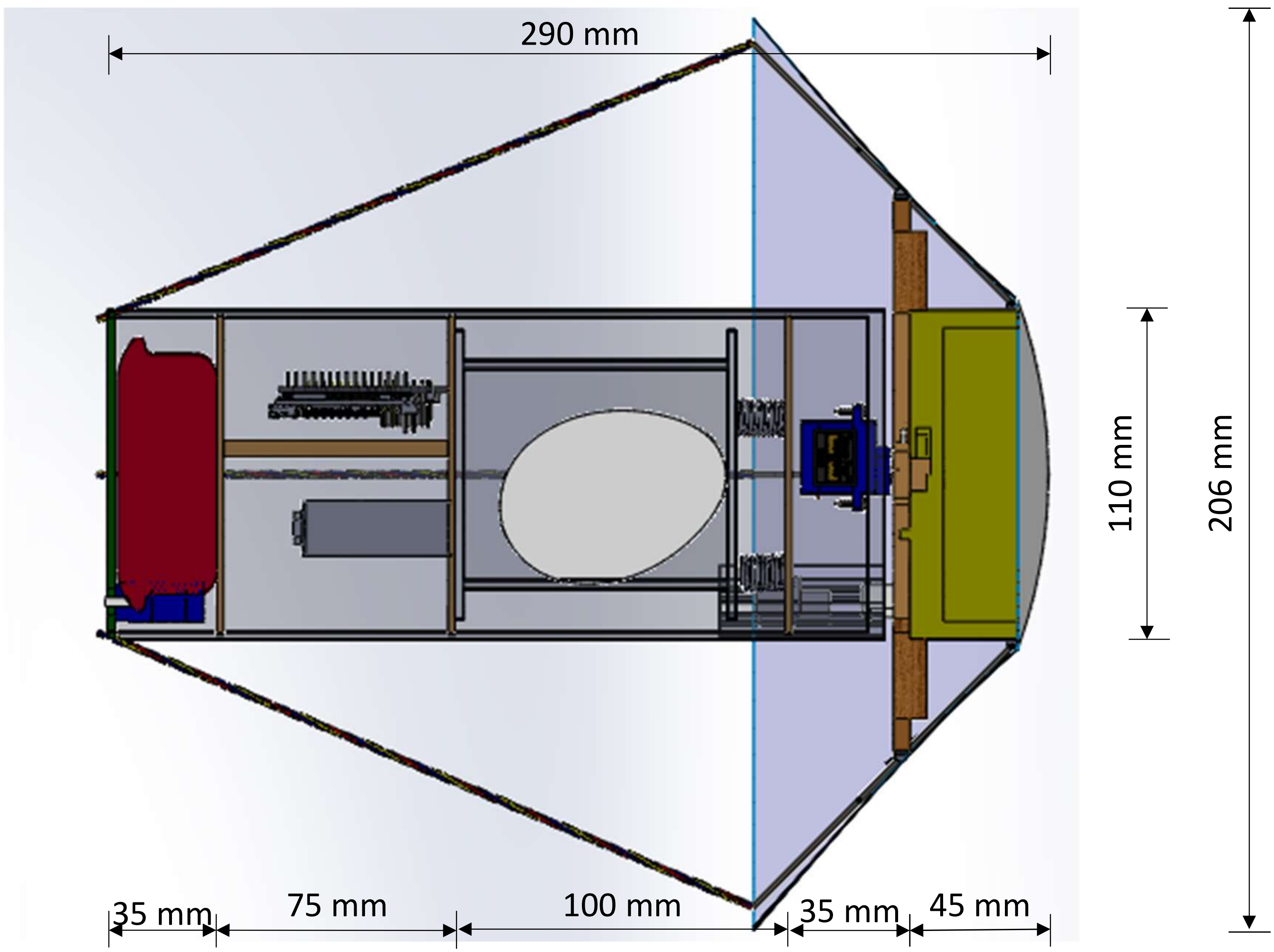
Design \ Property	Strength	Ease of Fabrication	Feasibility	Weight	Cost
Configuration 1	8	7	7	9	9
Configuration 2	9	9	9	7	7

Configuration 2 was selected owing to its high strength and Ease of fabrication

Grading (0-10) :
0 – Least
10 - Most

Physical Layout

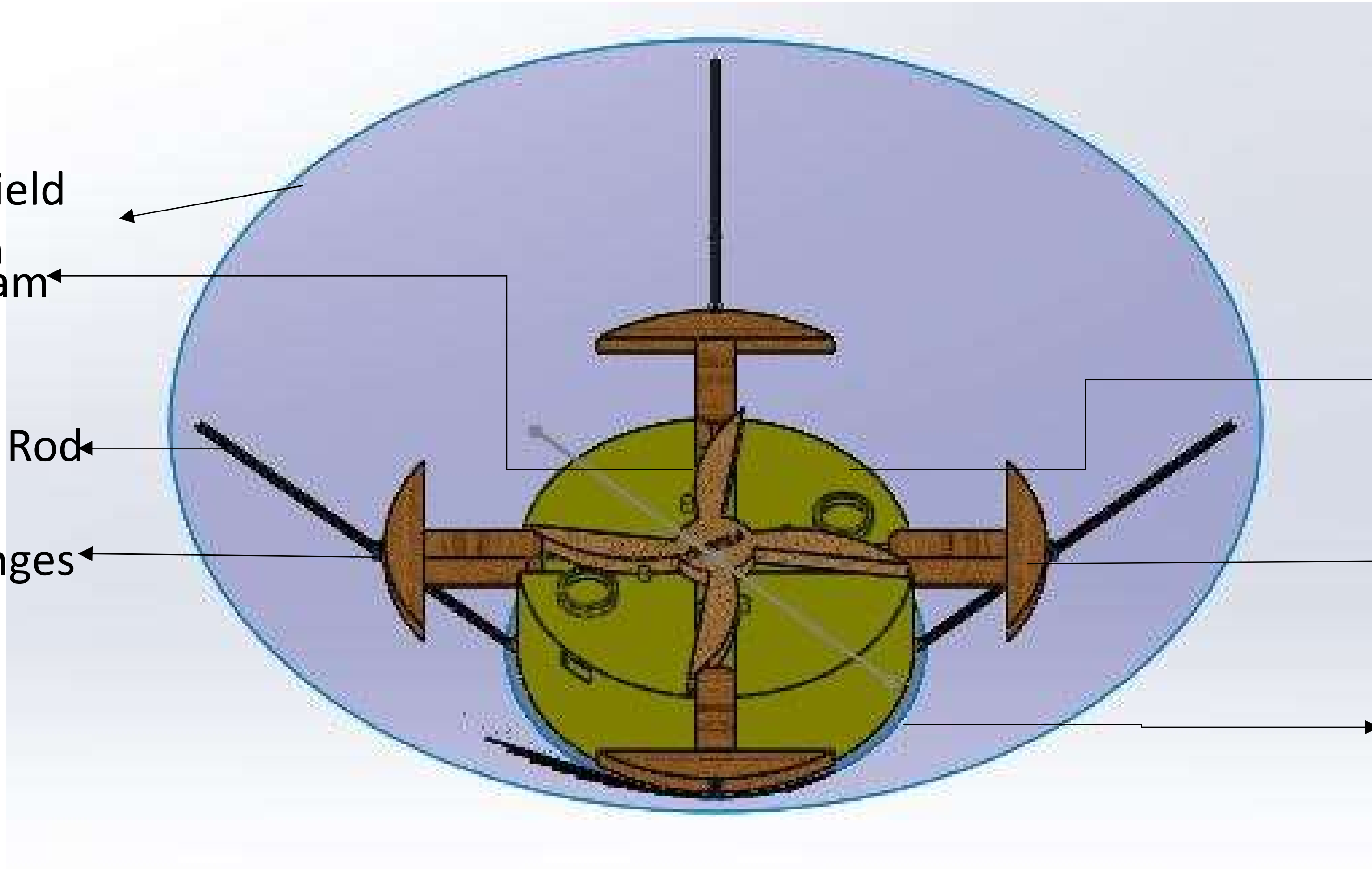
CanSat Dimensions Layout



Physical Layout

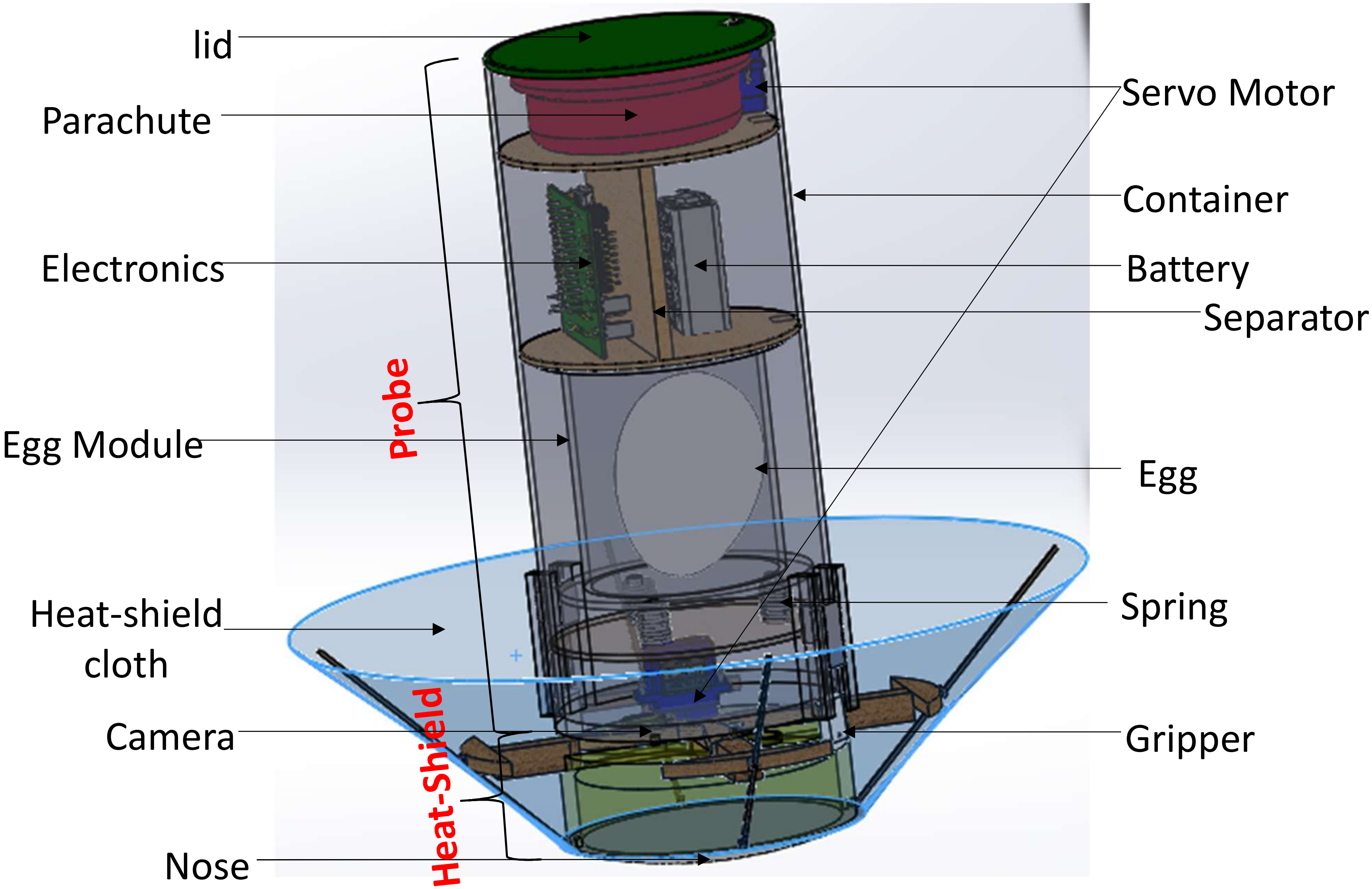
ANNUAL CANSAT COMPETITION

Heat - Shield



Physical Layout

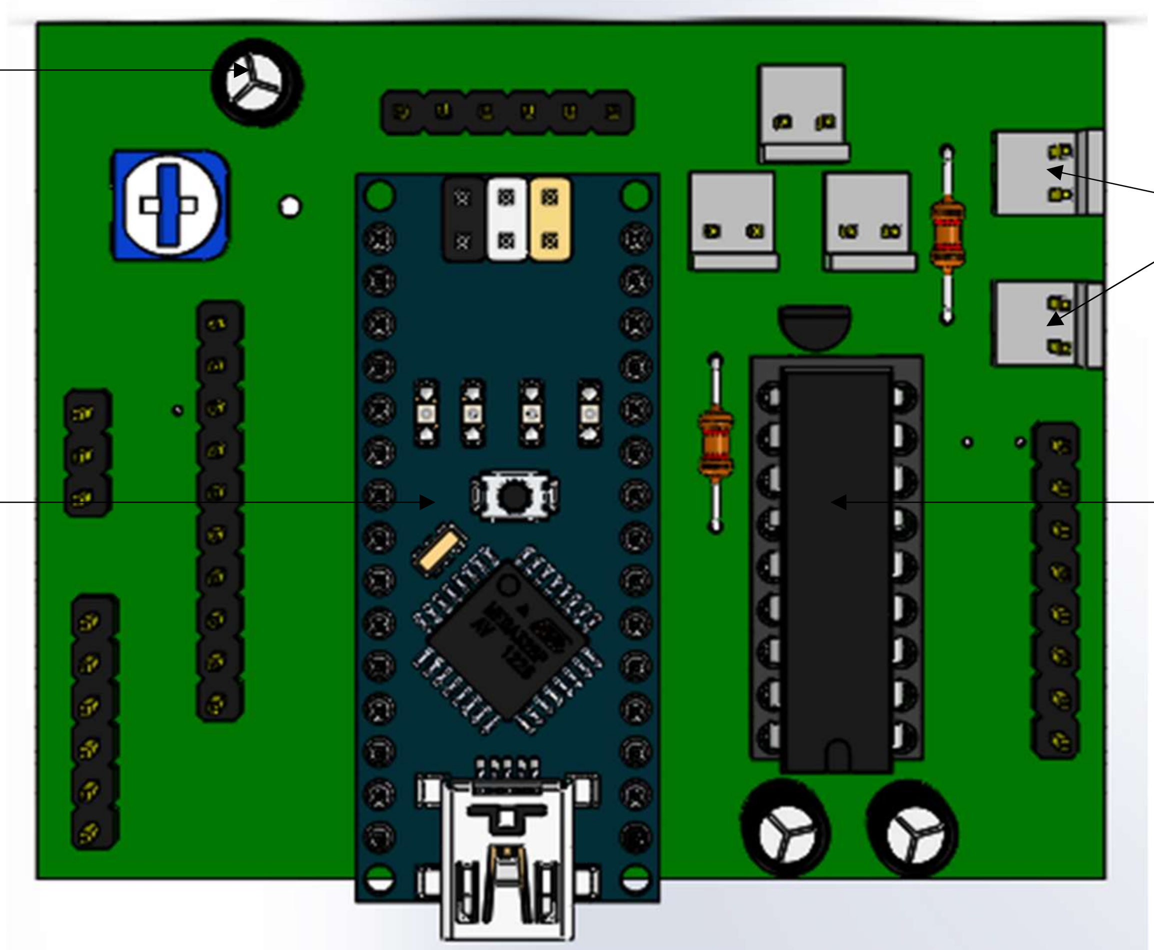
CanSat Layout



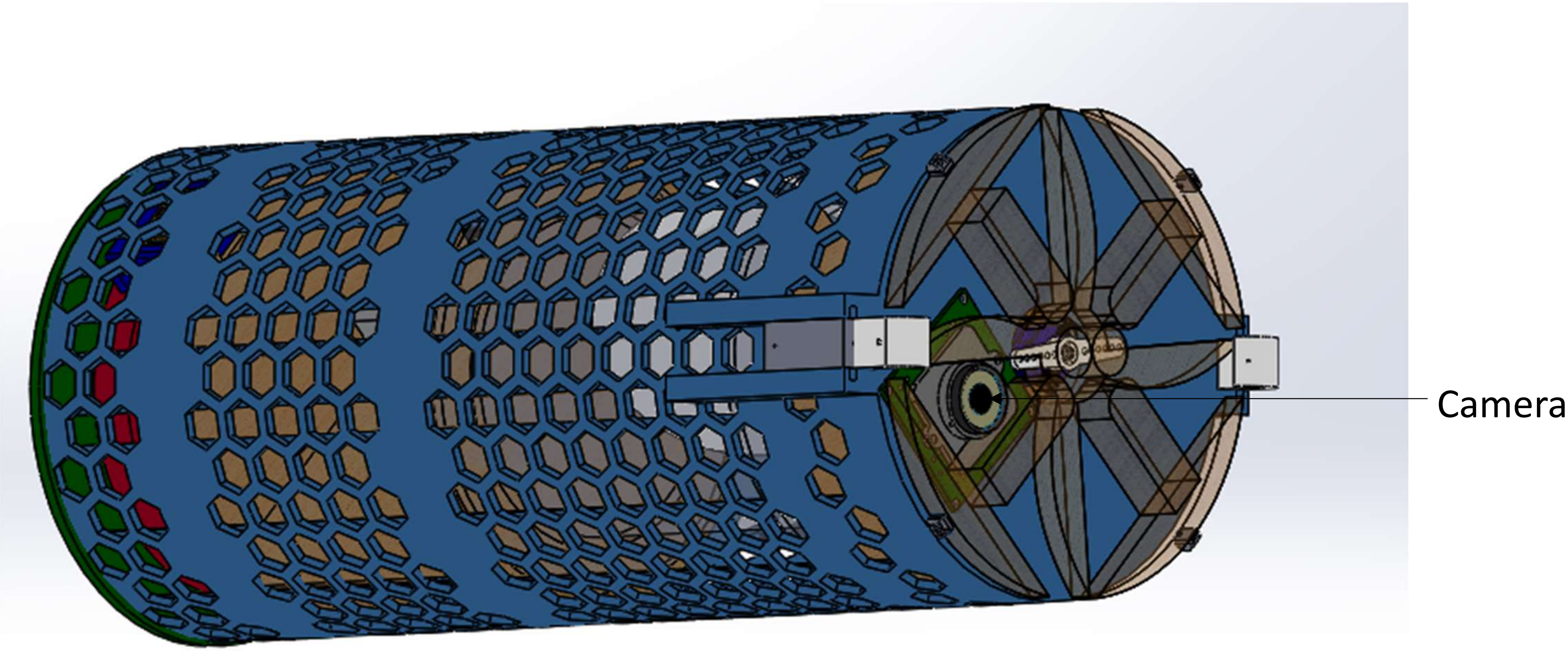
Physical Layout

Placement of Electronics components

(This is only tentative design of the electronics component final design may vary)



Placement of Camera



System Concept of Operation

Pre-Launch

- Team briefing
- Mechanical and Electronics integrity checks
- Taking CanSat to launch site
- Ground station set up

Loading of CanSat

- Heat-Shielded is folded and placed at starting point with release mechanism
- Parachute is folded and placed at end of the container for easy release
- The CanSat will be switched ON and will start transmitting telemetry data
- The CanSat will be placed into the payload section of the rocket

Rocket Deployment

- Flight Software will initiate its next state and the same will be updated on the ground station
- CanSat will be deployed from the rocket at 670 to 725 meters and Heat-Shielded open with deployment

System Concept of Operation

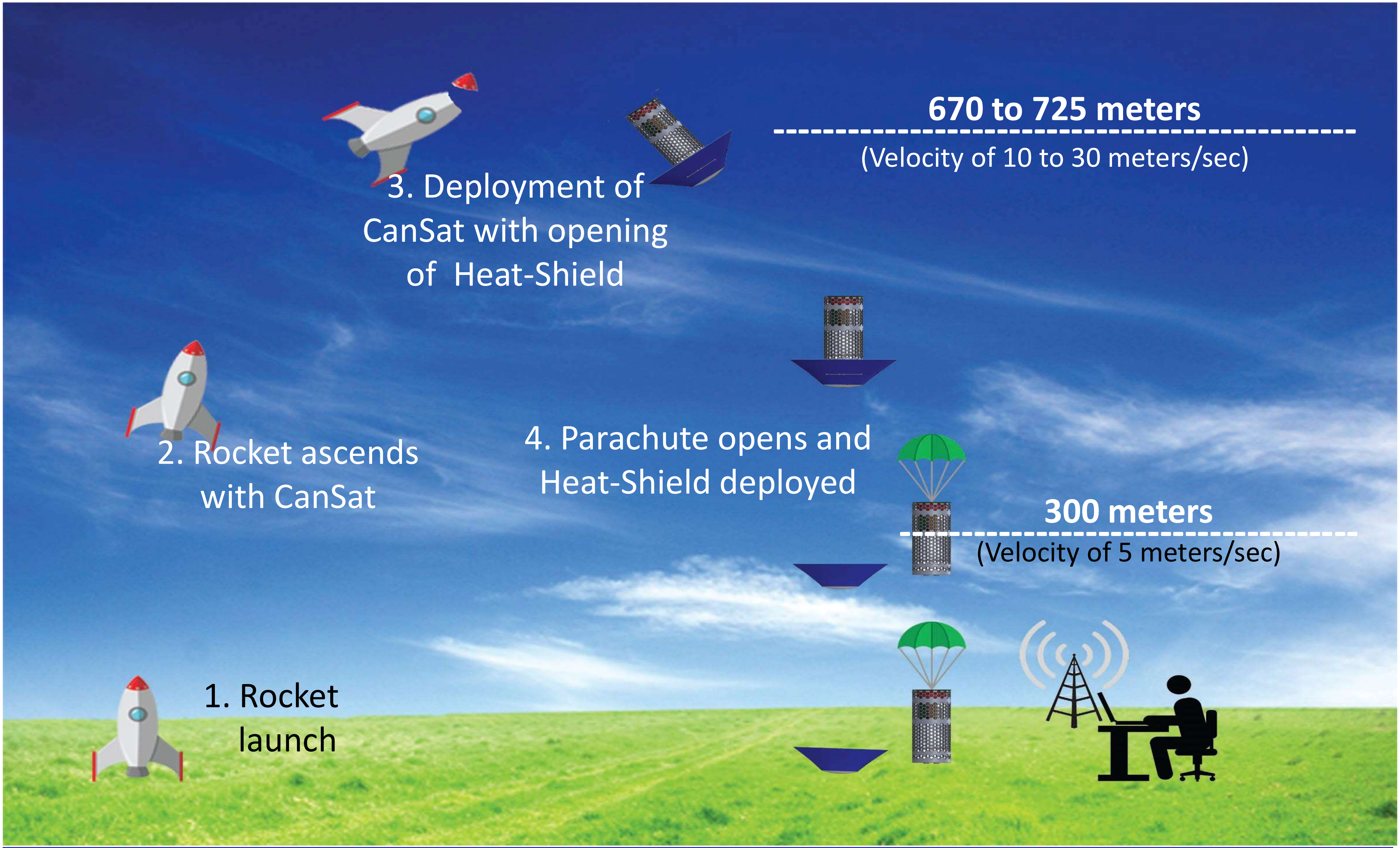
Detachment

- At 300 meters Heat-Shielded will deployed and parachute will open at that time by actuation of servo motor
- Camera will recorded the detachment of Heat-Shielded and all decent period after this

Landing

- The flight software state will be updated to landing and Buzzer will be turned ON
- Telemetry will be stopped
- Recovery of CanSat
- Returning to ground station
- PFR preparation begins

System of Concept of Operation



Launch Vehicle Compatibility

Rocket Payload Section Dimension:

- **Height** : 310 mm
- **Diameter** : 125 mm
- **CanSat Overall Dimension**:
  - Height : 290 mm
  - Diameter : 110 mm
  - Unfolded diameter : 206 mm

The structure is designed in accordance with the CanSat parameters with safe tolerances

Sensor Subsystem Design

KHUSHAL TAMBOLI

Sensor Subsystem Overview

Sensor type	Model Name	Purpose
Temperature Sensor	DS18B20	To measure outside air temperature.
Pressure Sensor	BMP180	To measure air pressure.
Altimeter	BMP180	To measure Non-GPS altitude
Tilt sensor	MPU-6050	To measure orientation in 3d.
GPS	UBLOX neo6m	To measure position and altitude.
Voltage sensor	Voltage divider circuit	To measure battery voltage.
Camera	Memore spy keychain	To capture the video of release of the heat shield and the ground.

Sensor Subsystem Requirements

ID	Requirement (Payload)	Rationale	Priority	Parent	VM			
					A	I	T	D
SSR-01	To measure air pressure.	Mission Base Requirement	HIGH	SRS-21	✓	✓	✓	
SSR-02	To measure outside air temperature	Mission Base Requirement	HIGH	SRS-21	✓	✓	✓	
SSR-03	To measure Non-GPS altitude	Mission Base Requirement	HIGH	SRS-21			✓	✓
SSR-04	To measure orientation in 3d.	Mission Base Requirement	HIGH	SRS-03	✓		✓	✓
SSR-05	To measure position, altitude, time and the number of GPS satellites being tracked by the GPS receiver.	Mission Base Requirement	HIGH	SRS-21	✓			
SSR-06	To measure battery voltage.	Mission Base Requirement	HIGH	SRS-21	✓	✓		

Sensor Subsystem Requirements

ID	Requirement (Payload)	Rationale	Priority	Parent	VM			
					A	I	T	D
SSR-07	All sensor shall survive 15 Gs of acceleration and 30 Gs of shock	Mission Base Requirement	HIGH	SRS-24	✓		✓	✓
SSR-08	SD card is used to store images and telemetry	To back up the data	MEDIUM	SRS-38	✓	✓		
SSR-9	Audio beacon to be used on payload	Mission Base Requirement	HIGH	SRS-30	✓			
SSR-10	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Mission Base Requirement	HIGH	SRS-14	✓			
SSR-11	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Mission Base Requirement	HIGH	SRS-16	✓			
SSR-12	All the sensor data should be updated every one second	To update the telemetry at 1Hz	HIGH	SRS-21	✓	✓		

Probe Air Pressure Sensor Trade & Selection

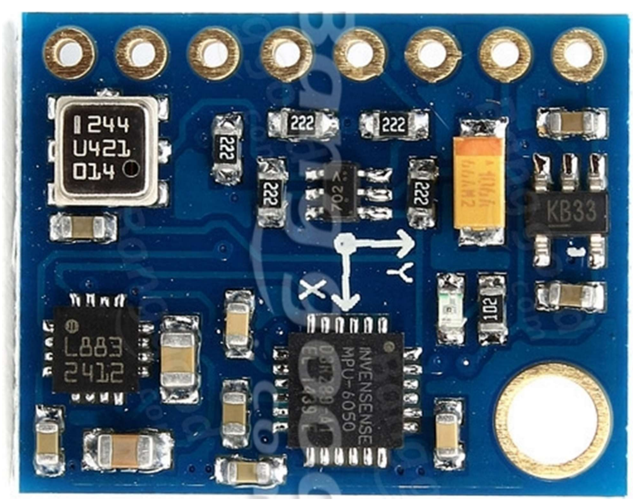
Model Number	Interface	Operating Voltage	Resolution	Accuracy	Size $(mm)^2$	Weight	Cost (Rs)
BMP180	I2C	1.8V-3.6V	16-19 bits	0.03 hPa	3.6*3.8	<1 g	200
MPL 3115A2	I2C	1.6V – 3.6V	24 bits	+/- 0.05 kPa	5*3	<0.9 g	978
MS5611-01BA03	ADC	1.8V-3.6V	24 bits	1.5hpa	19*33	<1g	924

Source: Datasheet

SELECTED : BMP180
Reasons:

- High accuracy
- Light weight
- Low noise
- Easy to interface
- Low cost and easily available
- Very low current drawn (Ipeak= 650µA)

Note:
BMP 180 is integrated in 10DOF inertial measurement unit (imu)

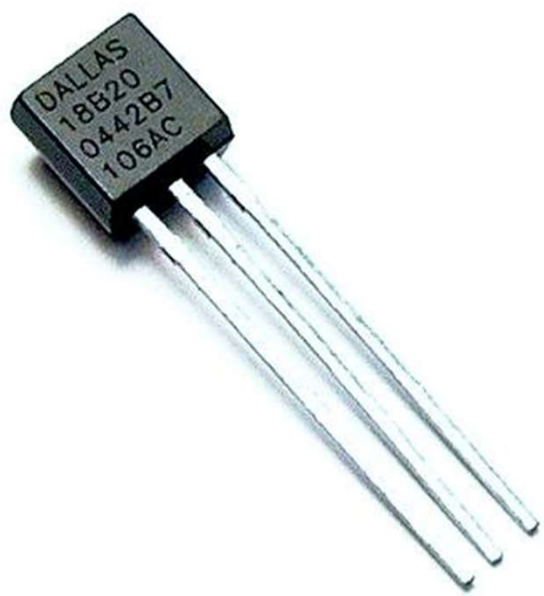


Probe Air Temperature Sensor Trade & Selection

Model Number	Interface	Operating Voltage	Resolution	Accuracy	Size $(mm)^2$	Weight	Cost (Rs)
DS18B20	One wire interface	3.0V-5.5V	9-12 bits	±0.5°C	14.4*4.5	<1 g	100
TMP35	ADC	2.7V-5.5V	12 bits	±2.0°C	17.7*5.2	<1 g	125
TMP112	I2C	3.3V	12 bits	0.1°C -1.0°C	16*12	<0.5g	180

Source: Datasheet

SELECTED : DS18B20



Reasons:

- Unique One Wire Interface requires only one port pin for communication.
- To reduce component count with integrated temperature sensor and EEPROM
- Highest accuracy.
- Meets required voltage.

GPS Sensor Trade & Selection

Module name	Operating voltage	Interface type	No. of search channels	Size $(mm)^3$	Time to first fix	weight	price
Ublox Neo – 6M gps	3.3V -5V	UART, SPI	50	16.0*12.2*2.4	27 sec	12 gm	Rs 899
Quectel L80(GPS L80)	3.3V	UART	66	16.0*16.0*6.45	36 sec	6gm	RS 695
GTPA 010	3.3V-5V	USART	66	16.0*16.0 *6.45	36 sec	6gm	RS 825

Source: Datasheet

GPS Sensor Trade & Selection

Selected: **UBLOX NEO 6M GPS**

REASONS :

- This GPS module has an antenna and inbuilt EEPROM
- This module is compatible with APM2 and APM 2.5, and EEPROM can save all your configuration data.
- Interfacing is very easy .
- Can work under RS232 –TTL level voltages.
- Baud rate is 9600 bps.
- Power supply is of 3-5 V.
- Size is very compatible.
- Time to start (that is COLD START) is very less and it was of 27 seconds.
- Even though cost is somewhat high its accuracy is very high and due to this it had a wide range of applications,

Probe Power Voltage Sensor Trade & Selection

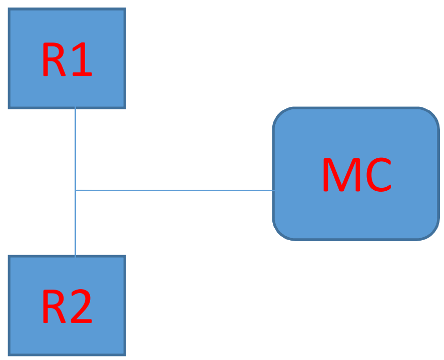
Sr. no	Module name	Operating voltage	Interface type	Error	Weight	Price
1	EPro lab Voltage Sensor Module	25 V	I2C	1%	8 gm	$ 2.5
2	KG045	0 -25 V	I2C	1%	10 gm	$ 2.36
3	Voltage Divider	50 V	Analog	1%	Negligible	Negligible

Source: Datasheet

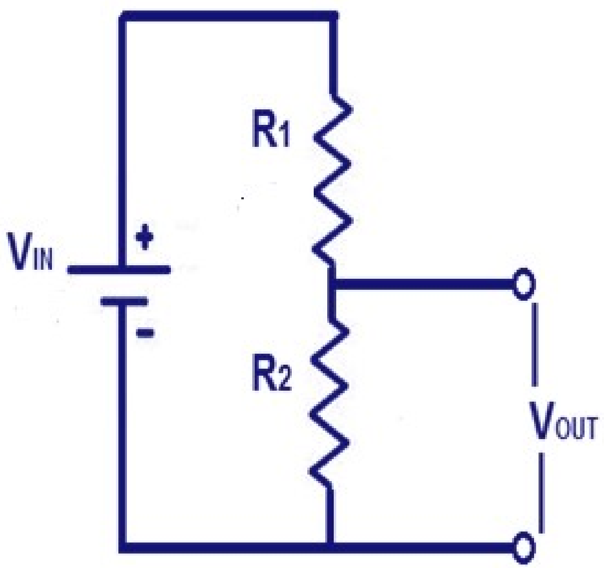
Selected :**Voltage divider using ADC port**

REASONS:

- Negligible weight
- No cost & greater accuracy
- Low space consumption
- Space occupancy is very less
- Analog interface type
- Good range & error chances are too low



Probe Power Voltage Sensor Trade & Selection



R1=1MΩ
R2=100KΩ
Vin= 9V

Here V_{out} is to the ADC pin of MC

- Output of the voltage divider circuit is given of the ADC pin of the microcontroller.
- The voltage across the power bus is calculated using
- (R2/R1+R2) Vin = V ADC
- Vin = V ADC(R1+ R2)/R2
- Maximum voltage provided by the ADC pin of the MCU is 5V and the battery voltage of our circuit is 9 V.

Hence R1+R2)/R2=1MΩ/100kΩ
(R1+R2)=10R2
R1/R2=1/9

- Hence resistances selected are 1 MΩ and 100kΩ
- The circuit with the particular values shown has an input impedance of 1MΩ + 100kΩ = 1.1MΩ and is suitable for measuring DC voltages up to about 50V.
- Resolution of the ADC pin is 10 bit Therefore accuracy=5/1024=0.00488

Tilt Sensor Trade & Selection

Accelerometer							
Model Number	Interface	Operating Voltage	Resolution	Accuracy	Size (mm)^2	Weight	Cost (Rs)
ADXL345	I2C	2.0 V to 3.6 V	13 bits	±16g	3 × 5	<1 g	149
LIS302DL	I2C	2.16V to 3.6V	8 bits	±8g	3 x 5	668 mg	189
MPU-6050	I2C	2.3V to 3.4V	16 bits	±16g	4 x 4	2.1g	250

Gyroscope							
Model Number	Interface	Operating Voltage	Resolution	Accuracy	Size (mm)^2	Weight	Cost (Rs)
L3G4200D	I2C	2.4V-3.6V	16 bits	+/- 2000 deg/s	4 x 4	<1 g	700
MPU-6050	I2C	2.3V to 3.4V	16 bits	±2000 deg/s	4 x 4	2.1g	250

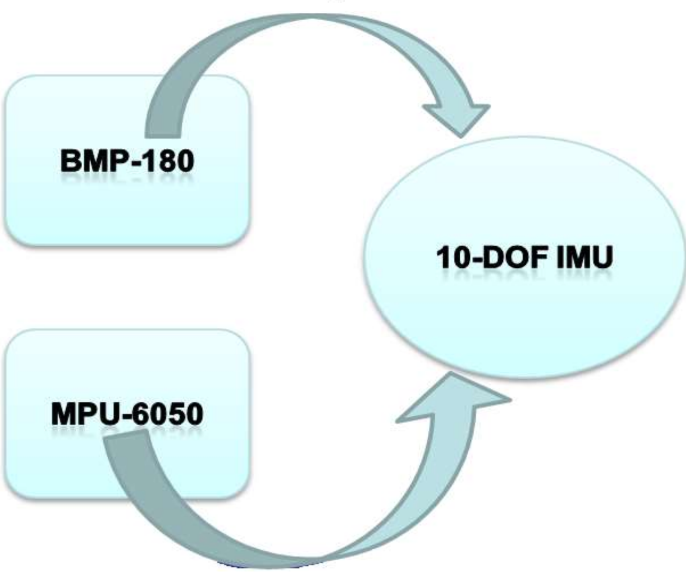
SELECTED : MPU-6050

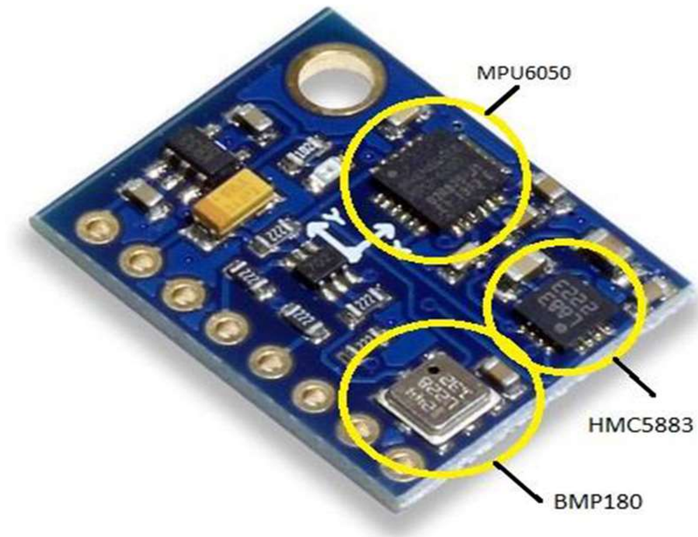
Source: Datasheet

SELECTED : MPU-6050

Reasons:

- It combines a 3-axis gyroscope and a 3-axis accelerometer
- It has more accurate 16-bit converter instead of 13-bit.
- It has built-in **DMP** (*Digital Motion Processor*).
- It facilitates the conversion of processed data thereby relieving the microcontroller.
- Low cost and easily available





Note:

- MPU-6050 is integrated in 10DOF inertial measurement unit (imu).
- We chose IMU as it combines BMP-180 and MPU-6050 in a single IC, reducing hardware, weight, space required and circuit complexity.

Bonus Camera Trade & Selection

Model Number	Operating Voltage	Resolution	fps	Megapixel count	Size $(cm)^2$	Weight	Cost (Rs)
Memore Spy Keychain	5V	720X480	30	3	9.8 x 7.4	98 g	385
mdskart Spy keychain Cam	5V	640x480	30	3	9.8 x 7.4	100 g	425

SELECTED : **Memore spy keychain**

Reasons:

- It records video and directly stores it into the SD card without the involvement of the microcontroller.
- Reduces complexity.
- It has inbuilt battery.
- Low cost

Buzzer

Sensor	Cost (Rs)	Size (mm*mm*mm)	Weight (gram)	Operating voltage (volt)	Operating current(mA)	Frequency (Hz)
Pies buzzer	10	15*3	2	5	30	2500
CSS-I4B20-SMT-TR	220	8.5*8.5*3	6	4.7	80	2730
CMT-1075-SMT-TR	260	10.1(d)*3	3	5	5	5200

Pies buzzer is selected as it has :

- Cost efficient
- Smallest size
- High decibels compared to others
- Less weight.

Descent Control Design

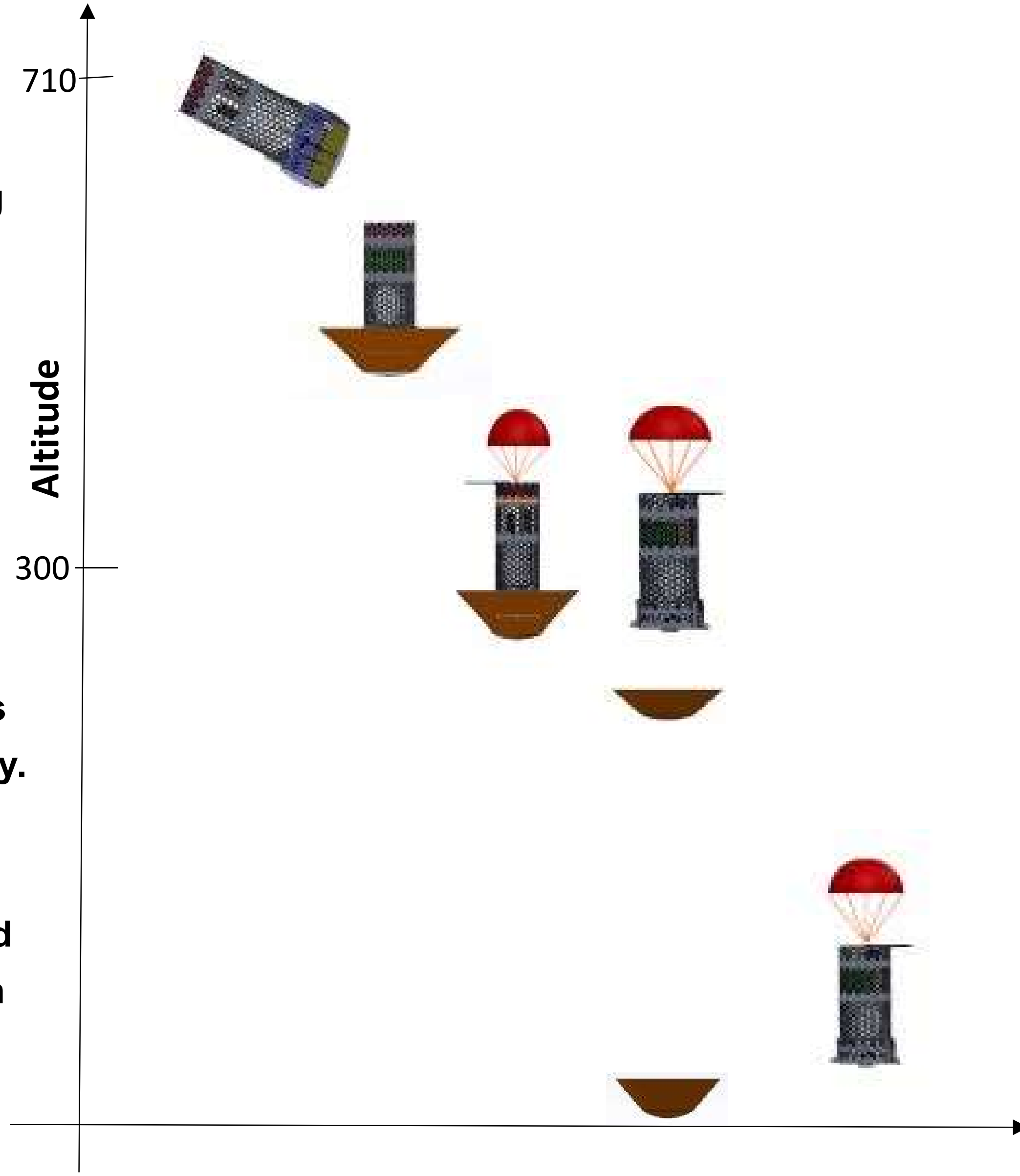
AJINKYA ZALTE

Descent Control Overview

Payload Descent Control System

Aero-braking Heat shield

- Descent control system consists of a aero-braking heat shield which will function both as an aero-braking and heat shielding system.
- It shall consist of a fixed, rigid nose made from Heat resistant material which will shield the probe and a flexible part will not function much as a thermal insulator but, rather mainly as an aero-brake.
- The diameter of the outer flexible part is 20.6 cm which is selected such that the required air drag is experienced to attain the required descent velocity.



Probe Descent Control System

- At 300m heat shield is released from the probe and Parachute is released having base diameter of cm and spill diameter of cm to provide stability
- The Probe has an audio beacon on-board which activates once it lands.

Descent Control Requirements

ID	REQUIREMENT	RATIONALE	PRIORITY	PARENT	VM			
					A	I	T	D
DCS- 01	Total mass of the CanSat (container and payload) shall be 500 grams +/- 10	Mission Requirement	HIGH	SRS-01	✓	✓		
DCS- 02	The probe with the aero-braking heat shield shall fit in a cylindrical envelope of 125 mm diameter x 310 mm.	Mission Requirement	HIGH	SRS-02	✓	✓		
DSC- 03	The probe shall not tumble during any portion of descent and maintain the heat shield orientation in the direction of descent.	Mission Requirement	HIGH	SRS-04	✓		✓	✓
DSC- 04	All descent control devices shall survive 30 Gs' of shock.	So it can sustain sudden impact and air drag force	HIGH	SRS-12		✓		
DSC- 05	The descent rate of the probe with the heat shield deployed shall be between 10 and 30 meters/second	Mission Requirement	HIGH	SRS-29	✓			

Descent Control Requirements

ID	REQUIREMENT	RATIONALE	PRIORITY	PARENT	VM			
					A	I	T	D
DSC- 06	The heat shield must not have any openings.	Essential for performing its function	HIGH	SRS-05		✓	✓	
DSC- 07	The aero-braking heat shield shall not have any sharp edges	Mission requirement and To ensure easy deployment High	HIGH	SRS-05		✓		
DSC- 08	The aero-braking heat shield shall be released from the probe at 300 Meters along with the release of parachute	Mission requirement	HIGH	SRS-10	✓		✓	✓
DSC- 09	The descent rate of the probe with the heat shield released and parachute deployed shall be 5 meters/second.	Mission requirement	HIGH	SRS-29	✓		✓	
DSC- 10	Parachute must be designed to avoid tangling of shroud lines while descending	Prevent tangling during descent that could lead to a failed recovery	HIGH	--		✓		

Descent Control Requirements

Atmospheric Data :

Altitude	Properties	Value
At sea level	Mean Temperate	298K
	Wind Velocity	3 km/h (SE)
	Pressure	1.01325×10^5 N/m^2
	Density	1.225 Kg/cm^3
At 300 meters	Pressure	9.77726×10^4
	Temperature	296.05 K
	Density	1.15051 Kg/cm^3
At 700 meters	Pressure	9.31936×10^4
	Temperature	293.45 K
	Density	1.10634 Kg/cm^3

Configurations of Payload

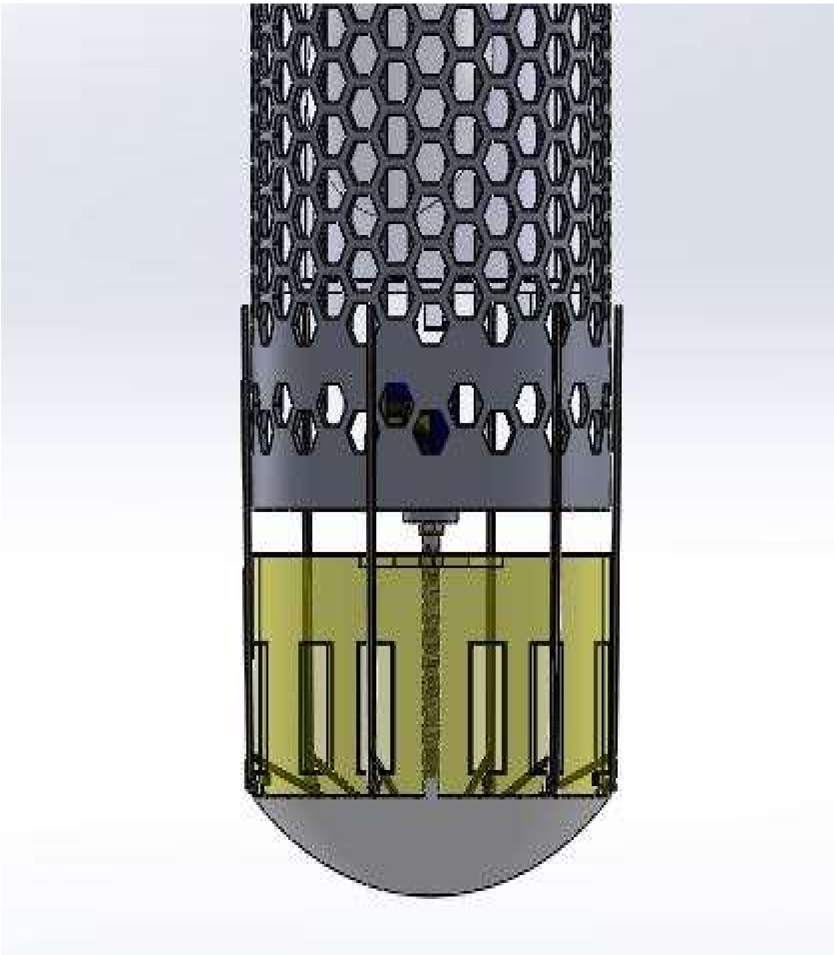
A- Lead screw design based payload

Pros

- Simple design
- Easier locking of the heat shield configuration.

Cons

- The overall design takes up a lot of space.
- The weight of the mechanism is considerable.
- Not feasible for the deployment of heat shield.



Payload Descent Control Strategy Selection and Trade

Configurations of Payload

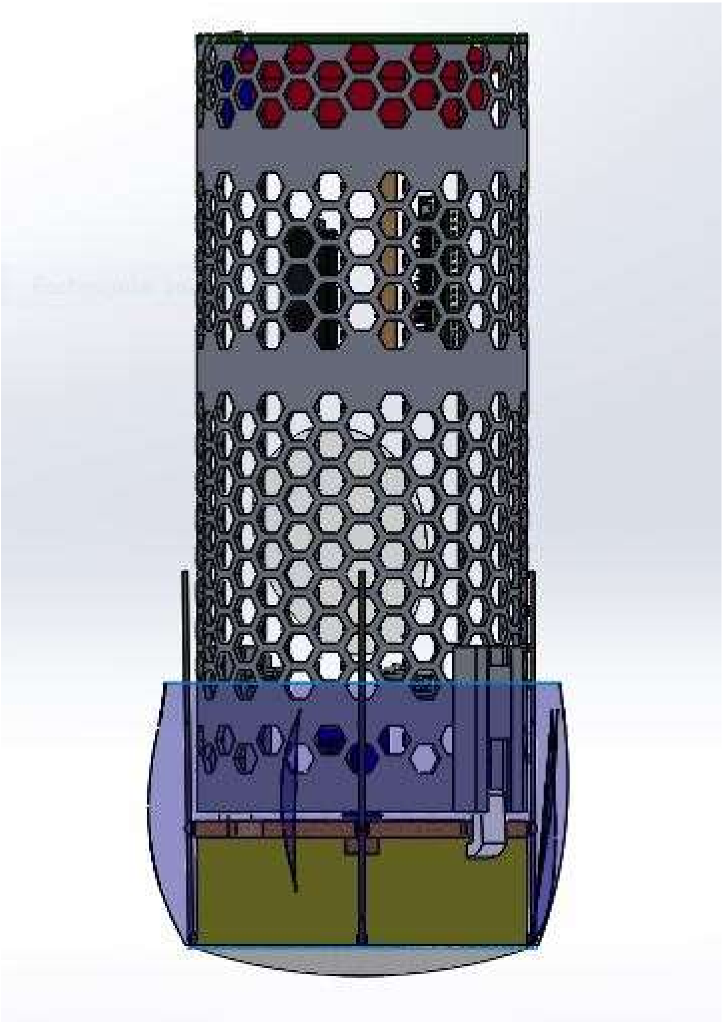
B- Cam design based payload

Pros

- The overall weight of the mechanism is considerably less.
- Easier deployment configuration.
- High reliability.

Cons

- Extra arrangement for locking of mechanism in one configuration.



Payload Descent Control Strategy Selection and Trade

Model	Strategy	Strength	Ease of manufacturing	Ease of deployment	Feasibility	Cost
A	Lead screw design based payload	9	6	5	6	6
B	Cam design based payload	8	7	8	7	8

Selected**: Model B**: **Cam Design Based Payload**

Reason:

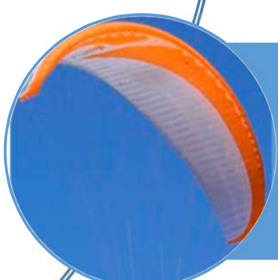
- Ease of manufacturing,
- ease of deployment,
- cheap cost and
- feasibility of the use of mechanism

Grading (0-10):
0 – Least
10 - Most

Payload Descent Control Strategy Selection and Trade

Cruciform parachute provide stable gliding, high vertical gliding, reduces sway.

Round Parachute with spill hole reduce the effective size of chute and provide stability with speed reduction as per requirement



Para- foil Parachute has greater steerability, higher gliding capability and greater control of descent rate

Payload Descent Control Strategy Selection and Trade

SHAPE OF PARACHUTE	C_D	DIMENSIONS OF PARACHUTE	PROS	CONS
Round Parachute	1.5	70 cm(Diameter)	• Higher stability due to spill hole • Compact and light-weight	• Difficult to manufacture. • Chances of entanglement of cords.
Para- foil Parachute	0.2	3.5 m^2	• Good gliding capability. • Great steerability. • Great control over descent rate.	• Deployment shock is experienced which can be eliminated by drag canopy. • Higher glide. • Difficult to manufacture.
Cruciform	0.75	33 cm(Side)	• Light in weight. • Time-lag on opening of the chute is very less. • Greater stability.	• Difficult to manufacture.

Payload Descent Control Strategy Selection and Trade

Round parachute with spill hole is chosen because:

- Due to simple in construction and smaller size.
- Easy to control the drag, thus the descent velocity.
- Good stability.

Colour – Florescent Orange

- Connections: to prevent the entangling of the nylon wires a swivel is used to attach the parachute to the nylon wires.
- Length of the shroud lines is 1.5 times the base diameter of the parachute.

•In case of Failure the Re-entry Payload is tested to survive 30 Gs of shock. (Simulation tests passed)

Payload Descent Control Strategy Selection and Trade

Parachute material selection

Materials	Pros	Cons
Ripstop Nylon	• Light-weight • Waterproof, Tear Resistant, no-porosity • Good strength to weight ratio	• Costlier than nylon
Silk	• Good strength • Light weight • springy	• Expensive
Kevlar	• Very high strength to weight ratio • Thermally stable	• Do not stretch • More sensitive to the environment • Difficult to cut.
Nylon	• Durable • Stretchier material • Cheaper	• Weaker when wet • Affected by ultra-violet rays

Payload Descent Control Strategy Selection and Trade

Parachute Material selected

- **Ripstop nylon** was selected for parachute because of the tear resistance, favourable strength to weight ratio and wide texture range.

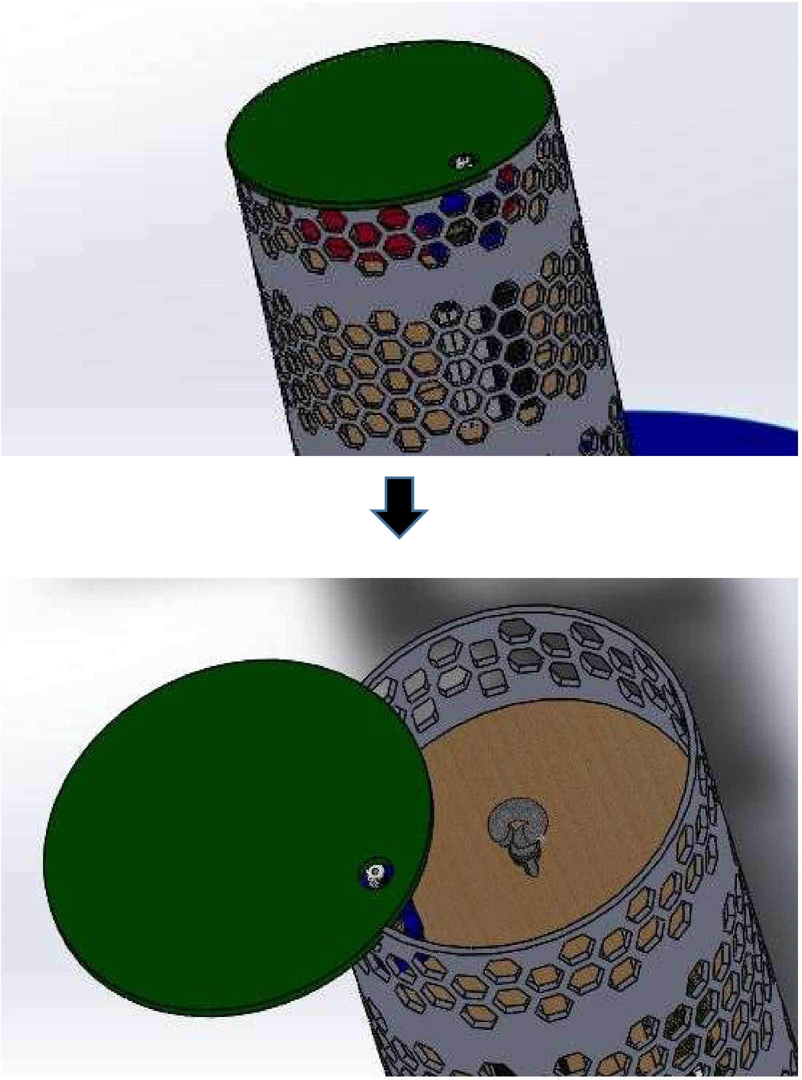
- **Kevlar threads** were chosen to connect the parachute because it strengthen itself when force is applied own it was the reason for choosing it.

- **Swivel** is used to tie up the Kevlar threads. This will allow parachute to freely rotate by not affecting the CanSat.

Payload Descent Control Strategy Selection and Trade

Parachute Release Mechanism

Configuration A



Pros

- ➢Simple design
- ➢High reliability

Cons

- ➢Air drag directly acts on the lid, thus high strength build is required.
- ➢ Orientation problem after opening of lid.

Payload Descent Control Strategy Selection and Trade

Parachute Release Mechanism

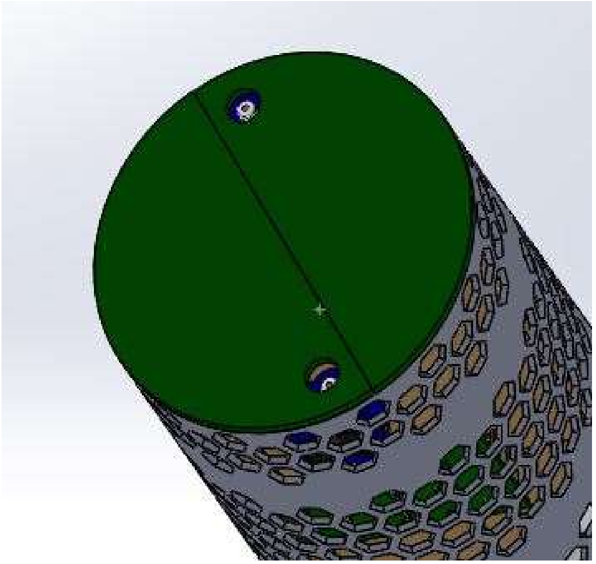
Configuration B

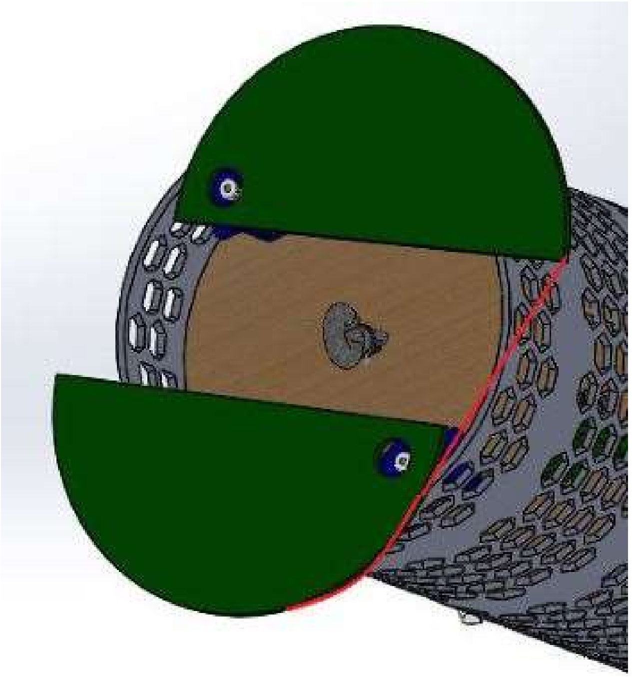
Pros

- Easy construction.
- Stability is not affected

Cons

- Less reliability
- Requirement of twin
- motors.





Payload Descent Control Strategy Selection and Trade

Model	Strategy	Ease of fabrication	Ease of actuation	Reliability	Cost
A	Lid opening using servo motor	8	8	7	8
B	Half opening and ejection of lid	7	7	6	8

Selected: **Model A**

Reason:

- **ease of actuation,**
- **ease of fabrication and**
- **reliability**

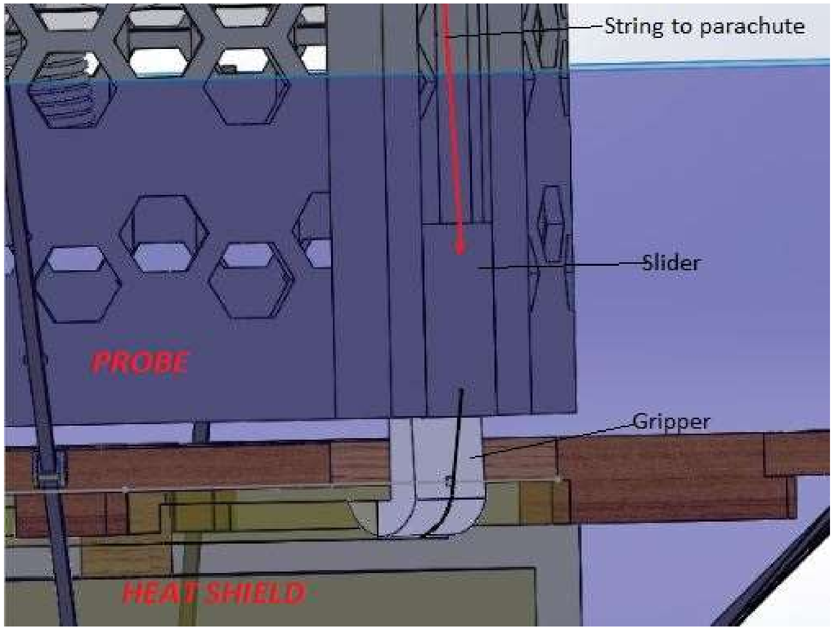
Grading (0-10):
0 – Least
10 – Most

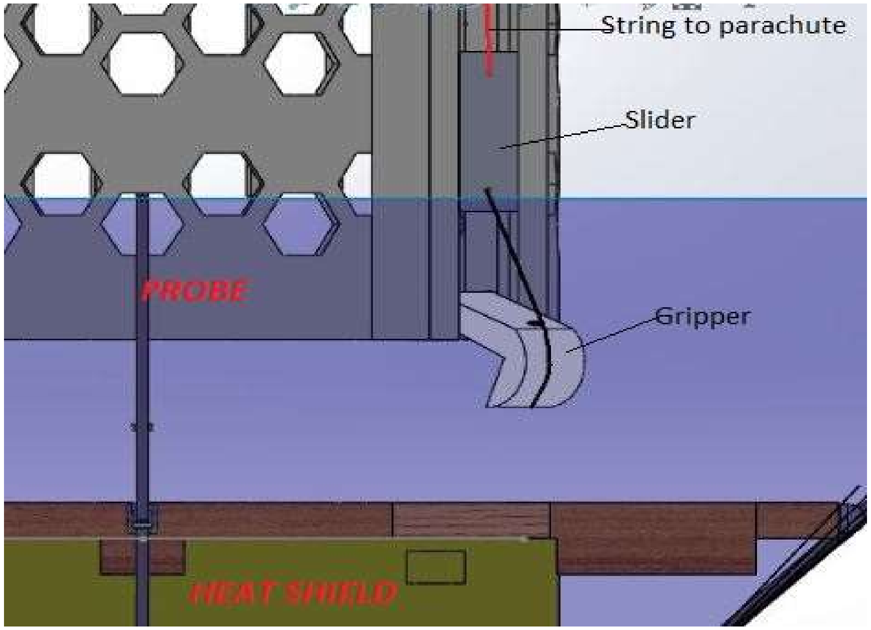
Payload Descent Control Strategy Selection and Trade

Aero-braking Heat shield deployment mechanism

Configuration 1: Gripper mechanism

- The heat shield will be attached to the probe with the help of grippers as shown.
- Gripper is connected to slider which is in turn connected to threads connecting it to the parachute.
- As soon as the parachute is release the thread is pulled thus sliding the slider hence releasing the tension on the gripper and deploying the heat shield.





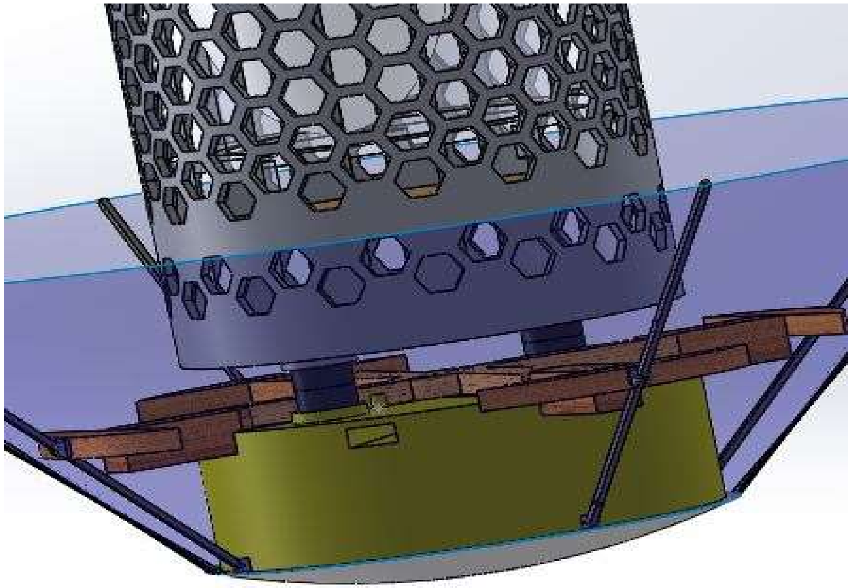
Aero-braking Heat shield deployment mechanism

Configuration 2 – Magnetic Attachment

The probe and the heat shield are attached with each other with the help of magnet.(as shown)

Release –

- At 300m when the heat shield is to be deployed the parachute is released with the help of servo motor.
- As the parachute opens up due to the sudden inflation as the air rushes, a jerk is experienced by the body which is used to separate the two magnet, thus deploying the heat shield.



Payload Descent Control Strategy Selection and Trade

Aero-braking Material Selection

Material	Pros	Cons
Nylon	• Tear resistant, non porosity • Good strength to weight ratio. • Withstand friction wear. • Endures repeated bending and flexing. • Good tensile strength.	• Cannot withstand higher temperatures.
Kevlar	• High strength to weight ratio. • High tensile strength. • Does not expand on heating. • Abrasion resistant.	• Absorb moisture • Poor compressive strength. • Difficult to cut. • Comparatively higher density.
Carbon fibre	• Good tensile strength. • Good compressive strength. • Good stiffness. • Heat resistance.	• High cost. • Higher density compared to nylon.

Payload Descent Control Strategy Selection and Trade

Aero-braking Material Selection

Material	Stiffness (GPa)	Strength (MPa)	Extendibility (%)	Toughness (MJ/m^3)
Nylon	5	950	18	80
Carbon fibre	300	4000	1.3	25
Kevlar	130	3600	2.7	50

Selected: Nylon

Reasons:
- Nylon have comparable strength to the others.
- Nylon have good toughness and extendibility.
- Required heat resistance for the mission.
- Lower density.

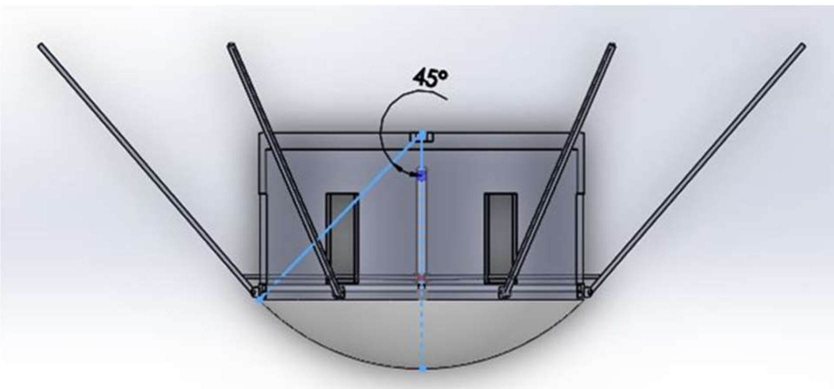
Payload Descent Control Strategy Selection and Trade

Heat shield Configuration

➢ The overall strength, stability of payload depends upon the configuration of the aero-braking heat shield.

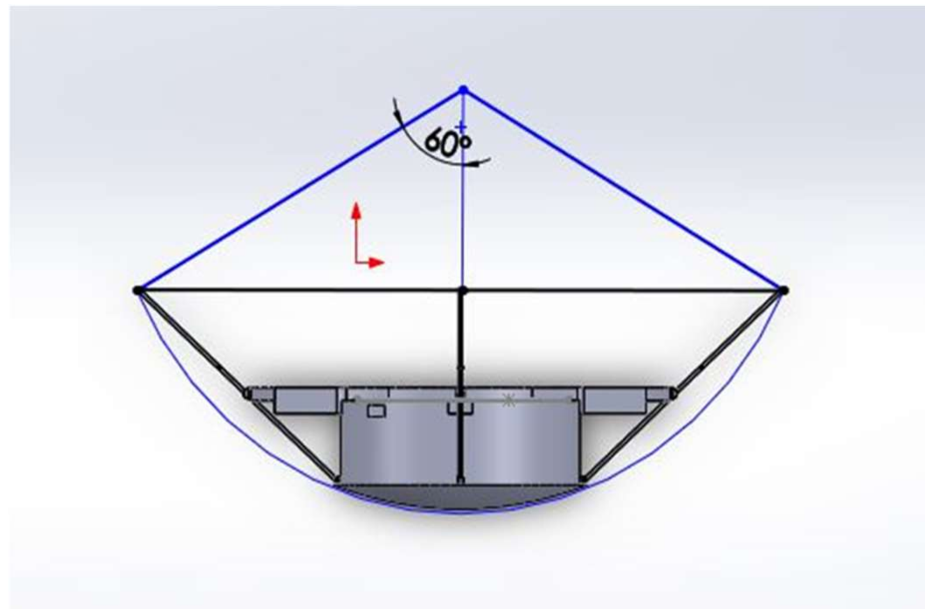
Configuration 1:

45 Half angle



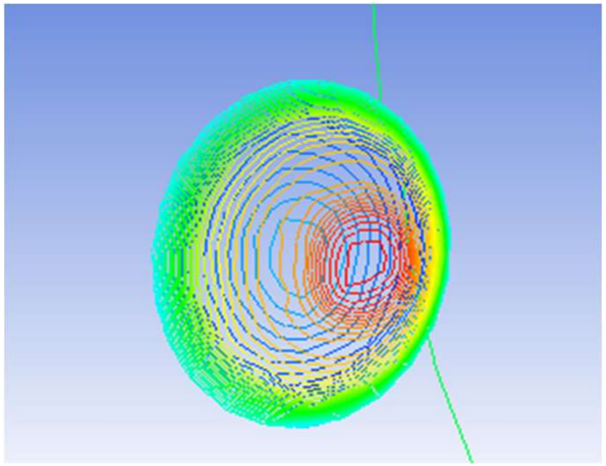
Configuration 2:

60 Half angle



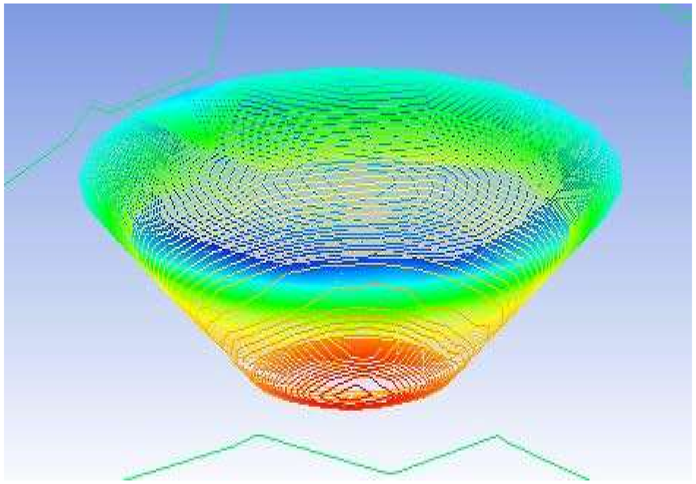
Payload Descent Control Strategy Selection and Trade

Half cone angle 45



P_{max} = 16.1504 Pa

Half cone angle 60



P_{max} = 15.9102 Pa

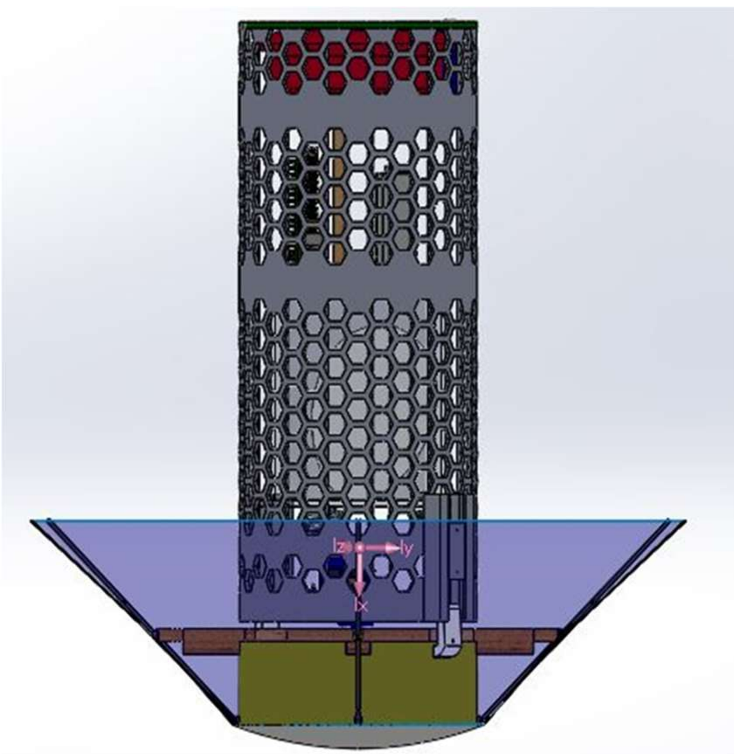
- The pressure experienced plays an important role in determining the appropriate material.
- The 60 degree half cone angle experiences lower pressure, thus appropriate for the heat shield.

Payload Descent Control Strategy Selection and Trade

Mechanism are shown below:

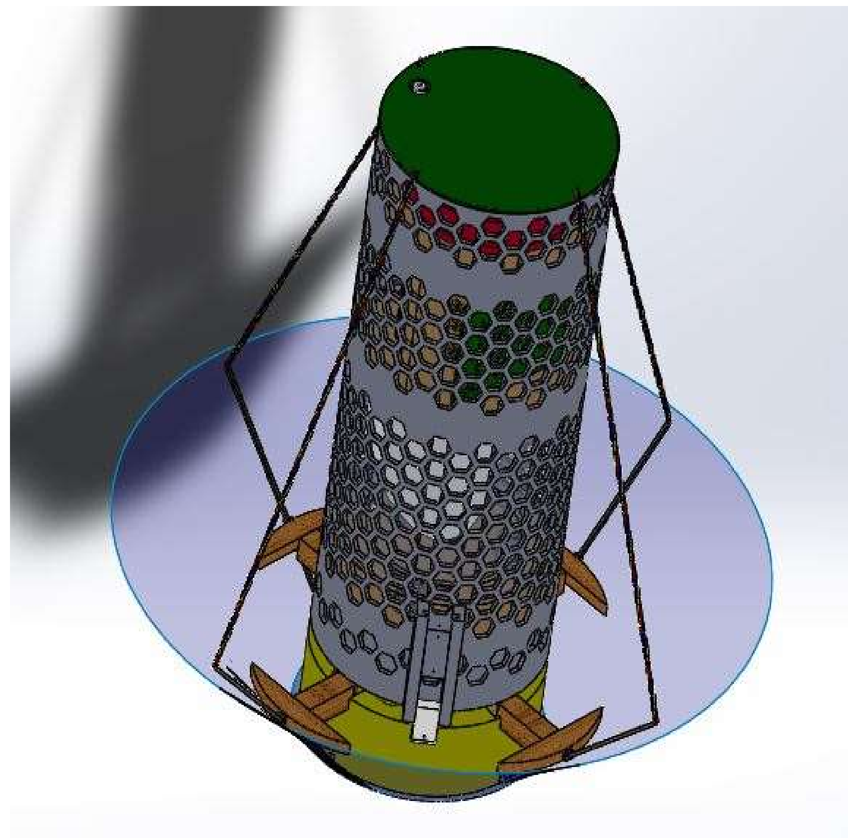
Configuration 1

➢Maintaining the Cg below the Developed heat shield.



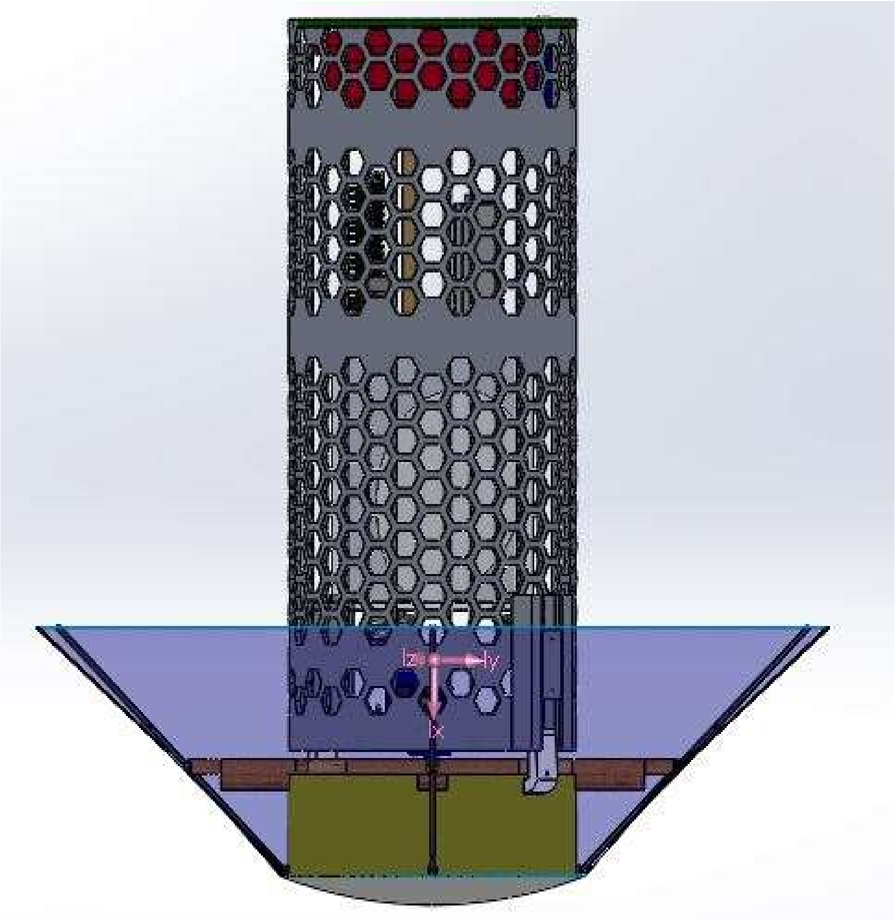
Configuration 2

➢Use of ropes to form a conical shape structure.



Payload Descent Control Strategy Selection and Trade

Configuration 1

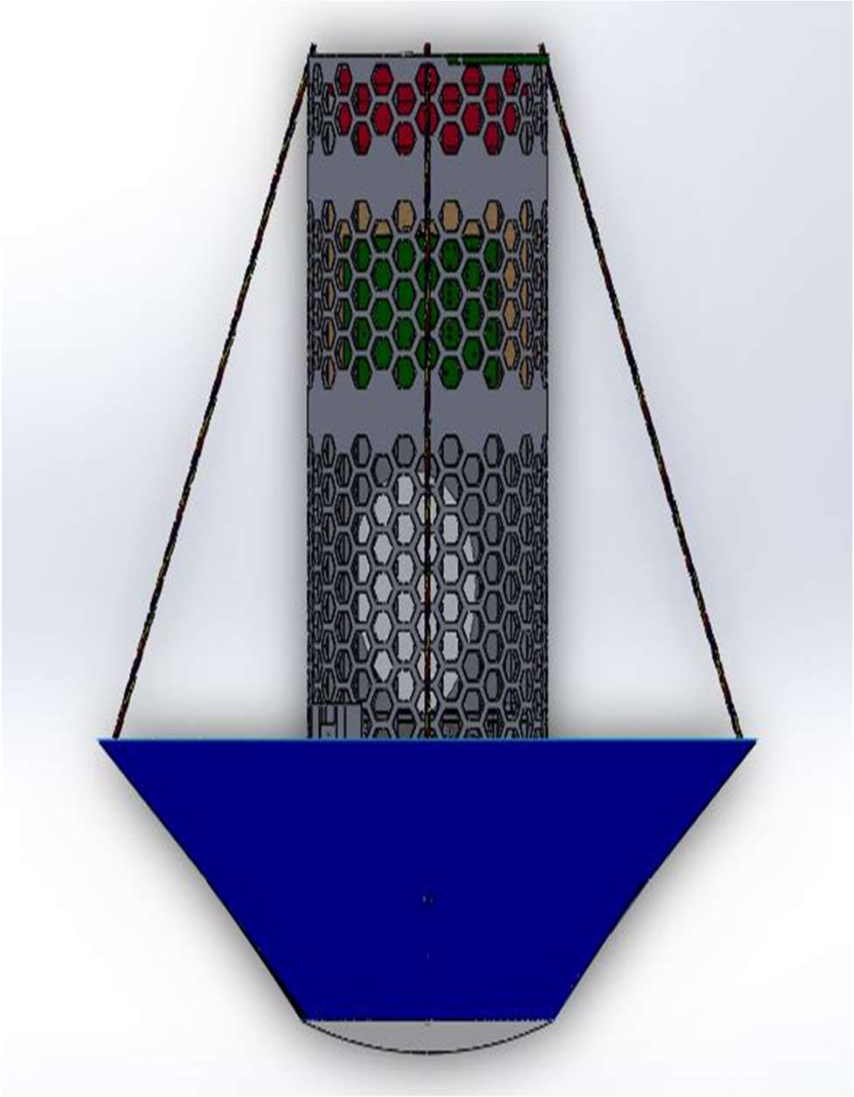


- This configuration stabilizes the payload by dropping the position of the centre of gravity below the developed heat shield.
- The unequal forces acting from every side during the descent of payload would apply rotational torque trying to tumble the payload, but due to the unique position of Cg the magnitude of the torque would be reduced drastically leading to stable descent.

Payload Descent Control Strategy Selection and Trade

Configuration 2

- The unique arrange uses ropes in tension to attached the heat shield cloth and the top of the Payload.
- The ropes resist the change in the overall structure of the heat shield when a turbulent air flows around the payload exerting unequal forces.
- Thus the position centre of gravity remains constant, and forces are equally distributed to stabilize the payload.



Payload Descent Control Strategy Selection and Trade

Configuration	Reliability	Stability	Feasibility	Cost
Displacement of C_g	8	7	8	9
Rope Structure Based	7	7	7	7

Selection: Displacement of Cg
Reason : Reliability, the feasibility of design without increasing component and weight, cost.

Grading (0-10):
0 – Least
10 – Most

Descent Rate Estimates

•Formulae Used For Calculating Descent Rate:

Equations:

- $F_d = 1/2\ \rho A C_d v^2$

- $A = 0.95\pi R_p^2$

F_d = Drag force

C_d = Coefficient of drag

A = Surface area

V = Descent Velocity

ρ = Air density

A = Projected surface area

R_p = The radius of parachute with

5% spill hole radius

Descent Rate Estimates

Calculation of the descent rate of payload

- To control the descent velocity of the payload a HEMISPHERICAL Aero-braking heat shield is used.
- Following formula was used to calculate the parameters like Air Drag, descent velocity, radius of the Aero-braking heat shield.

$$R^2 = \frac{2F_{drag}}{\rho V^2 Cd}$$

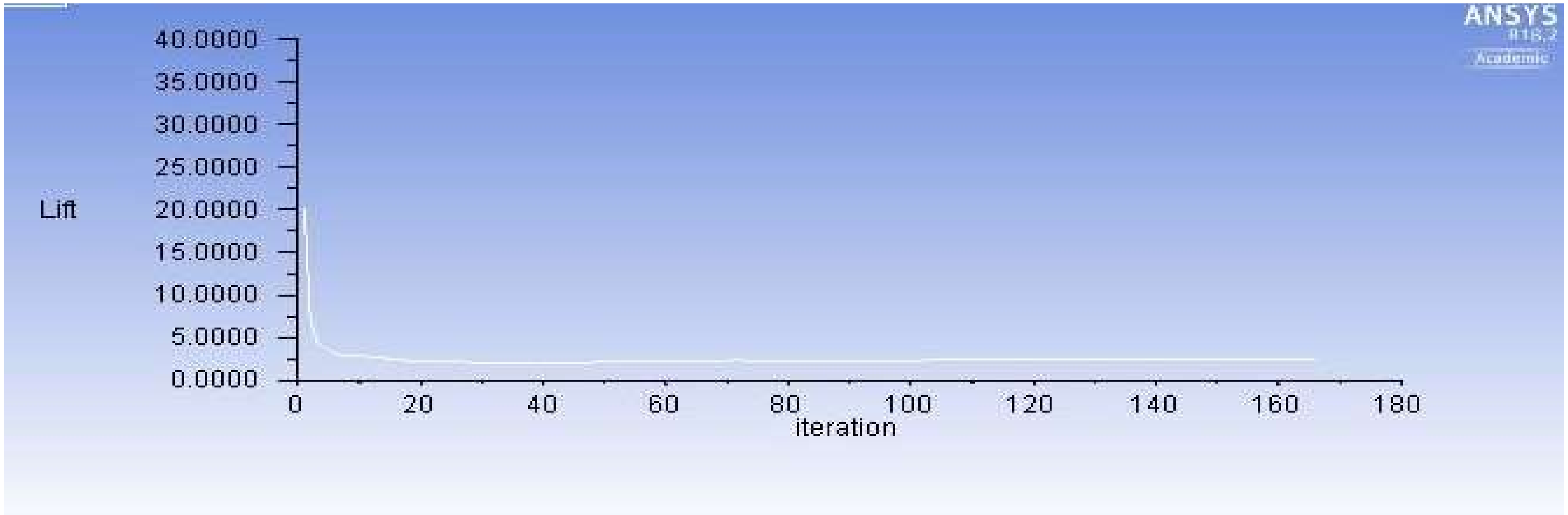
Where-

- **R= Radius of the aero-braking heat shield 13.5 cm**
- **π= 3.14159265359**
- **ρ = 1.12429 kg/m3(density of air as of Stephenville average temperature 32℃ above 500m level)**
- **Cd = (Coefficient of Drag for parachute)**
- **F_{drag} = 4.905 kg.m/s (m.g)**

Descent Rate Estimates

Cd calculation for configurations

45 half cone angle



But, Lift experienced by the body = Drag Force

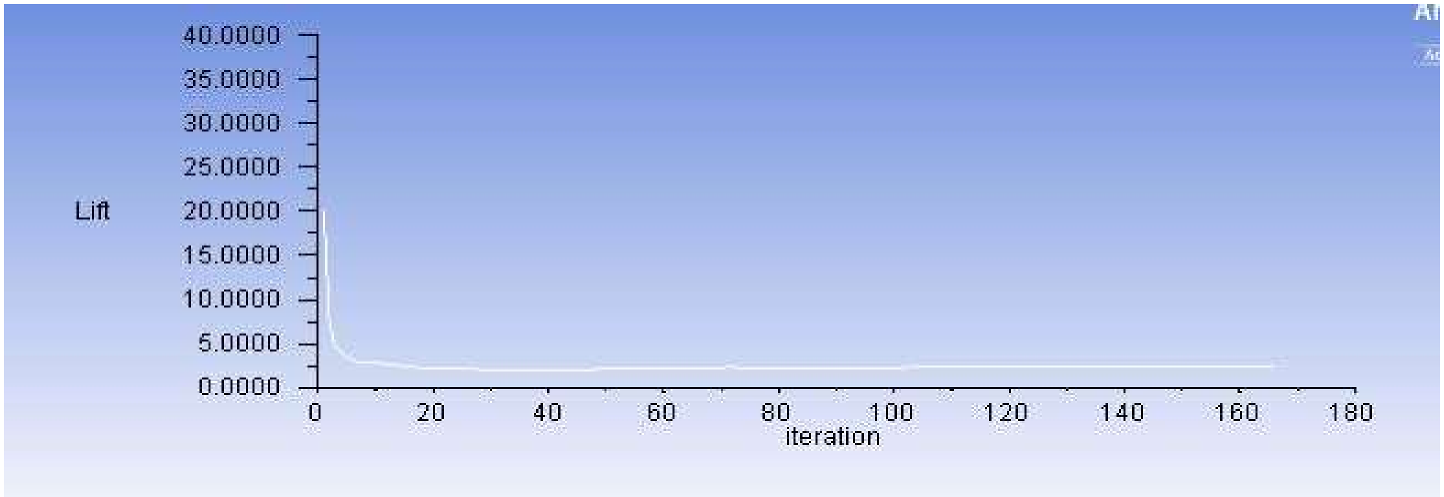
$$\mathbf{F_{lift} = (A\rho V^2 C_d)/2}$$

Thus , C_d = **1.03**

Descent Rate Estimates

Cd calculation for configurations

60 half cone angle



But, Lift experienced by the body = Drag Force

$$F_{lift} = (A\rho V^2 C_d)/2$$

Thus , C_d = **1.4**

Descent Rate Estimates

- The descent rate calculation are important for deciding the optimum configuration of the Aero-braking shield.
- Following are few decent rate observation:

Descent Rates (m/s)	Diameter of the Aero-braking heat shield (cm)	
	Configuration 1: Half angle 45	Configuration 2: Half angle 60
25	13.1	10.6
20	16.4	13.2
15	20.8	18
13 (SELECTED)	25.2	20.6
10	32.8	26.6

Descent Rate Estimates

Calculation of the descent rate of payload

- **To control the descent velocity of the payload a Round parachute with spill hole is used.**
- **Following formula was used to calculate the parameters like Air Drag, descent velocity, radius of the parachute.**

Formula used is:

$$F_{drag} = \frac{1}{2} C_d \rho A v^2 = mg$$

Where,

M = Mass of probe

ρ = 1.12429 kg/$m3$

Cd = 0.21(co-efficient of Drag for parachute)

$Fdrag$ = 4.905$kg.m/s2$

Area (A) = .95 times the projected area of parachute due to spill hole

K= 1.83×10^4

V= Descent velocity

R= Radius of Heat shield

Note: For the calculation of heat flux used in thermal analysis Sutton-Graves and Tauber model is used:

$$\dot{q}_{conv} = K\sqrt{\frac{\rho}{R_n}}V^3 \quad \left[\frac{W}{m^2}\right]$$

Descent Rate Estimates

Calculation of the descent rate of payload

For recovery;

Drag = Weight

and $$\mathbf{R} \propto \frac{\mathbf{1}}{\boldsymbol{V}}$$

•Thus Descent rate would decrease with increase in the radius of the parachute.

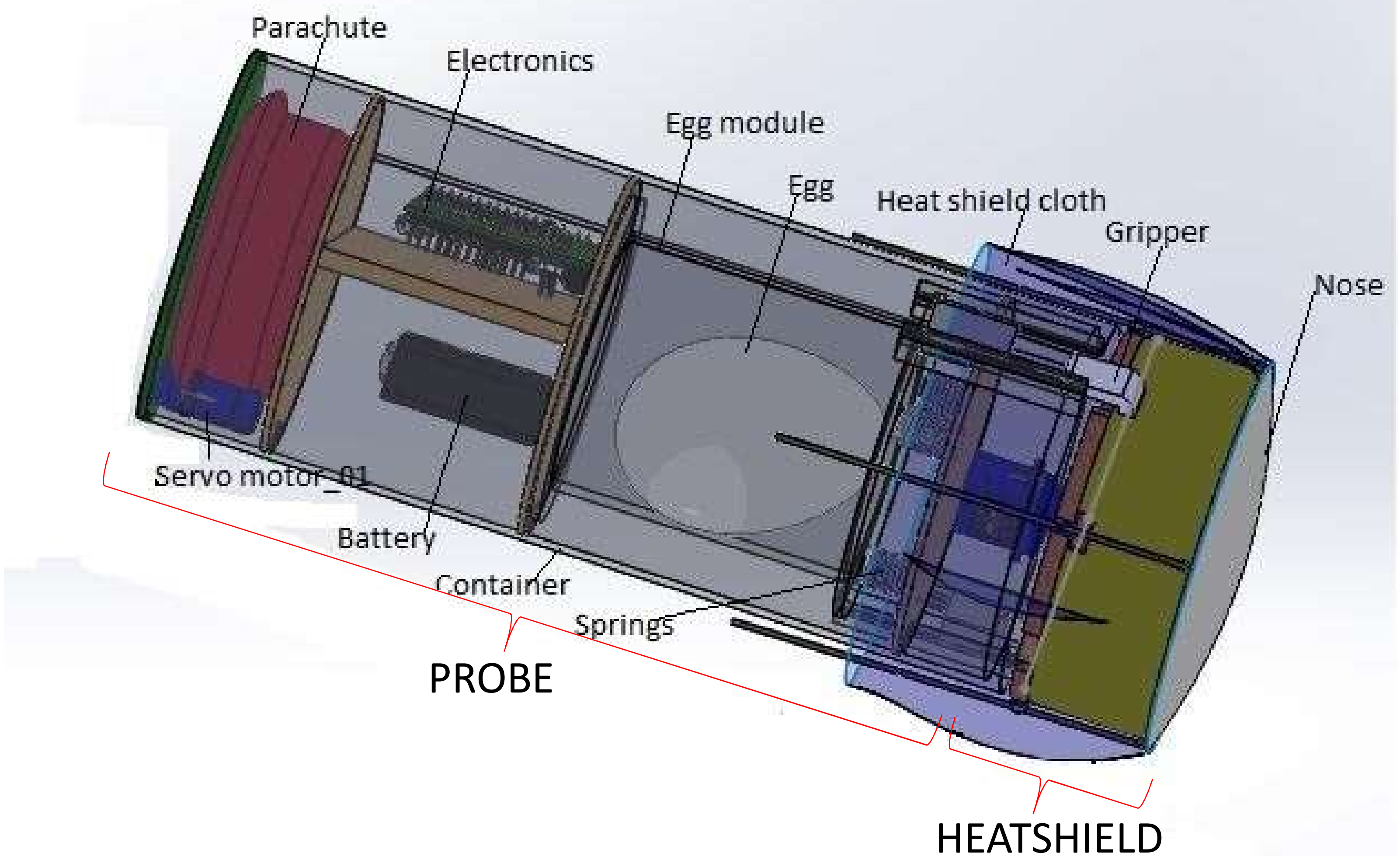
Diameter of the Parachute(cm)	Descent velocity m/s
46(SELECTED)	5
58	4
78	3
112	2
232	1

Mechanical Subsystem Design

SANKET AMBEDKAR

Mechanical Subsystem Overview

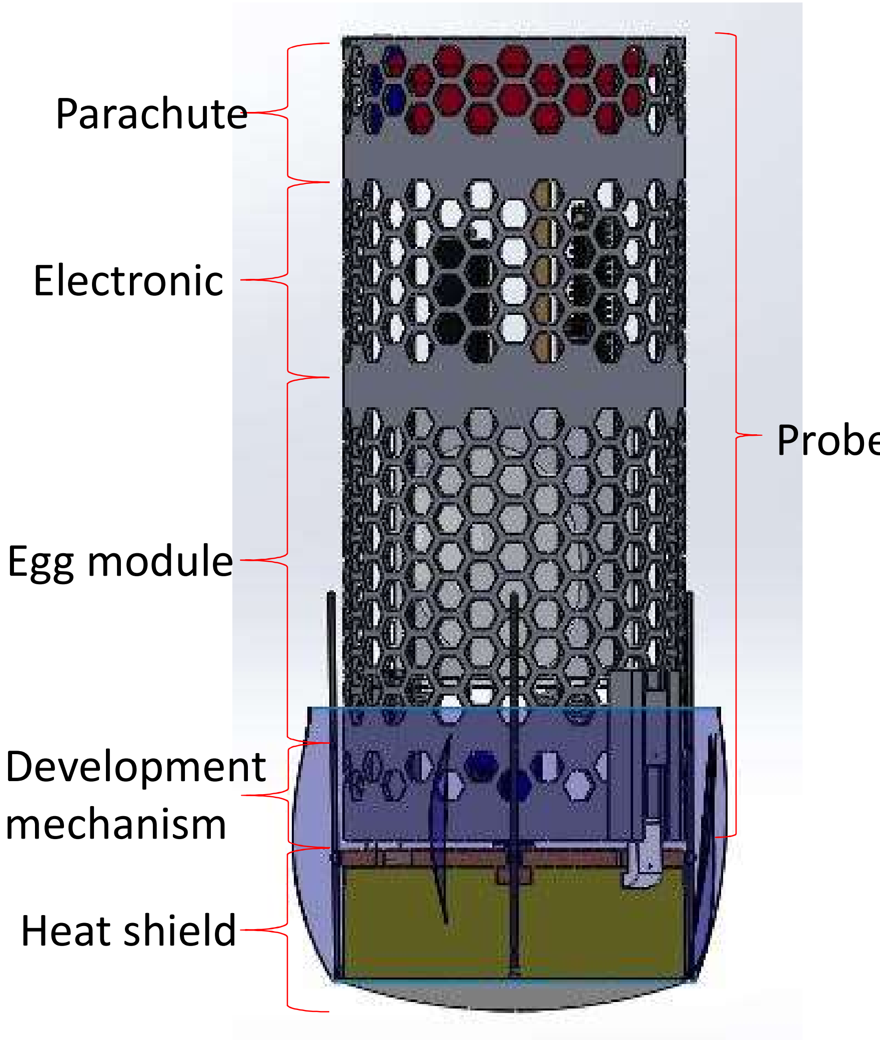
- Major structural components of the CanSat includes the **Probe** (containing egg module, electronics) and the **Heat Shield.**



Mechanical Subsystem Overview

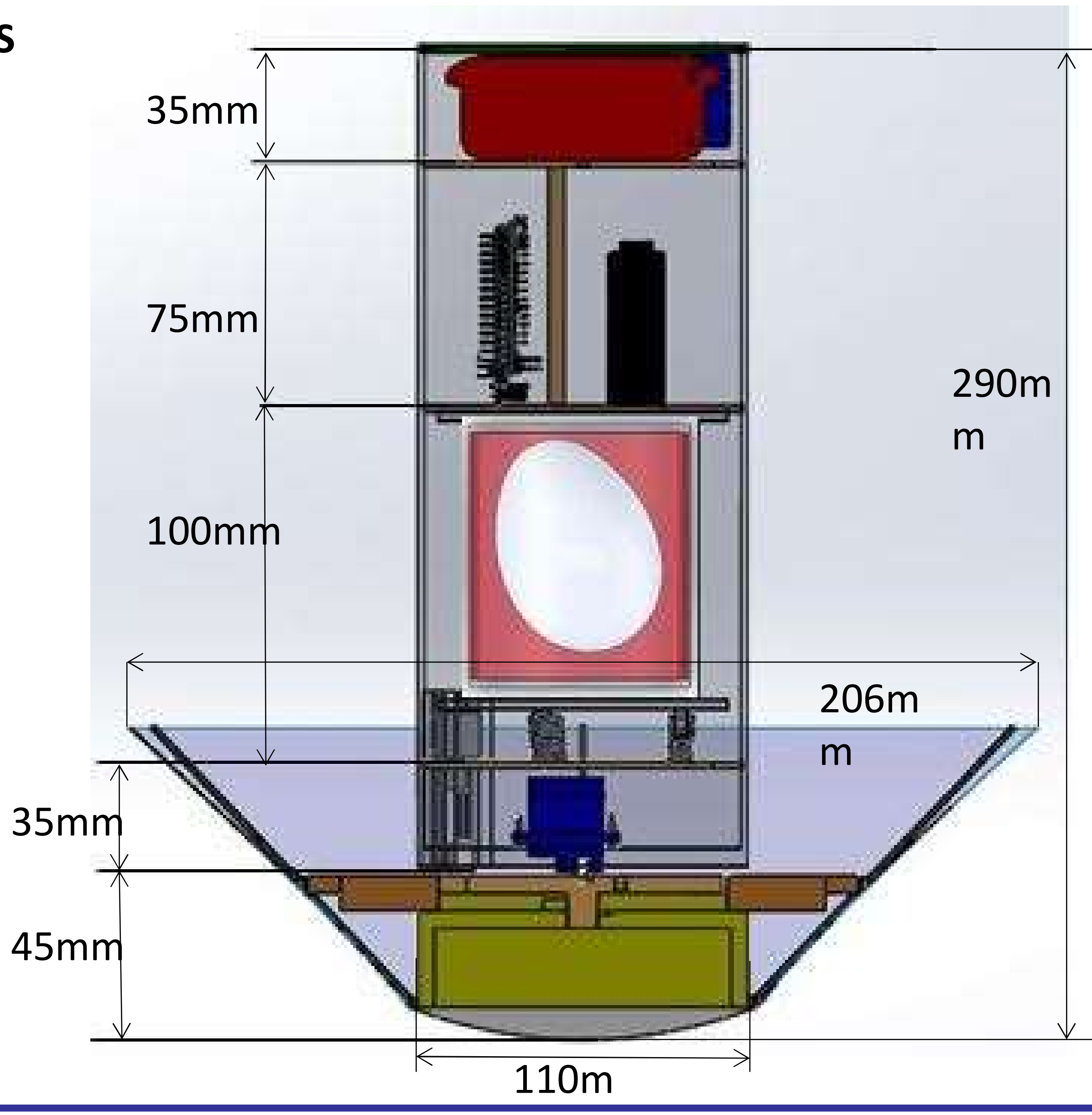
COMPARTMENTS

- **Parachute**- Parachute is kept at the top of PROBE.
- **Electronics**-
- **Egg module**- It contains egg protection structure and damping to protect egg.
- **Development mechanism-** This includes servo motor placed in probe and heat shield development mechanism operated by the servo.
- **Heat shield-** The heat shield is bottom most part of payload.
- **Bonus objective-** The camera is attached near the lower servo motor so that ejection of heat shield can be captured.

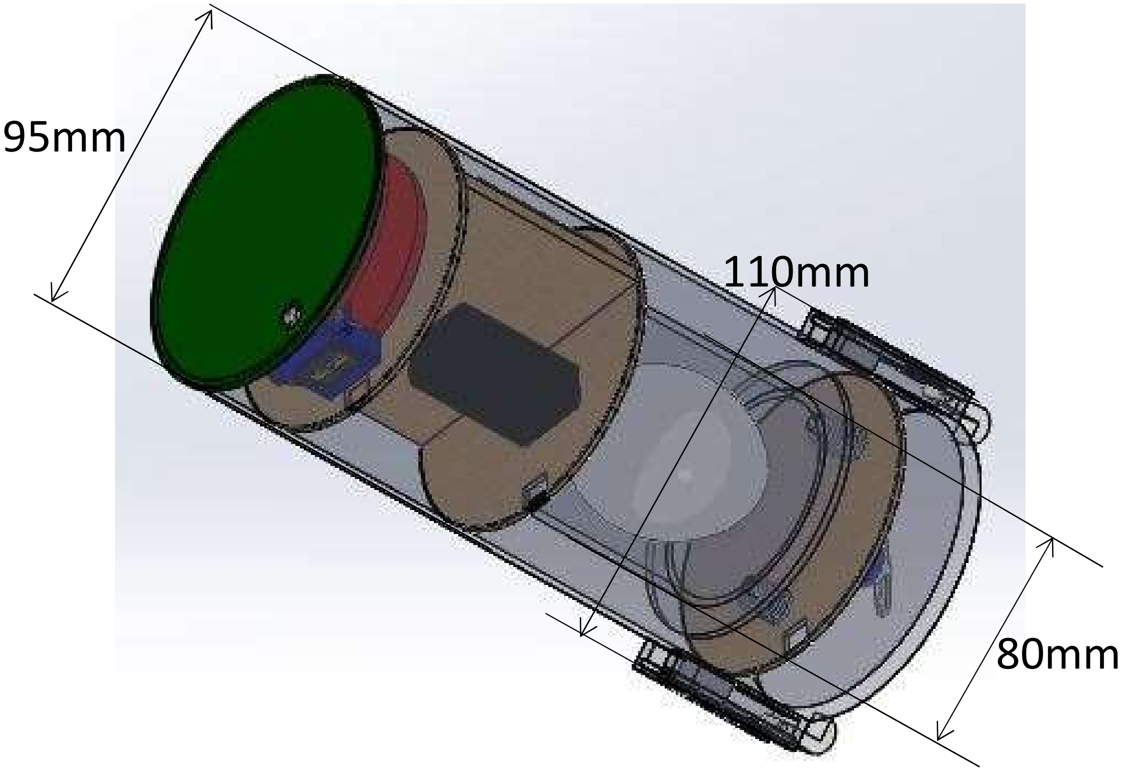


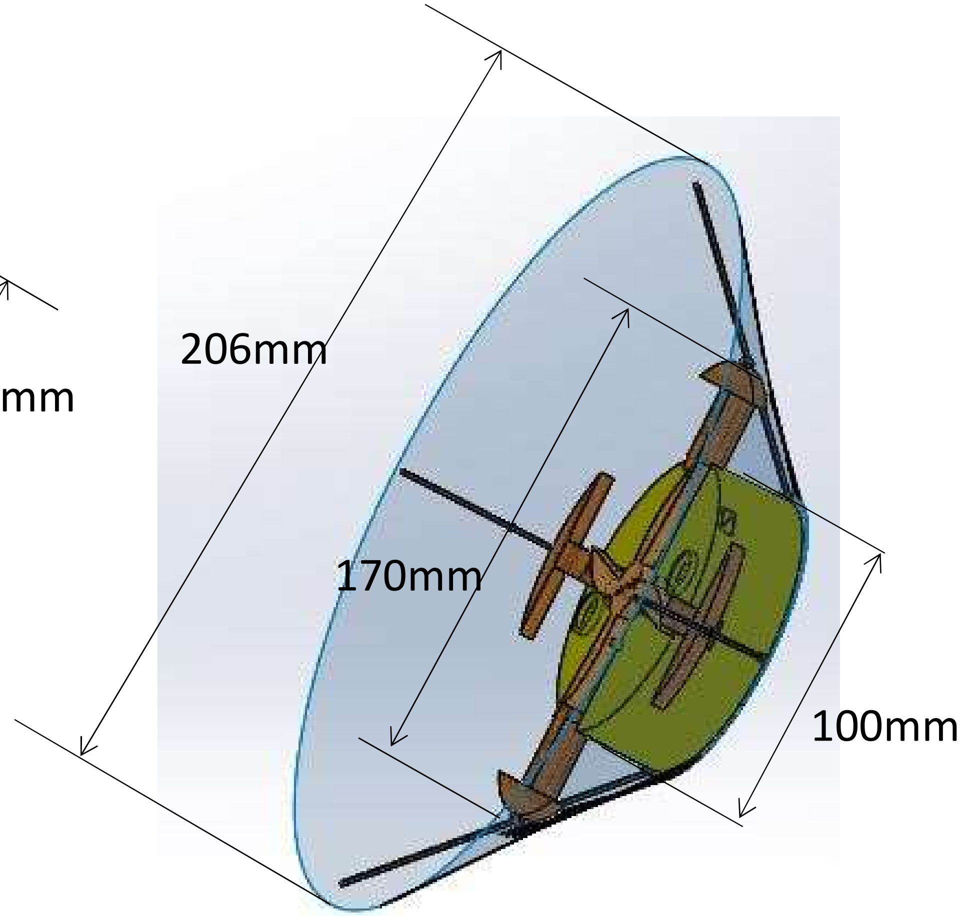
Mechanical Subsystem Overview

DIMENSIONS



Mechanical Subsystem Overview





Mechanical Subsystem Overview

Category	Components	Materials	Usage
Probe	Cylindrical tube	3D Printed Acrylonitrile butadiene styrene(ABS)	To protect electronic components and egg module.
Egg Module	Cylinder container, Springs.	Bubble wrap and plastic container.	To protect egg.
Probe Descent Control	Parachute	Ribstop nylon	Ensure smooth descent of PROBE after heat shield is detached.
Heat Shield	Cylindrical tube, Rods, Hinges.	Kevlar.	To protect the Payload.
Heat Shield Descent Control (Aero braking)	Developable cloth, Nose	Nylon,	Ensure smooth descent of PAYLOAD before detachment.
Probe and Heat shield Mechanical Interface	Grippers, Strings.	-	To hold Probe and Heat shield together.

Mechanical Sub-System Requirements

ID	Requirement (Payload)	Rational	Priority	Parent	VM			
					A	I	T	D
MSR-01	Total mass of the CanSat (payload) shall be 500 grams +/- 10 grams.	Mission Base Requirement	HIGH	SRS-01	✓	✓	✓	
MSR-02	The Payload (probe +heat shield) shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length.	Mission Base Requirement	HIGH	SRS-02	✓	✓		
MSR-03	The Payload shall not have any sharp edges.	Not to get stuck in the rocket	HIGH	SRS-05	✓	✓		
MSR-04	All mechanisms shall be capable of maintaining their configuration or states under all forces.	To ensure mechanisms work	HIGH	SRS-17		✓	✓	
MSR-05	Mechanisms shall not use pyrotechnics or chemicals.	Mission Base Requirement	HIGH	SRS-18	✓		✓	
MSR-06	The Payload shall be built to survive 30 Gs of shock and 15 Gs of launch acceleration.	To ensure that Payload can withstand the rocket deployment conditions.	HIGH	SRS-24	✓	✓		

Mechanical Sub-System Requirements

ID/	Requirement (Probe)	Rational	Priority	Parent	VM			
					A	I	T	D
MSR-07	All electronics shall be hard mounted using proper mounts.	To ensure that they remain intact with probe	HIGH	SRS-16	✓	✓	✓	
MSR-08	The probe shall hold a large hen's egg and protect it from damage from launch until landing.	Mission Base Requirement.	HIGH	SRS-06	✓		✓	✓
MSR-09	The probe shall deploy a parachute at 300 meters.	Mission Base Requirement.	HIGH	SRS-10	✓	✓		
MSR-10	Probe descent control device attachment components and devices (parachute) shall survive 30 Gs of shock.	To ensure that descent control works properly.	HIGH	SRS-12	✓		✓	
MSR-11	An audio beacon is required for the probe.	To facilitate search of probe	HIGH	SRS-30	✓	✓		
MSR-12	Probe shall be labelled with team contact information.	Mission Base Requirement.	HIGH	SRS-20		✓	✓	

Mechanical Sub-System Requirements

ID	Requirement (Heat Shield)	Rational	Priority	Parent	VM			
					A	I	T	D
MSR-13	The aero-braking heat shield shall be used to protect the probe.	Mission Base Requirement.	HIGH	--	✓	✓		
MSR-14	The heat shield must not have any openings.	To ensure probe is protected	HIGH	SRS-05	✓	✓	✓	
MSR-15	Probe descent control device attachment components and devices (heat shield cloth) shall survive 30 Gs of shock.	To ensure that descent control works properly.	HIGH	SRS-12	✓		✓	
MSR-16	The aero-braking heat shield shall be released from the probe at 300 meters.	Mission Base Requirement.	HIGH	SRS-10	✓	✓		

Probe Mechanical Layout of Components Trade & Selection

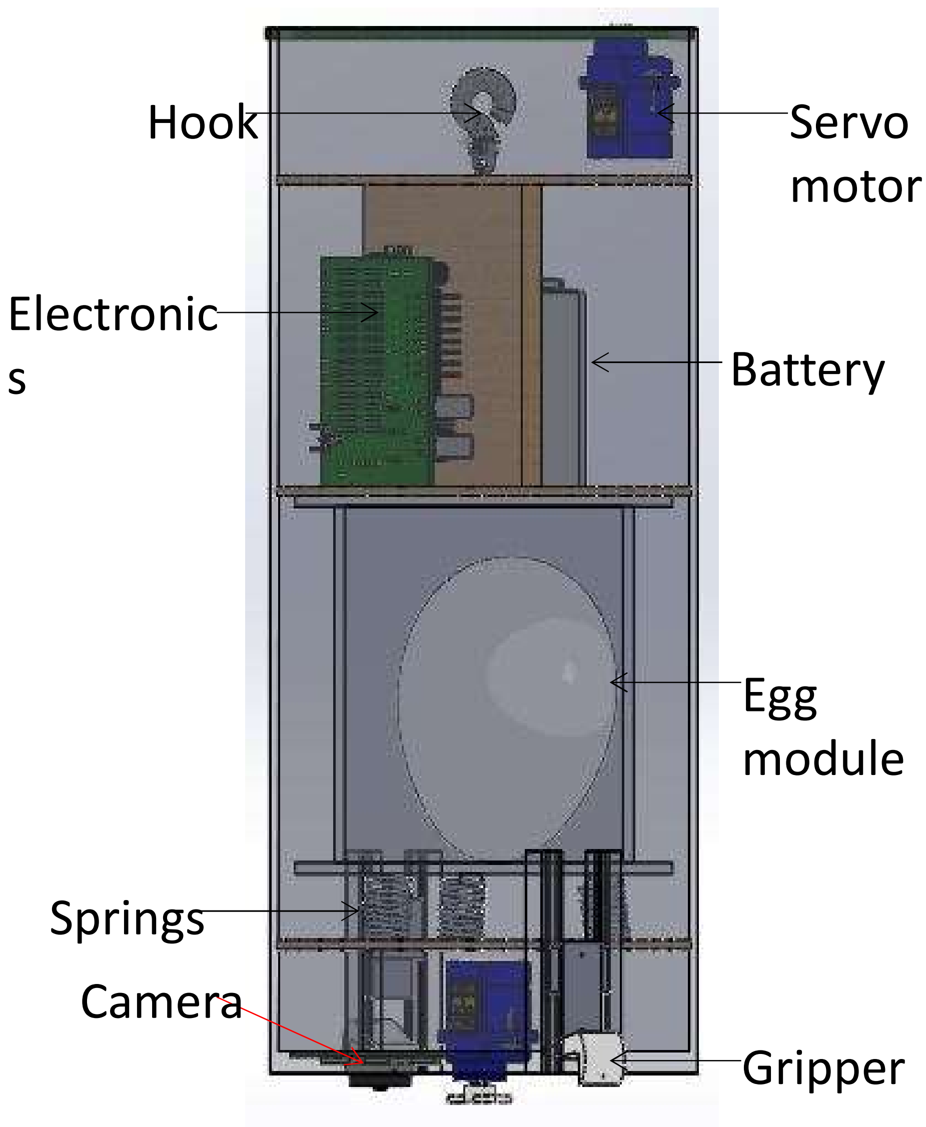
The probe mainly consist of

- **Parachute**
- **Electronics,**
- **battery,**
- **egg module,**
- **springs,**
- **Grippers, etc.**

Probe attachments points-

- **Swivel Hook -** it is used to attach parachute to the probe. It helps in maintaining orientation.

- ***Grippers-*** They are used to attach heat shield with Probe.



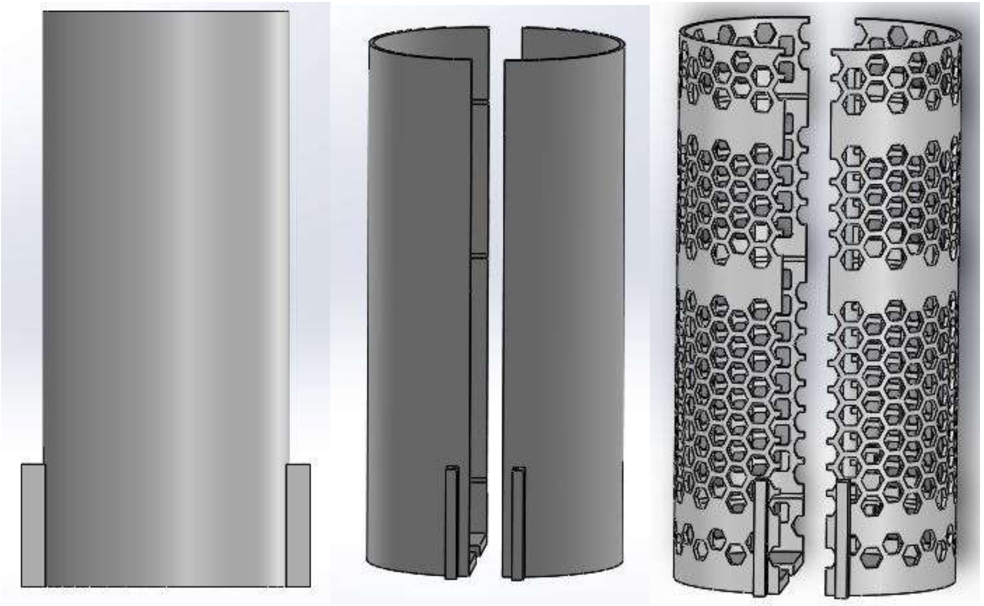
STRUCTURE OF PROBE

Probe Mechanical Layout of Components Trade & Selection

PoS / Designs	Strength	Ease of Fabrication	Ease of Integration	Weight	Cost
1. Full cylinder Solid	9	8	5	9	9
2. Half Cylinder Solid	8	9	7	9	8
3. Half Cylinder Honeycomb.	8	8	9	6	7

Half Cylinder Honeycomb structure was selected due to its **lower weight** and **higher ease of integration**

Grading (0-10):
0 –Least
10 -Most



1 2 3

Probe Mechanical Layout of Components Trade & Selection

Probe Material Selection

Material	Cost	Density $\left(\frac{g}{cm^3}\right)$	Pros	Cons
1. 3D Printed Polylactic Acid (PLA)	15 to 20 $/Kg	1.25	• Easier to print than ABS • Biodegradable • High strength	• Low flexibility • Cannot tolerate considerable temperatures • Degrades over time
2. 3D Printed Acrylonitrile butadiene styrene(ABS)	20 to 50 $/Kg	1.07	• Tough, water and impact resistant • High strength and Durability • Able to withstand high stress	• Can cost high • Composite structure may or may not withstand high temperatures

Probe Mechanical Layout of Components Trade & Selection

Material	Cost	Density $(\frac{g}{cm^3})$	Pros	Cons
3. Fibreglass	$2/lbs.	1.9-1.99	• High Strength to weightratio • Cheaper and flexible than carbon fibre • Good tensile strength	• Cracks on impact • Comparatively not durable • Deform with heat • Dense material
4. Carbon Fibre	$11/Kg	1.68	• High strength to weight ratio • Light weight • Can sustain high stress • Good tensile strength	• Costly • Rigid and somewhat brittle • Difficult to fabricate

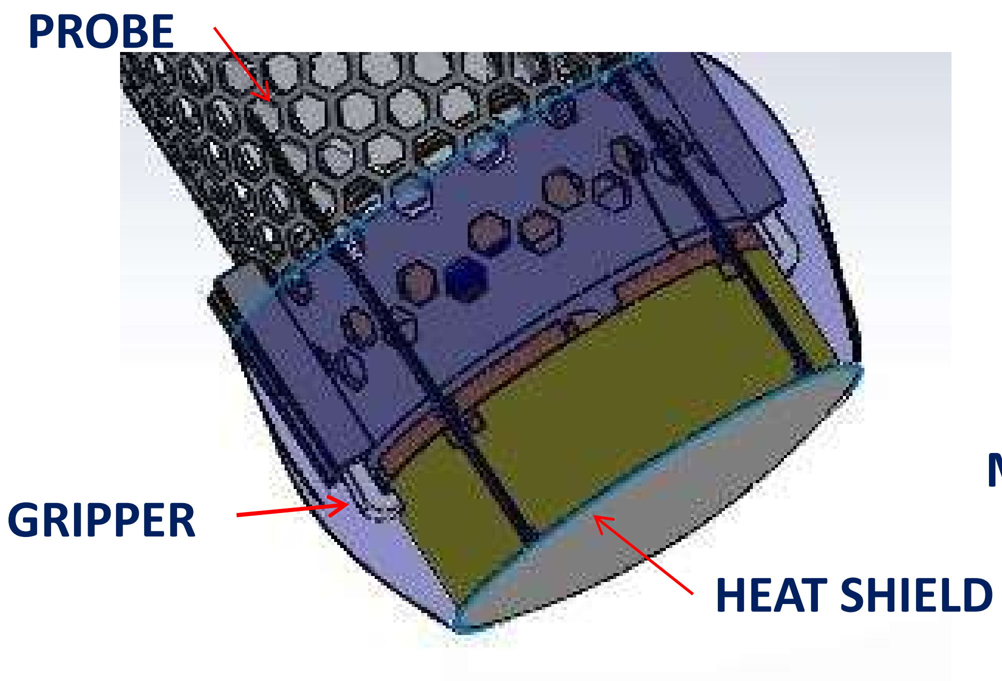
3D Printed Acrylonitrile butadiene styrene(ABS) was selected because of **low density, structural Strength, ease of shaping, Impact resistance** which would lead to light weight body and sustain the impact of fall.

Payload Pre Deployment Configuration Trade & Selection

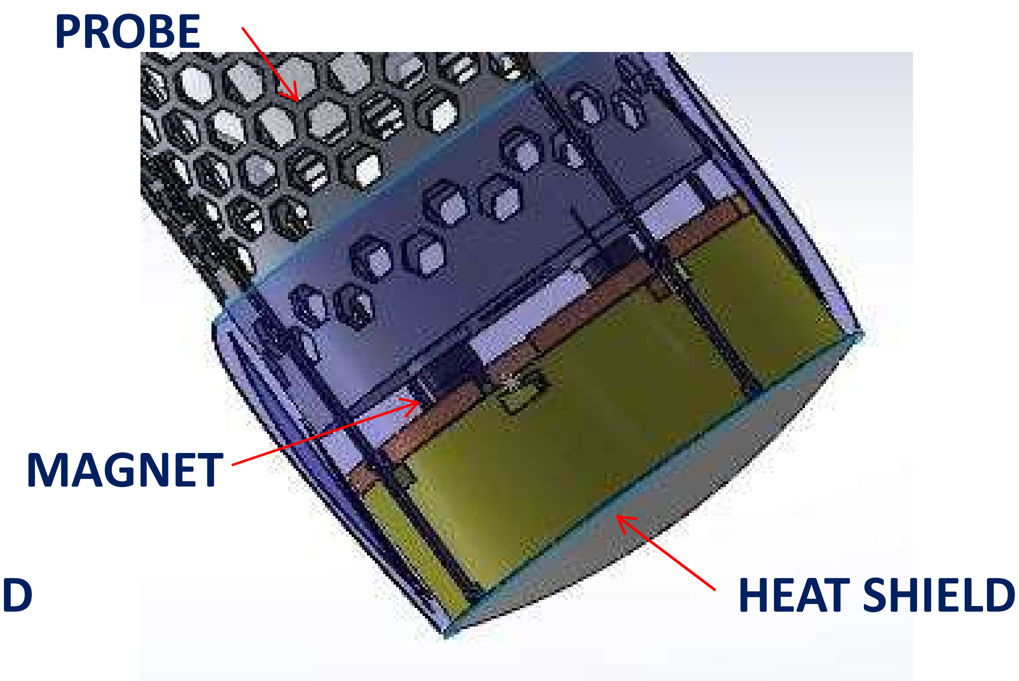
Predevelopment Configuration

- The payload consist of two different parts viz. probe and heat shield which is to be detached.
- The probe and heat shield can be kept together in two ways:

1.Gripper



2. Magnets.



Payload Pre Deployment Configuration Trade & Selection

PoS / Designs	Strength of attachment	Ease of Fabrication	Stability	Weight	Cost
1. Gripper	9	9	9	9	7
2. Magnets	8	8	8	8	9

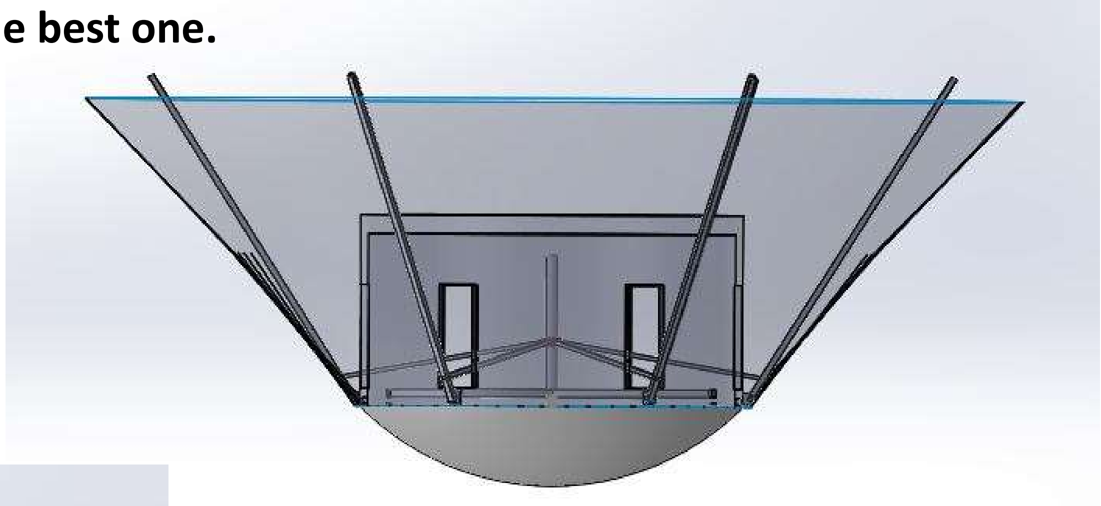
Grippers were selected owing to its **high strength** and **high stability**.

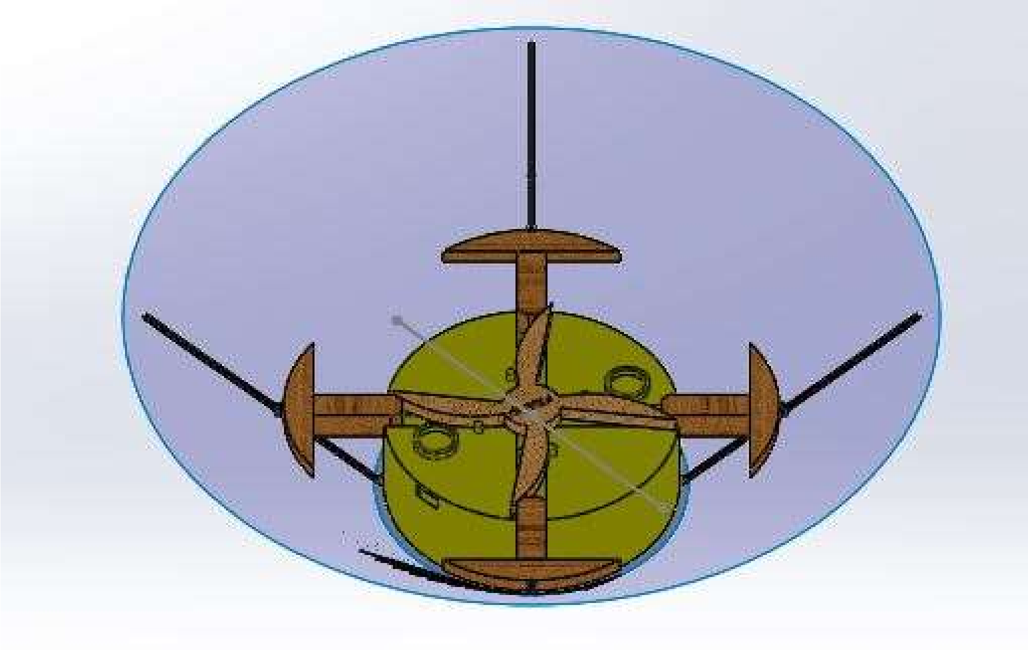
Grading (0-10):
0 –Least
10 -Most

- Heat shield is to be developed once it comes out of rocket.
- Three designs were analysed to select the best one.

1. UMBRELLA.

In this, the mechanism similar to umbrella is used to develop the heat shield. This mechanism is hard to manufacture. As linear motion is to be given, it makes it difficult to detach.





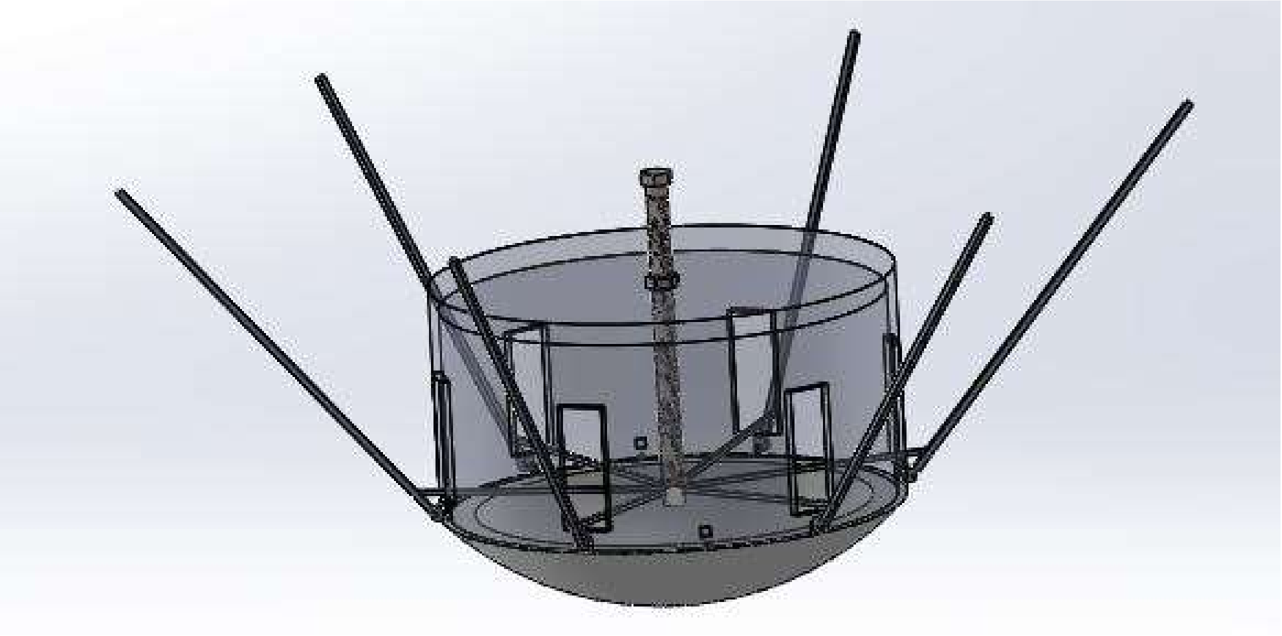
2.CAM.

Here a Cam follower mechanism is used. The servo motor rotates the cam through gears pushing the followers outside and opening the heat shield. The gears are used to transfer motion so no fixed contact with motor which in probe, this facilitates the detachment of heat shield.

Heat shield Pre Deployment Configuration Trade & Selection

3. LEAD SCREW.

- Here a BOLT(lead screw) is attached to servo motor which on rotation imparts linear motion to heat shield through nut attached to heat shield.
- When heat shield cylinder moves down the heat shield is developed with the help of rods which are hinged.
- This mechanism is difficult to detach it is fixed with motor in probe.



Heat shield Pre Deployment Configuration Trade & Selection

PoS / Designs	Strength	Ease of Fabrication	Ease of detachment	Ease to develop	Cost
1. Umbrella	8	7	5	8	7
2. Cam	9	8	9	9	8
3. Lead screw	9	7	5	7	9

CAM and FOLLOWER MECHANISM was selected due to its **good ease of fabrication and detachment** and **high strength.**

Grading (0-10):
0 –Least
10 -Most

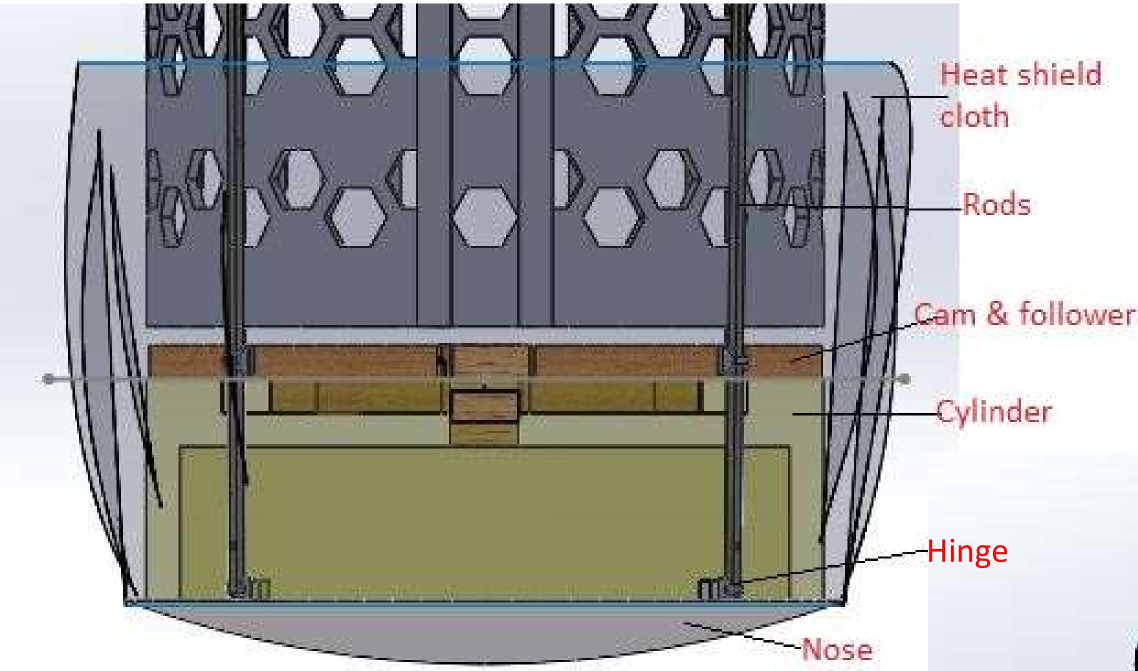
Heat shield Mechanical Layout of Components Trade & Selection

Aero-braking Heat Shield

- **The purpose of a heat shield is to prevent a spacecraft from being damaged by high temperatures as it decelerates through a planet's Atmosphere.**
- **The larger the total surface area of the heat shield, greater the drag force generated.**
- **The larger heat shield produces more friction at higher altitudes, slowing the payload down faster in thinner atmospheres.**
- **Heat shield is designed to withstand temperature and pressure characteristics to high velocity.**

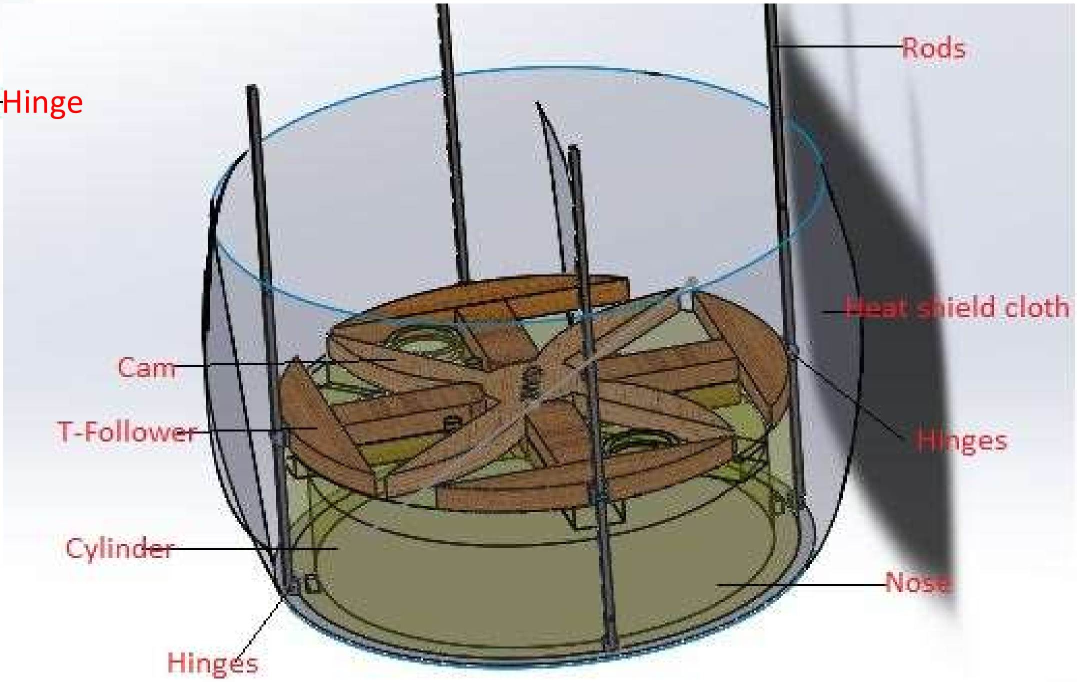
The Heat shield was mainly divided into three parts viz.

- Shielding by **Nose**
- Development by **cam and follower** mechanism
- Aero braking brought by opening the heat shield which is further called as **Heat shield cloth**



FRONT VIEW

Heat shield mainly consist of
- **Heat shield cloth,**
- **Rods,**
- **Cam & follower,**
- **Cylinder, and**
- **Nose**

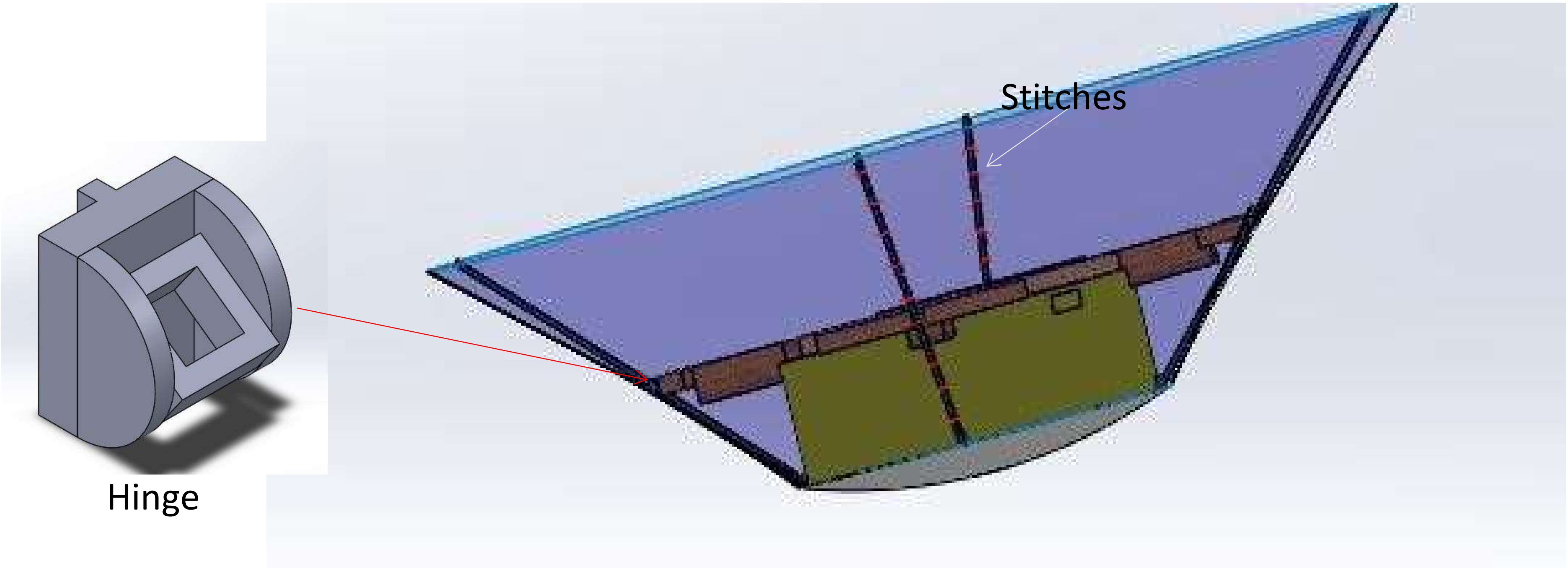


ISOMETRIC VIEW

Heat shield Mechanical Layout of Components Trade & Selection

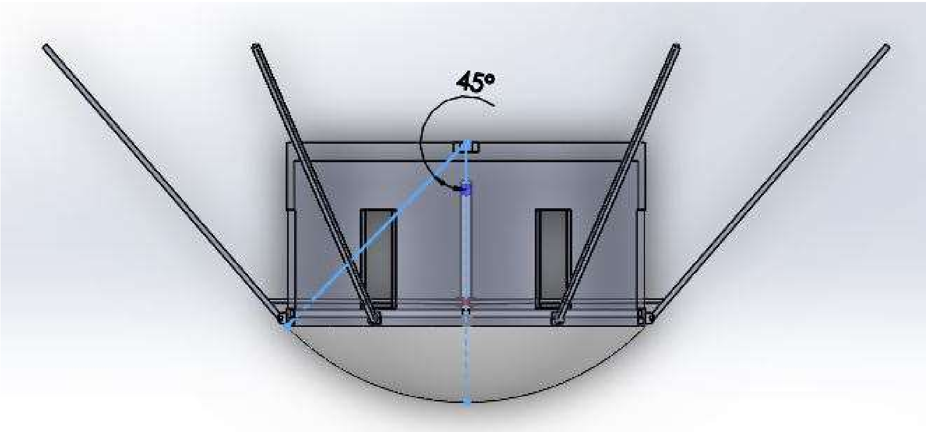
Attachments points Of Heat Shield

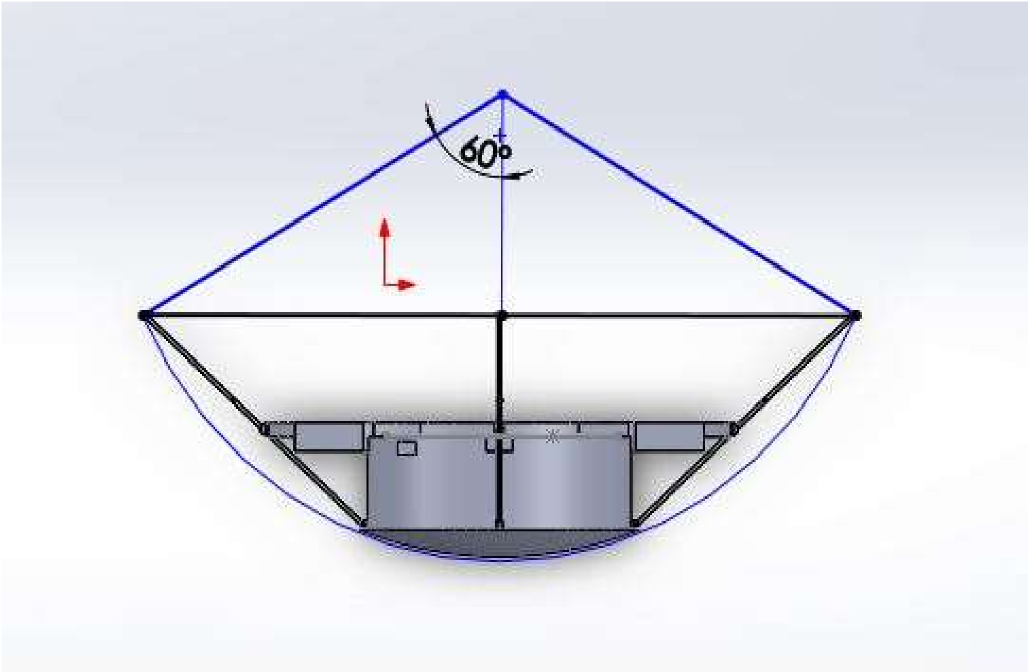
- **Hinges** are used to join rods with cylinder at bottom and also with followers.
- *The follower* slides in groves made on cylinder.
- *Cam* rests on cylinder and is maintained on position by rotating gears.
- The rods will be stitched with the heat shield cloth



Heat Shield Configurations

- The most important component which affects the mechanical layout of heat shield is shape of ***NOSE and DEVELOPED HEAT SHIELD***
- Nose is ***SPHERE*** section and the drag co-efficient of this shape depends on the ***HALF SPHERE-CONE ANGLE.***
- Hence two designs were made with taking ***45 and 60*** as half angle for nose and nose+developed heat shield respectively

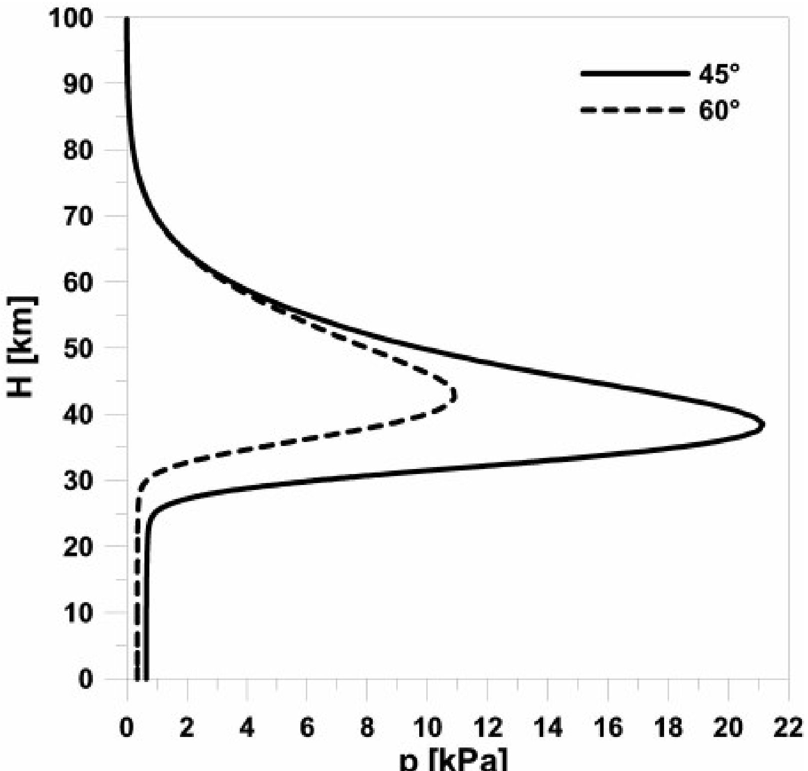




Heat shield Mechanical Layout of Components Trade & Selection

Half-cone angle [°]	D [m] Diameter	S [m2] Surface Area	Cd Co-efficient of drag	β= m/(Cd*S) Ballistic co-efficient
60	1	0.79	1.4	18
45	0.84	0.58	1.03	33

Reference-
IRENE PRELIMINARY STUDY (ITALIAN RE-ENTRY NACELLE PRELIMINARY STUDY).



- It is evident that, due to the steeper re-entry trajectory, caused by the larger ballistic coefficient, the design with 45 deg half-cone angle experiences the highest **heat fluxes** and **impact pressures**, in particular on the nose-cone.
- It must be also pointed out that, due to the relatively blunter configuration, the capsule with 60 deg half-cone angle exhibits comparable heat fluxes and pressures on the conical surface.
- Therefore 60 deg offer the advantage of a **better static** and **dynamic stability.**

Hence ***60 deg Half sphere-cone angle*** for nose+developed heat shield was selected.

Heat shield Mechanical Layout of Components Trade & Selection

ANNUAL CANSAT COMPETITION

Material selection-

Types of Heat shield

1. **<u>Ablative type heat shield</u>** – The ablative heat shield functions by lifting the hot shock layer gas away from the heat shield's outer wall. The boundary layer comes from *blowing* of gaseous reaction products from the heat shield material and provides protection against all forms of heat flux.
2. **<u>Abrasive type (Heat sink) heat shield</u>** - This method provide sufficient mass of material to absorb the heat being generated. The material used must have a high melting point, high heat capacity, heat density and heat capacity product and high thermal conductivity so that the surface temperature does not exceed melting.

The heat sink or abrasive type is used due to following reasons:

- The CanSat is deployed at relatively lower altitude thus the heat developed is very less compared to that of a re-entry vehicle. So using ablative type won't solve the problem in this case as the temperature required for the gas formation in the ablative is not obtained. Thus the use of Ablative type cannot be justified.
- The lack of availability of ablative material.
- The heat sink type is easily available.

Heat shield Mechanical Layout of Components Trade & Selection

Nose Material selection-

Materials	Operating temperature	Pros	Cons	Justification for Rejection
Ceramic composite with Carbon fibre matrix	1200°C	• Light weight compared to other shielding material. • Resistant to high temperature.	• Expensive • Availability • Mechanical properties fall at high temperatures	• Excels the temperature requirement. • Availability • Change in property is not desirable.
Glass ceramic composite reinforced with silicon carbide	1000ºC and beyond	• Light weight compared to other shielding material. • Heat Resistant. • Retain mechanical properties at high temperature	• Expensive • Availability	• Excels the temperature requirement. • Availability
Teflon	327°C	• High flexibility • High electrical resistance • Low coefficient of friction.	• Cannot sustain high temperature. • Produces harmful chemical on burning.	• Harmful for wildlife • Unable to sustain high temperatures.

Heat shield Mechanical Layout of Components Trade & Selection

Material	Operating Temperature	Pros	Cons	Justification for selection
Polybenzimid--azole Fibre (PBI)	About 420º C	• Thermal and chemical stability • Do not burn in air. • Retain property when exposed to extreme heat.	• Expensive • Difficult to manufacture • Low tenacity	• Ideal for the mission • Thermal stability
Calcium Silicate	1540º C	• Good thermal insulator • High melting point • Availability	• Difficult to mould into desired shape	• High operating temperature
Kevlar	About 350º C	• Good mechanical properties • Handle large amount of pressures • High tensile strength to weight ratio	• Tensile strength decreases with temperature • Production is expensive	• Good shock absorption • Pressure is handled well.

Heat shield Mechanical Layout of Components Trade & Selection

ANNUAL CANSAT COMPETITION

Heat Shield Cloth Material selection-

Material	Pros	Cons
Nylon	• Tear resistant, non porosity • Good strength to weight ratio. • Withstand friction wear. • Endures repeated bending and flexing. • Good tensile strength.	• Cannot withstand higher temperatures.
Kevlar	• High strength to weight ratio. • High tensile strength. • Does not expand on heating. • Abrasion resistant.	• Absorb moisture • Poor compressive strength. • Difficult to cut. • Comparatively higher density.
Carbon fibre	• Good tensile strength. • Good compressive strength. • Good stiffness. • Heat resistance.	• High cost. • Higher density compared to nylon.

Heat shield Mechanical Layout of Components Trade & Selection

ANNUAL CANSAT COMPETITION

Heat Shield Cloth Material selection-

Material	Stiffness (GPa)	Strength (MPa)	Extendibility (%)	Toughness (MJ/m^3)
Nylon	5	950	18	80
Carbon fibre	300	4000	1.3	25
Kevlar	130	3600	2.7	50

Nylon was selected due to following reasons:

- Nylon have comparable strength to the others.
- Nylon have good toughness and extendibility.
- Required heat resistance for the mission.
- Lower density.

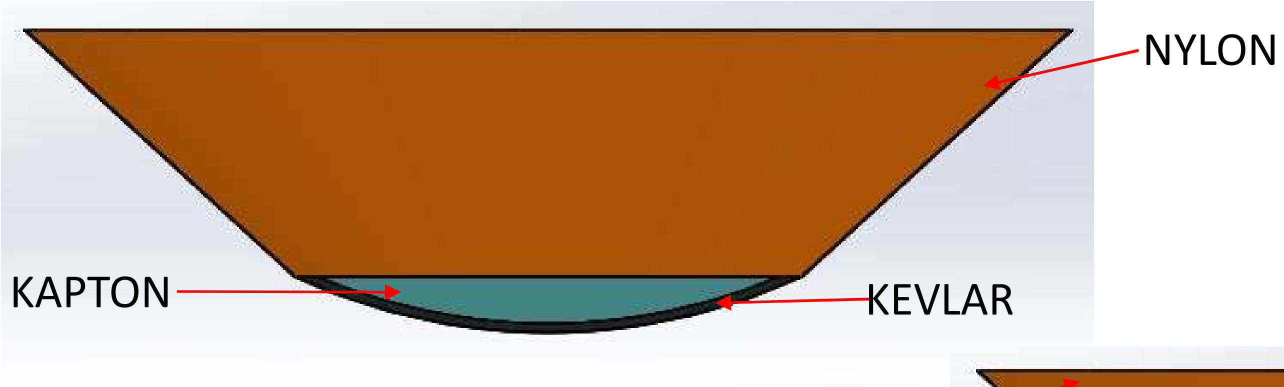
Heat shield Mechanical Layout of Components Trade & Selection

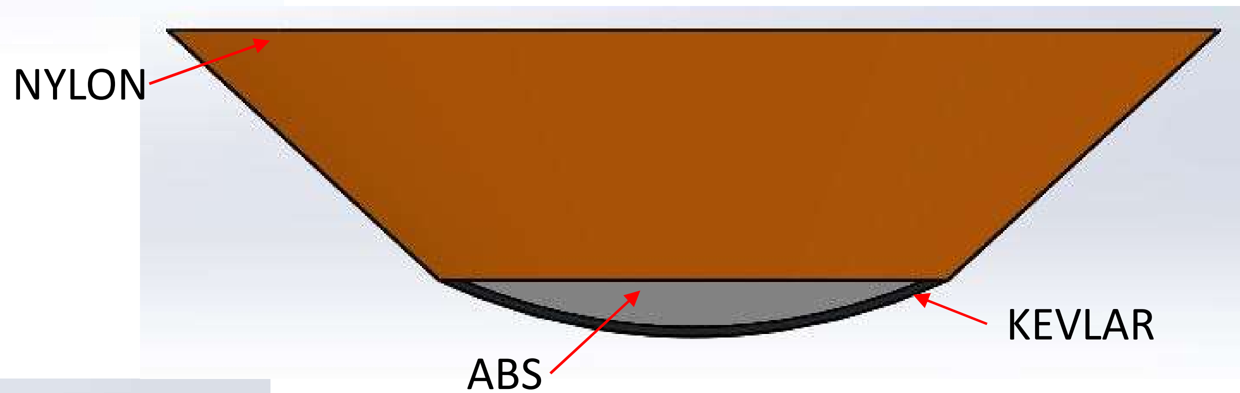
Different Combination of Materials of Heat shield

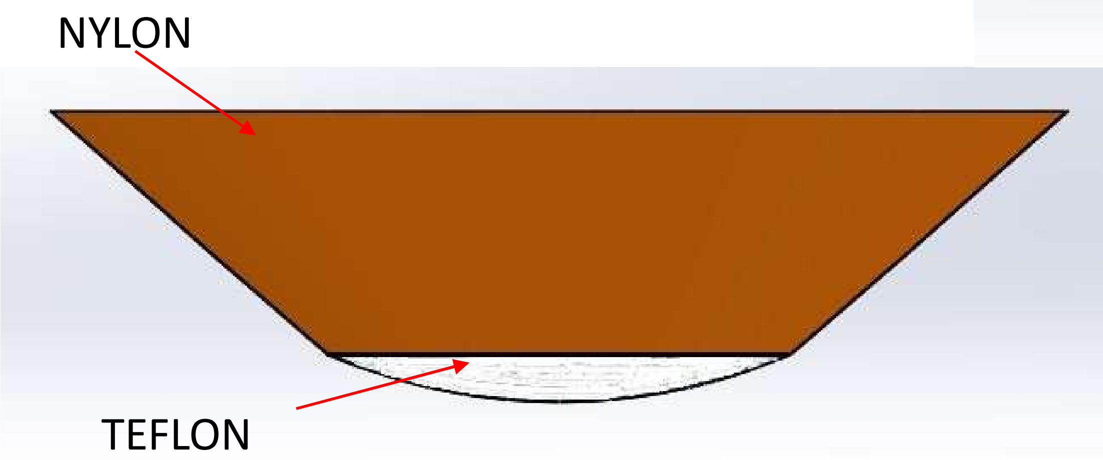
Combination	Pros	Cons
Nose- **Kapton** Nose coating- **Kevlar** Cloth- **Nylon**	• Good shielding. • Kevlar can resists large amount of pressures • Kapton has good thermal resistance and is non permeable to gas.	• It is costly. • Difficult to cut and shape.
Complete Nose - **Teflon** Cloth- **Nylon**	• Good thermal resistance • Tear resistant, good structural strength • Less thermal conductivity	• Material are harmful to fauna.
Nose- **ABS** Nose coating- **PBI fabric with calcium silicate lining** Cloth- **Nylon**	• Good thermal Shielding • Good mechanical properties like flexibility • Chemical resistance.	• Difficult to manufacture. • Comparable Surface friction
Nose**- ABS** Nose coating- **Kevlar** Cloth**- Nylon**	• Kevlar can resist large amount of pressures. • Tear resistant • Heat resistant	• It is expensive. • Difficult to integrate.

Heat shield Mechanical Layout of Components Trade & Selection

Different Combination of Materials of Heat shield



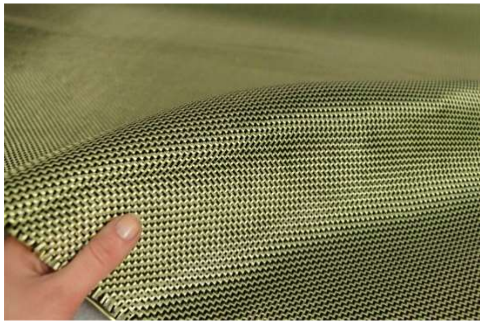




Heat shield Mechanical Layout of Components Trade & Selection

Combination of Nylon, Kevlar, Kapton was selected due to following reasons:

- Good thermal shielding.
- Light weight.
- Good mechanical properties like flexibility, low moisture regain, outstanding strength to body ratio.
- Chemical resistant.



Kevlar is to be coated on the kapton shell

Nylon is to be attached to the supporting rods and T-follower.

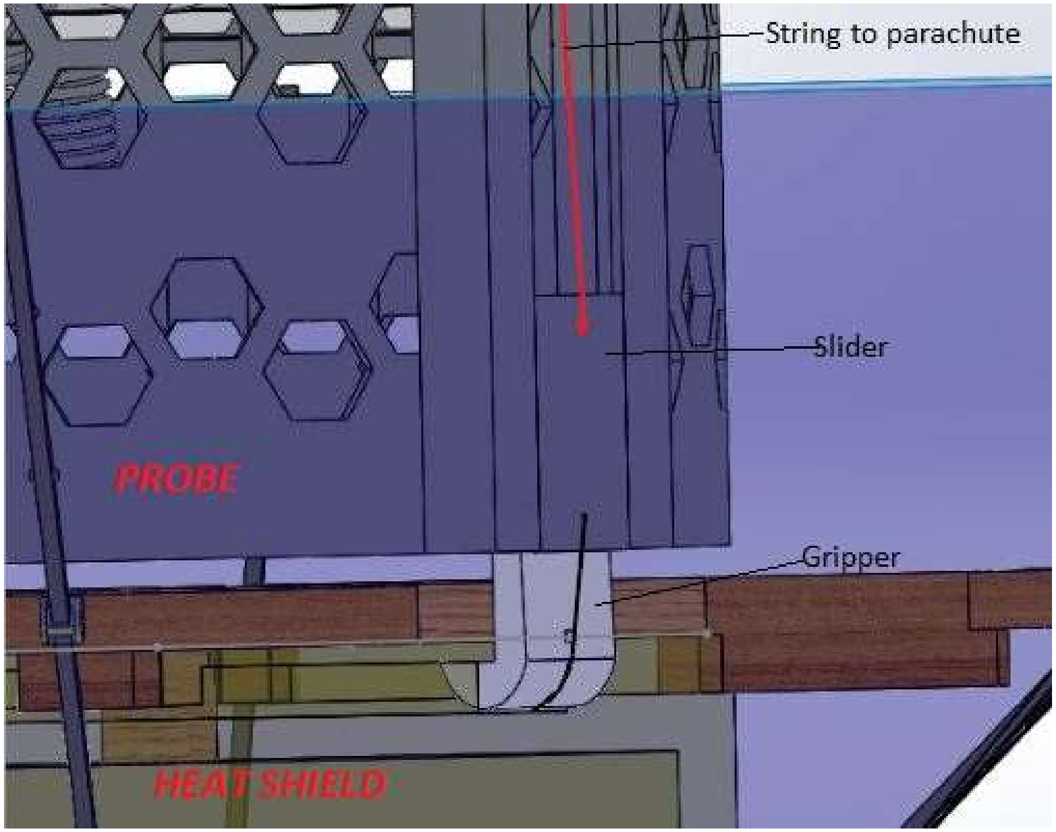
Kapton shell is 3D printed to form the base of nose.

Heat shield Release Mechanism

- *Heat shield and probe are held together by two techniques viz. grippers and magnets.*
- *The grippers were selected owing to its ease of detachment, lets see how this happens.*

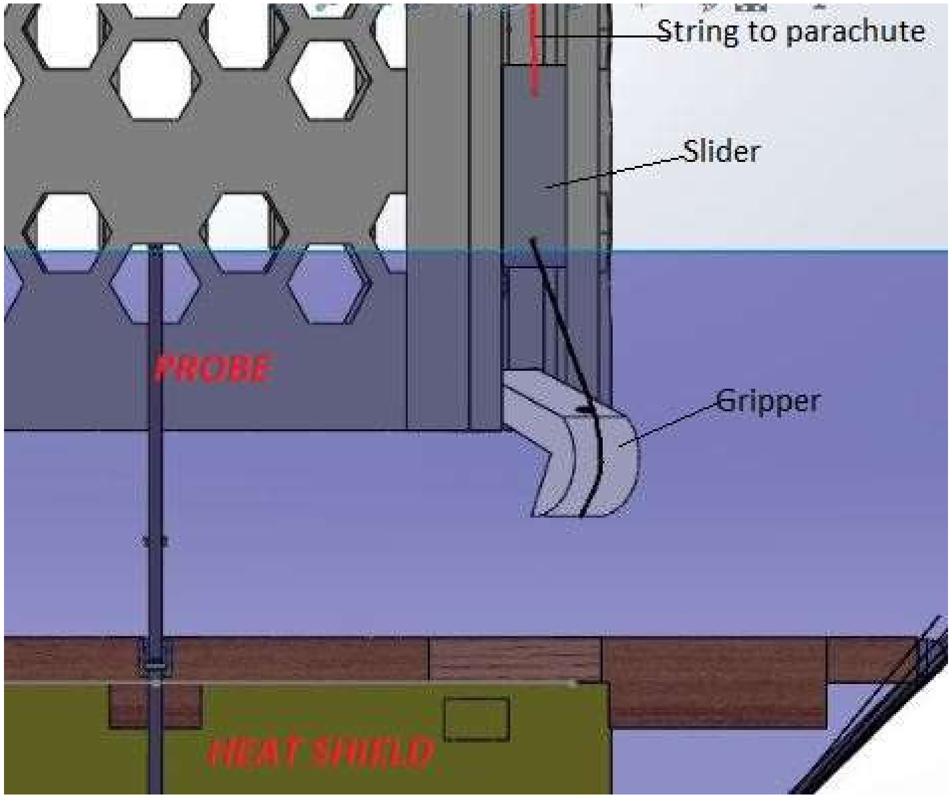
Method of Operation-

- The grippers consist a gripper and slider which slides on probe. The gripper is attached to probe.
- The gripper enters the hole on heat shield, hence holding it. The slider covers the gripper making it stable and helps in retaining position.



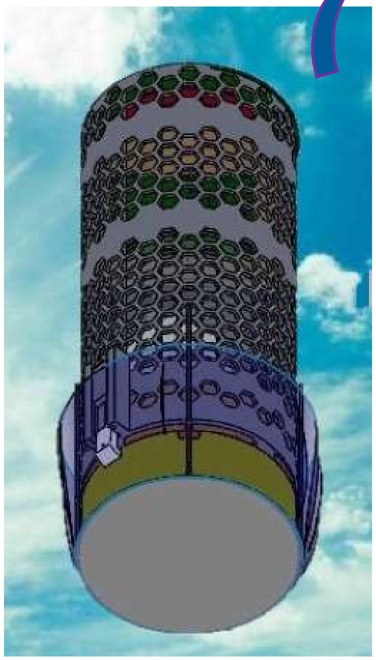
Heat shield Release Mechanism

- The slider is connected to parachute through string.
- As soon as **parachute opens** at 300m. the strings are pulled up, pulling the slider and opening the gripper.
- The advantage of this mechanism is that no different power source is required to activate Grippers.



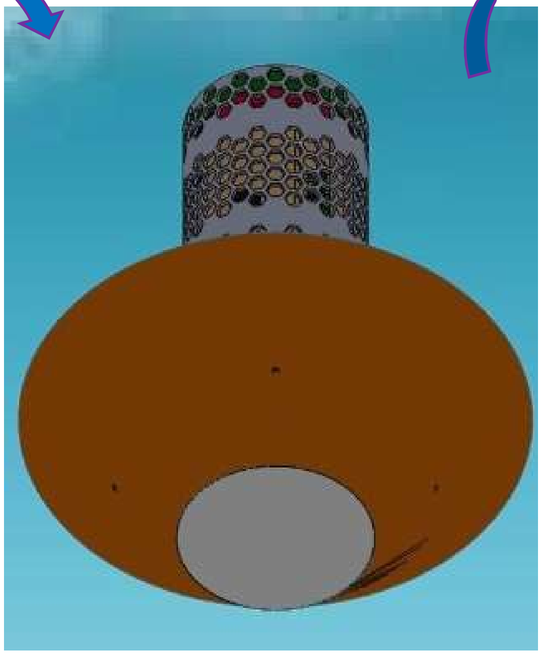
- The design of magnet worked on parachute jerk and so was little unreliable whereas the grippers are reliable i.e. it will always detach heat shield if parachute opens. The only disadvantage is it is difficult to ***keep in stowed condition.***
- Tests are to be done on magnets as well as grippers. Tests will give exact idea of which is better for both ***keeping in stowed condition and detachment***

Heat shield Release Mechanism



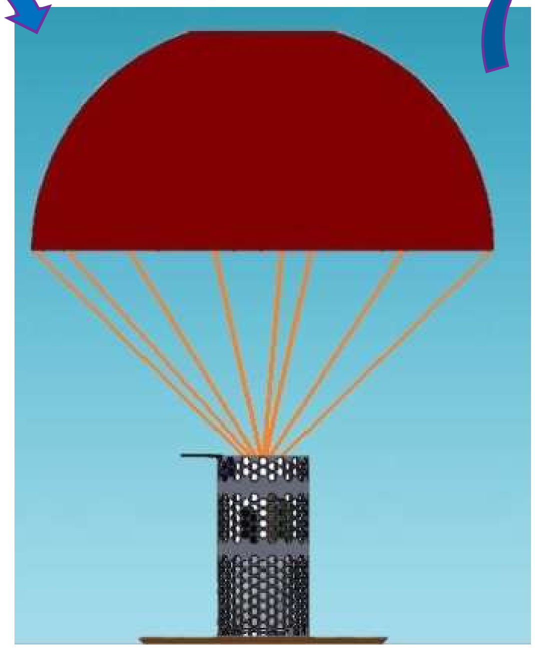
Stage 1

Payload launched at 650 to 725m.



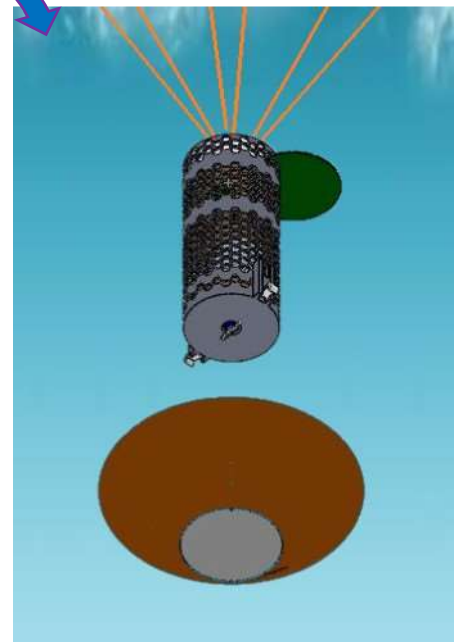
Stage 2

Heat shield developed as soon as payload ejects from rocket.



Stage 3

Parachute opens at 300m.



Stage 4

Heat shield deployed as soon as parachute opens.

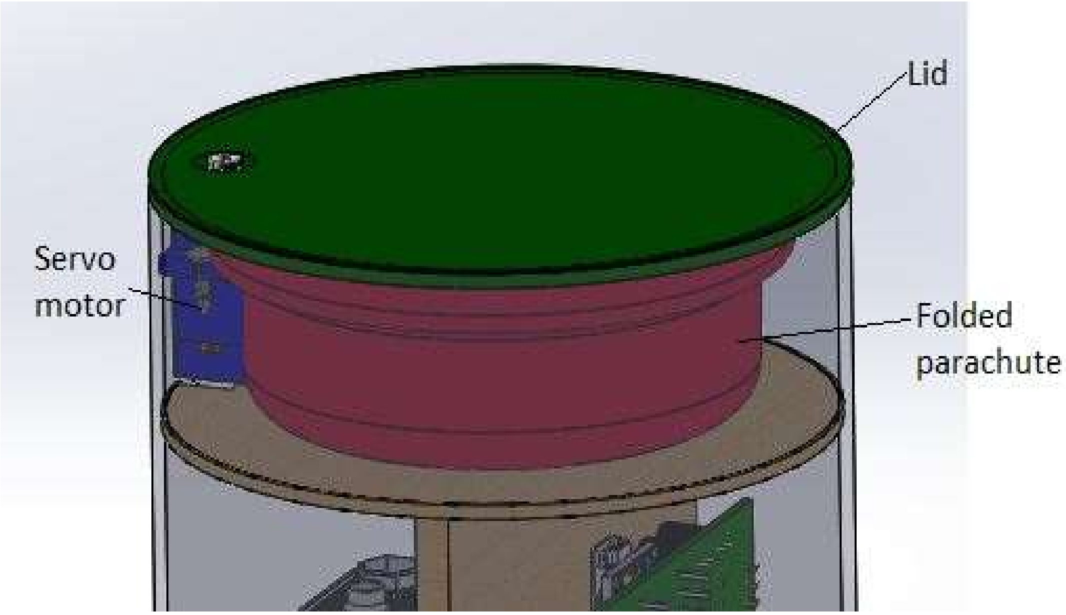
Probe Parachute Release Mechanism

The parachute is kept in the parachute compartment at the top of Probe.

- ***The probe has a lid.***
- ***servo motor is used to open the lid.***

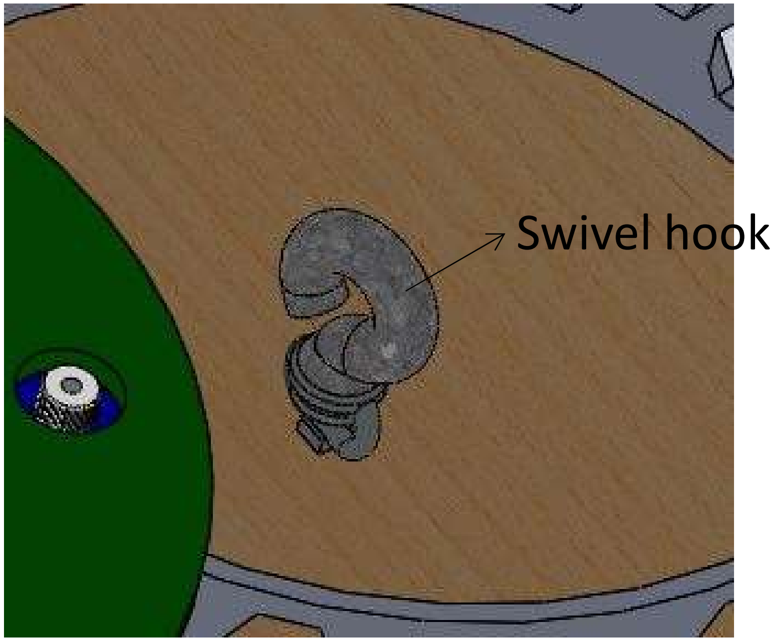
Method of Operation-

- *The parachute is stowed in folded condition.*
- *The servo motor is operated at 300m opening the lid*
- *As soon as lid is open, large air rushes in through holes present in honeycomb structure.*



Probe Parachute Release Mechanism

- **Swivel Hook** is used to attach the parachute with the probe.
- The swivel hook offers greater stability and maintains the orientation.

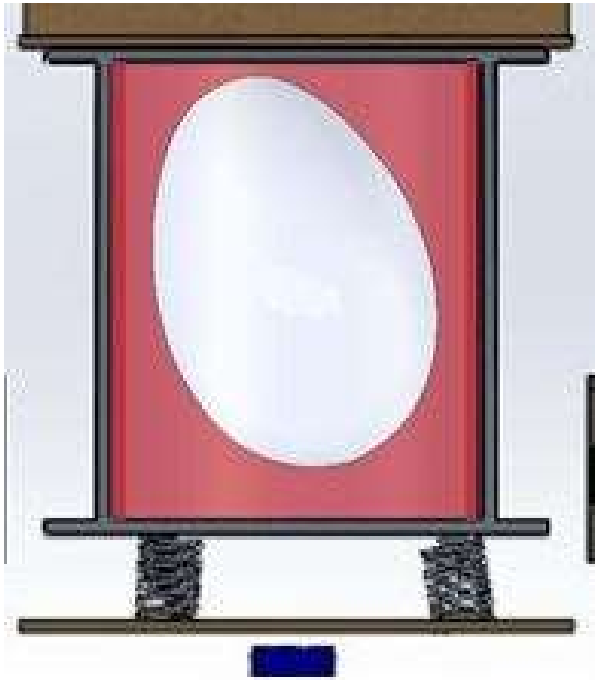


Egg Protection Structure

- *The Egg protection structure should protect egg from Launch shock as well as landing shock.*
- *The basic idea is to create a envelop around egg and place in a container . This is called as egg module.*
- *The egg module is then placed in probe.*

Egg protection structural design-

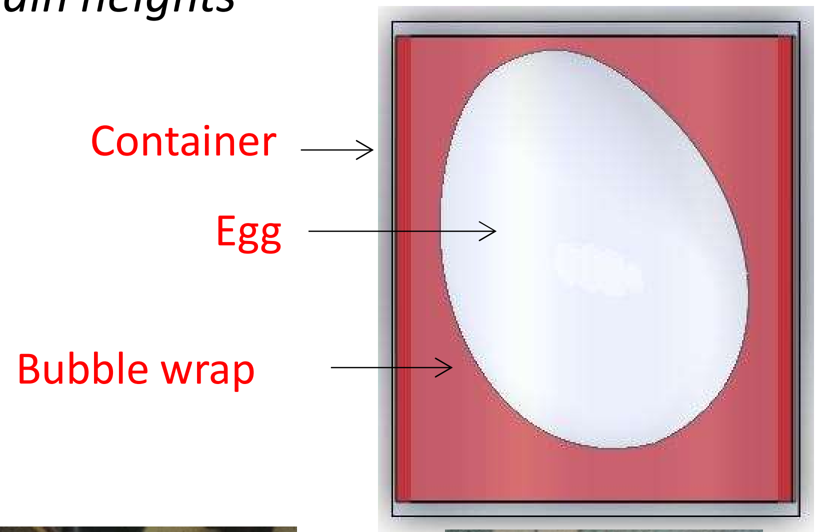
- *The structure includes egg module, the damping system and probe.*
- *The damping is provided by set of springs(3) placed under the egg module.*
- *The springs absorb shocks as well as maintains the stability of module.*



Egg Protection Structure

Egg module and Material selection-

- *Two types of egg module viz. bubble wrap and egg crate were made.*
- *Both this modules were drop tested through certain heights and then by parachute.*



1. Bubble Wrap

The egg is wrapped by bubble wrap and placed in the cylindrical plastic container.

Egg Protection Structure

2. Egg crate.

The egg is wrapped by cotton and sandwiched between two crates. This design lacks in strength and failed to sustain landing shocks.

Egg Protection Structure

Material selection

PoS / Designs	Strength	Ease of Fabrication	Drop test result	No. of egg broke out of 10. in drop test
1. Bubble wrap	9	9	9	1
2. Egg crate	7	8	6	4

Bubble wrap was selected due to its **high strength and drop test results.**

Grading (0-10):
0 –Least
10 -Most

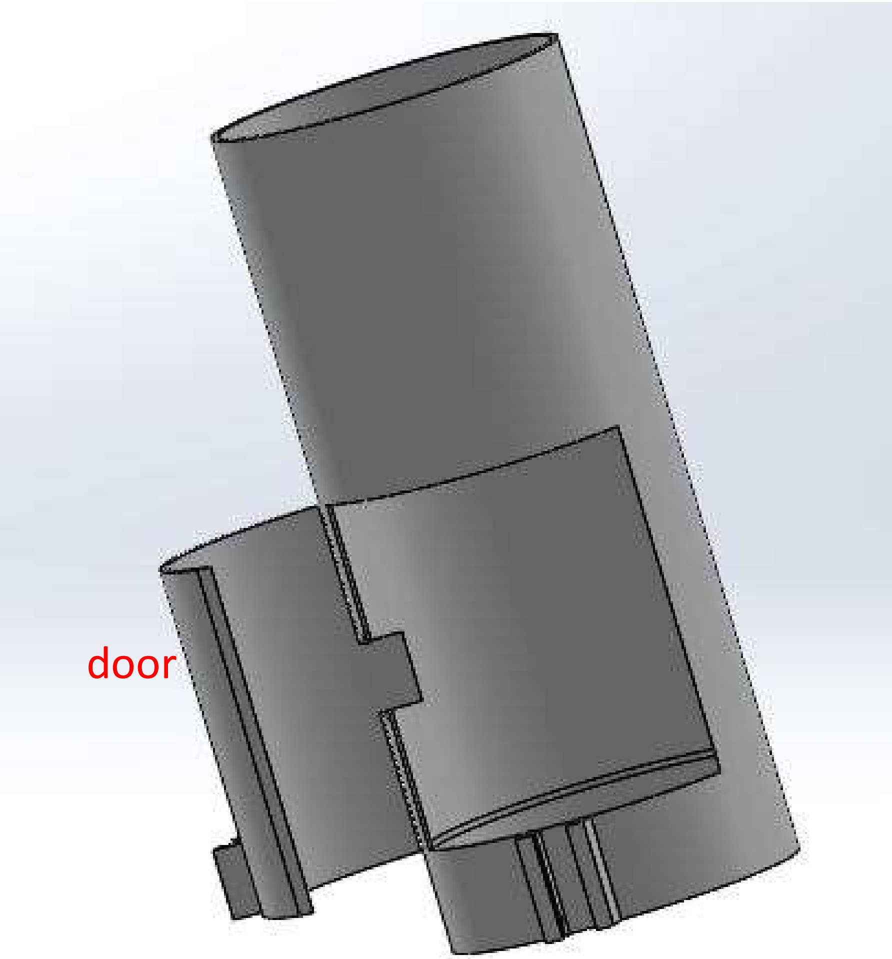
Egg Protection Structure

Method of insertion and removal of egg

- The Egg Module is first made i.e. egg is wrapped by bubble wrap and placed in cylindrical container.
- Now this egg module is to be placed in probe.
- Two designs were made to place the egg in probe viz. door and half cut probe.

1. Door

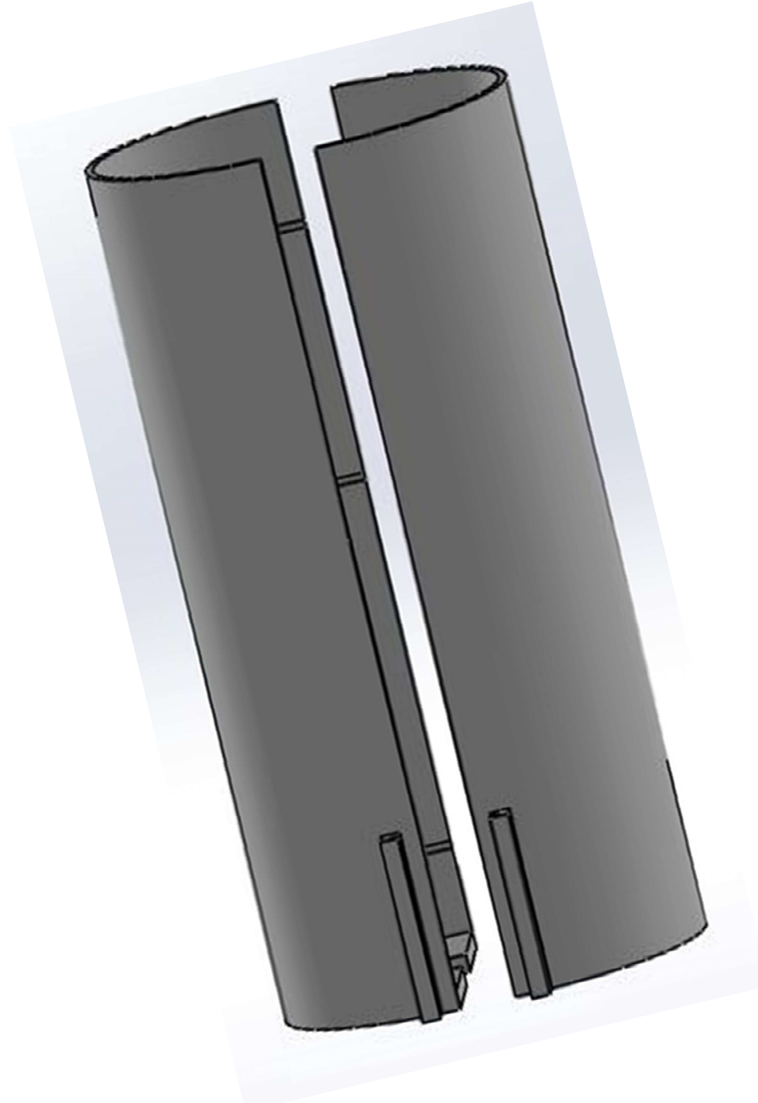
The door is made on the probe which facilitates the insertion and removal of egg module without disturbing other components



Egg Protection Structure

2. Half cut probe

The probe is cut into half as discussed earlier this makes the integration of component easier and also facilitates the insertion and removal of egg module without disturbing other components



Egg Protection Structure

Designs \ PoS	Strength	Ease of Fabrication	Ease of insertion of egg module	Disturbance to other components
1. Door	8	7	7	7
2. Halfcut probe	9	9	9	8

Halfcut probe was selected due to its **good ease of fabrication and insertion of egg module..**

Grading (0-10):
0 –Least
10 -Most

Electronics Structural Integrity

Electronic component mounting	• Mounting of PCB in probe will be by using epoxy adhesives with high peel strength and shock absorptivity. • No electronics are exposed to the outside atmosphere except for the sensors.
Electronic component enclosures	• Electronics shall be enclosed inside the electronic compartment in probe secured by wooden plates from top and bottom.
Securing electrical connections	• All electrical connections are verified and secured using insulated tape and hot glue.
Descent control attachments	• Parachute for container is attached using aluminium swivels crewed into container. • Kevlar cords secure parachute with swivel.

Mass Budget

PROBE

The probe is divided in different components weights of each are computed in following table

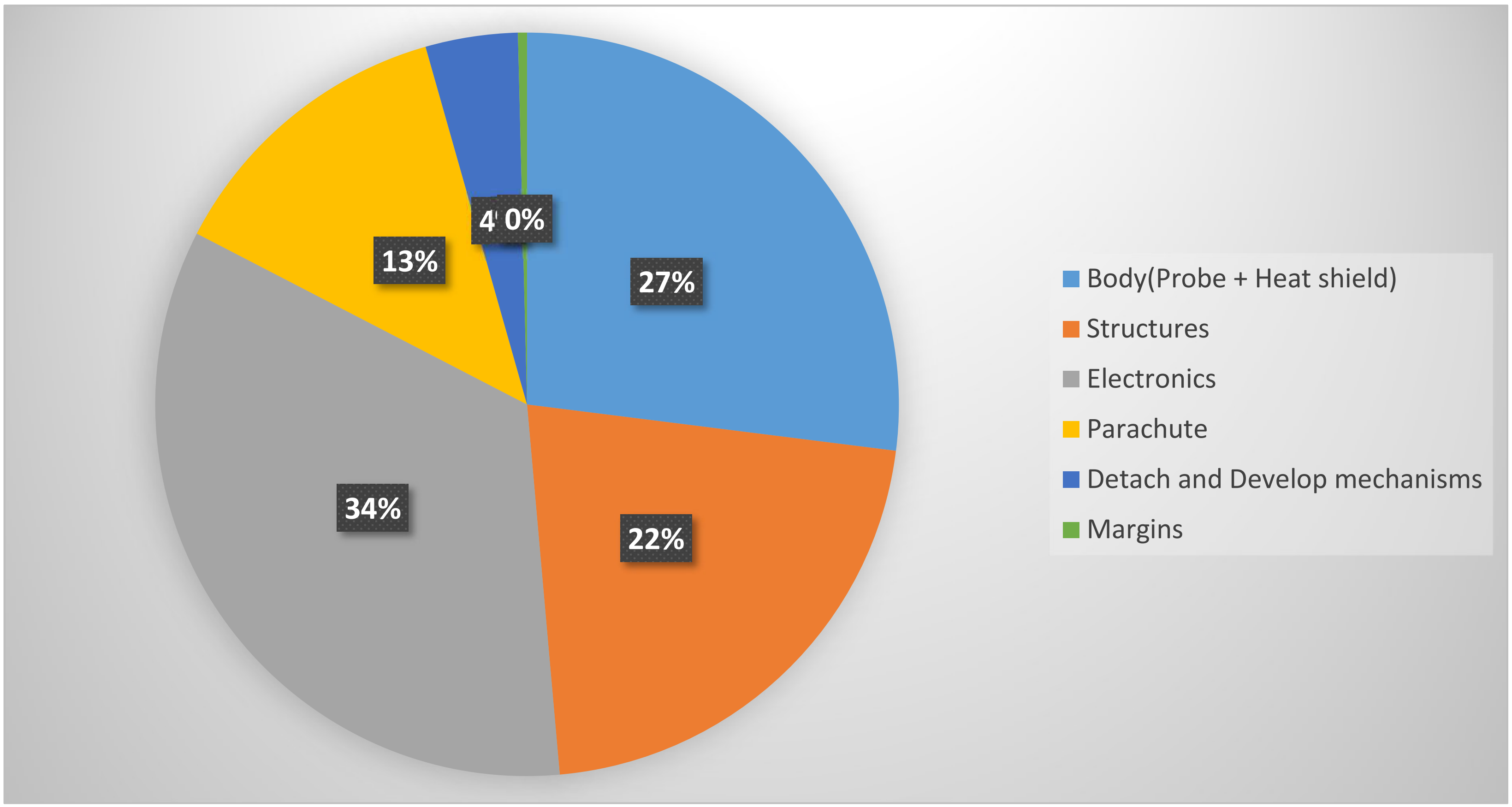
Part of Probe	Components	Weights	Total weight
1. Outer Cylinder	❖ Probe	80	80
2. Parachute compartment	❖ Parachute + strings ❖ Servo motors	10 for servo motor+10 for (strings + parachute)	20
3. Electronics compartment	❖ PCB ❖ Sensors ❖ Battery	100 30 40	170
4. Egg protection compartment	❖ Egg module ❖ Springs ❖ Wooden plates	50 for egg module 8 for four springs 10 for two plates	68
5. Release mechanism compartment	❖ Servo motor ❖ Gripper mechanism	10 for servo motor 25 for gripper mechanism	35

Mass Budget

HEAT SHIELD

Part of Heat shield	▪ Components	Weights	Total weight
1. Cylinder	▪ Heat shield	30	30
2. Cam & follower mechanism	▪ Cam ▪ Follower ▪ Gears	20 for cam + follower assembly + 10 for gears	30
3. Heat shield cloth and development mechanism	▪ Heat shield cloth ▪ Rods ▪ Hinges	25 for cloth + hinges 15 for rods	40
4. Heat shield Nose	▪ -	25 for nose with its assembly	25

Mass Budget

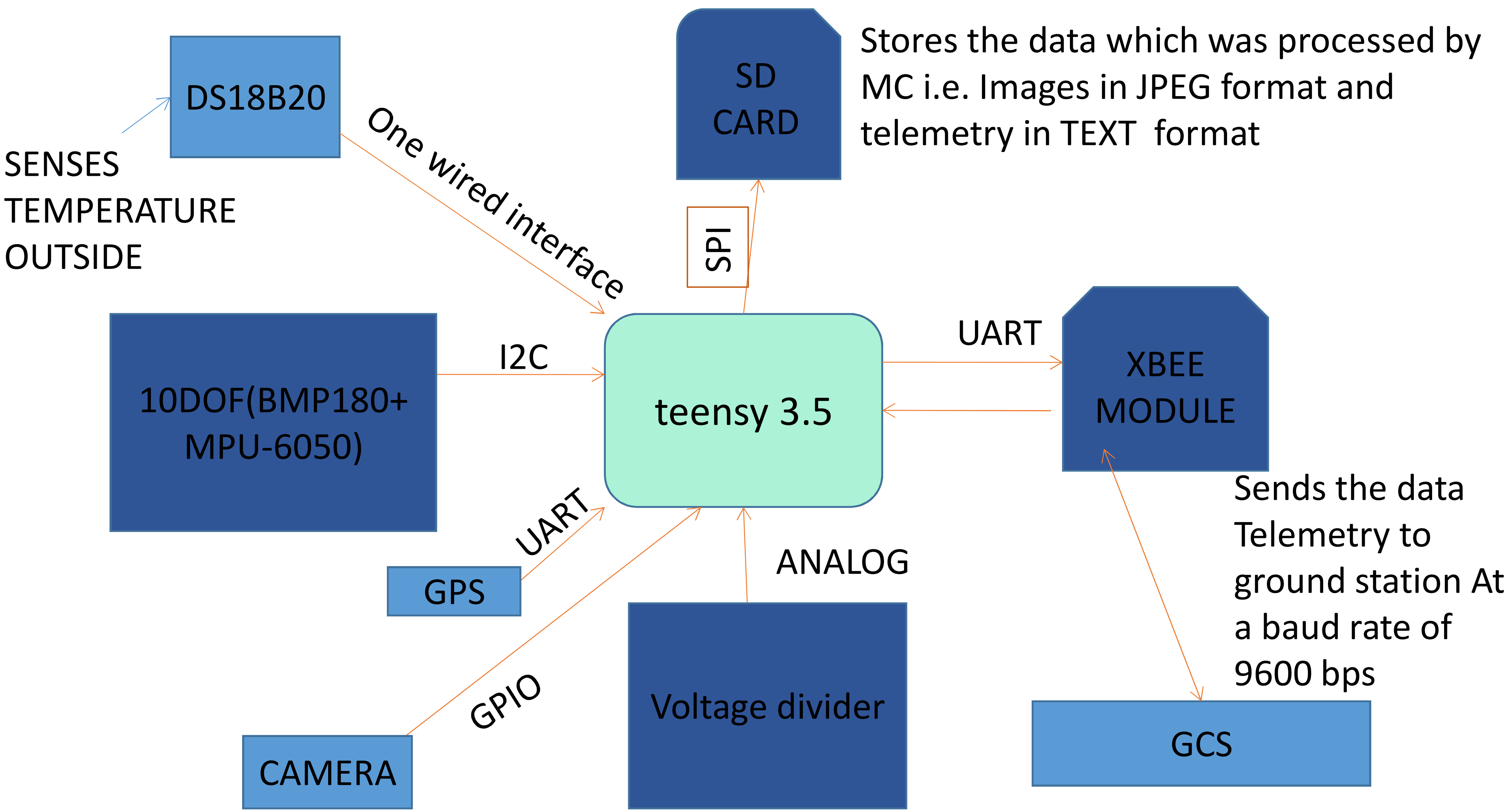


4
0%
13%
27%
34%
22%
Body(Probe + Heat shield)
Structures
Electronics
Parachute
Detach and Develop mechanisms
Margins

Communication and Data Handling (CDH) Subsystem Design

PRADEEP MANIKANTA

CDH Overview



CDH Overview

CATEGORY	COMPONENT	USAGE
Temperature	DS18B20	It is used to calculate the temperature outside the probe.
GPS	UBLOX neo 6m	It provides all the global data required by the probe.
Camera	Memore spy keychain	To capture the videos when parachute and heat shield are released.
Voltage measurement	voltage divider	To calculate the battery voltage.
Transmission	XBEE pro S2B	To transmit the required telemetry from probe to ground station.
pressure	BMP 180	To calculate pressure outside the probe.
Tilt angles	MPU 6050	To calculate tilt angles in X,Y,Z directions.

CDH Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
CDH-01	Probe shall transmit telemetry using Xbee PRO S2B of 2.4GHz at a frequency of 1 Hz	Mission requirement	HIGH	SRS-26	✓	✓	✓	
CDH-02	Telemetry shall include mission time with one second or better resolution	Mission requirement	HIGH	SRS-25				✓
CDH-03	Telemetry shall be transmitted in burst or continuous mode	Mission requirement and to prevent data loss	HIGH	SRS-32		✓		✓
CDH-04	All telemetry in a packet shall be comma separated	Telemetry requirement	HIGH	--				✓
CDH-05	Microcontroller on the probe shall have sufficient number of communication protocol	To support the requirement	HIGH	--	✓	✓		✓
CDH-06	Xbee radios shall have their NETID/PANID set to their team number	Mission requirement	HIGH	SRS-23		✓		✓

CDH Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
CDH-07	The probe telemetry shall end as soon as it lands	Mission requirement	HIGH	--		✓		✓
CDH-08	XBEE shall not be used in broadcast mode	Mission requirement	HIGH	SRS-32		✓		✓
CDH-09	Suitable antenna shall be used to boost the Xbee communication range to a minimum of 2km	Required for reliable communication	HIGH	SRS-28	✓			✓
CDH-10	The probe shall start transmitting telemetry as soon as it is powered on	Mission requirement	HIGH	--		✓		
CDH-11	SD card will be used to save telemetry of the payload i.e. probe	To backup data	HIGH	SRS-38				✓
CDH-12	SD card shall be used to save video captured by camera while releasing of heat shield and parachute.	BONUS	MEDIUM	SRS-39	✓			✓

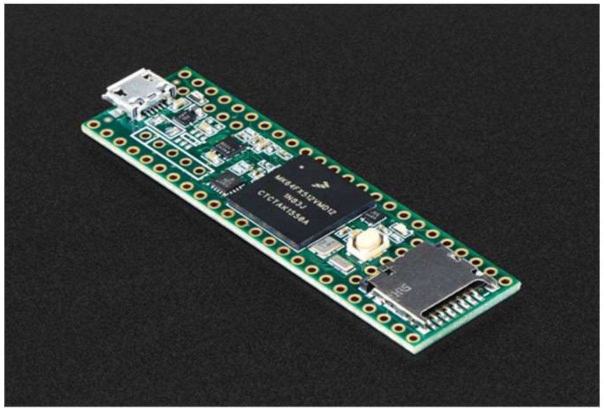
CDH Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
CDH-13	External RTC to microcontroller will be used to maintain time	Mission requirement	HIGH	--	✓		✓	
CDH-14	Flight software state shall be sent to the GCS along with telemetry	Telemetry requirement	HIGH	SRS-31				

Probe Processor & Memory Trade & Selection

MCU	Cost (RS)	Size (mm*mm*mm)	Clock Speed (MHz)	Features
Teensy 3.5	1595	62.3*18.0*4.2	120	8*ADC, 6*USART, 3*I2C, 3*SPI 8*Ext-Int., 5*Timers, 1*I2S, 2*DAC, SD card slot. In built RTC
MINI M4 STM32F4	1855	62.0*20.5*5.2	168	10*ADC, 6*USART, 3*I2C, 3*SPI, 17*Timers, 8*Ext-Int, 2*DAC,
TIVA C TM4C123G	830	62.0*51.2*5.1	80	6*ADC, 8*USART, 6*I2C, 4*SPI, 2* ADC, 4*Timers

Source: Datasheet



Selected: Teensy 3.5

REASONS :

- Have All peripherals which are required
- 512 kB Flash Memory, 192 kB RAM, 4 kB EEPROM
- Ethernet & memory card slot
- Famous & trusted NXP ARM MCU

.

Probe Processor & Memory Trade & Selection

Memory type	Cost(Rs)	Storage	Vcc Range(volt)	Max. Clock Frequency (kHz)	Size(mm*mm)	Interface
CAT24M01	140	128 kb	1.8-5.5	400	10.19*7.11	I2C
Sandisk (SDSDQM-002G-B35)	750	2 gb	_	_	1.1 *1.5	_
24LC256	125	32 kb	2.5-5.5	400	9.78*7.0	I2C
AT24C512C	78	64 Kb	2.5- 5.5	1000	6.20*5.5	I2C

Source: Datasheet

SELECTED : **SANDISK (SDSDQM-002G-B35)**

REASONS :

- As we have an inbuilt sd card slot on teensy 3.5 we selected this sd card.
- Size is **compatible**.
- As sd slot is directly interfaced using spi we directly insert it in the teensy 3.5

Memory Selection

CALCULATION FOR SELECTING SD CARD SPACE IS AS FOLLOWS:

- Higher frequency communication protocol [SPI 10 Mb/s]
- Memory card slot already available in Carrier MCU Teensy 3.5
- Data per one string is
  So, total data might be : 138 Bytes*300 seconds (5 Minutes flight time)   =   40 K Bytes
- Already available.
- Easy recovery & interfacing with smart phones & laptops

Probe Real-Time Clock

Module	Cost(rupees)	Size(mm*mm *mm)	Interfacing	Operating voltage(volt)	Frequency (kHz)
DS3231 AT24C32	88	38*22*14	I2C	3.3 - 5 .5	400
M276 DS1307	105	28*26*8	I2C	4.5-5	100
M458 DS1302	110	44X23X1.6	3 wire interface	3-5	32

SELECTED : **M276 DS1307**

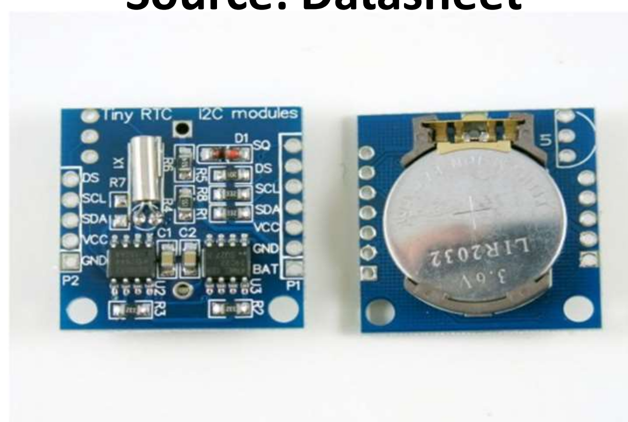
REASONS :

- I2C interfacing
- small size
- high frequency
- cost efficient

Note :

Here we can use an push button switch for RTC to power on When the probe requires it.

Source: Datasheet



Probe Antenna Trade & Selection

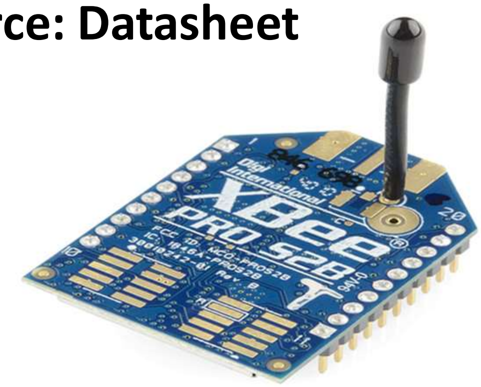
Xbee pro Series 2B Antenna :

Antenna	Range (Mile)	Tx Power (mW)	Data Rate (kb/s)	Drawbacks
RPSMA (Dipole)	1	63	250	Required large space & proper mounting
U.FL Connector	1	50	250	Required proper connector & lower Tx power
Wire (Whip)	1	63	250	Non-uniform Radiation Pattern
PCB (Chip)	1	63	250	Xbee should be expose to surrounding

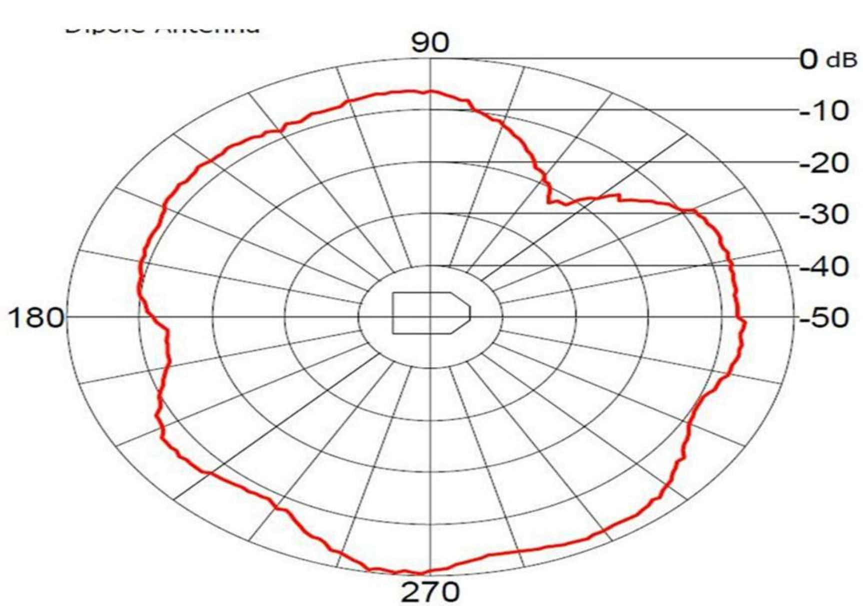
Source: Datasheet

SELECTED : **Whip type Antenna**

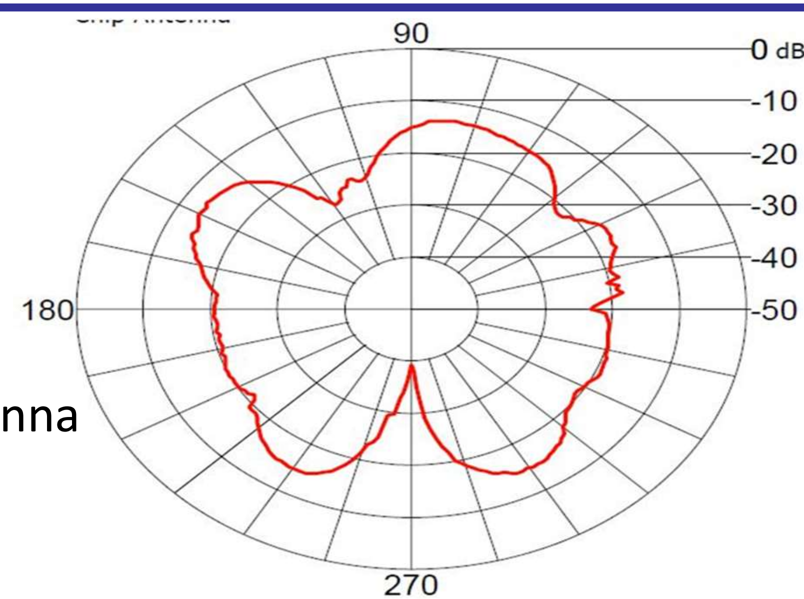
- Xbee is protected inside Container or Glider & Antenna can be easily exposed
- Satisfactory performance in our tests.
- No need to modify as it is already present.



Probe Antenna Trade & Selection



Dipole antenna



Chip antenna

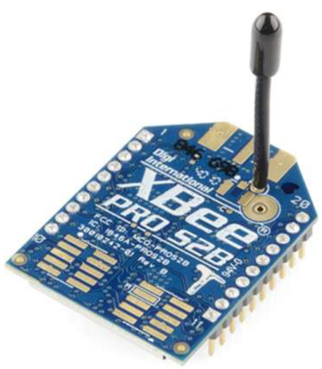
Probe Radio Configuration

Module	Cost (INR)	Size (mm*mm*mm)	Data Rate (kbps)	Operating Voltage(V)	Operating Current(mA)	Range (km)	Output Through	Power (mW)
XBEE 865/868L P L	1200	33.78*24.33	80	3.3	48	4	USART	16
XBEE PRO S1 RPSMA	3125	32.94*24.38	10	3.3	265	9	USART	100
XBEE PRO S2B	1900	32.94*24.38	250	3.3	208	3	USART	63

Source: Datasheet

SELECTED: **XBEE pro S2B**

- NETID/PANID is 2610.
- Payload works as router in API mode.
- The payload will start transmitting data when it is powered on.
- The payload telemetry will be transmitted once per second i.e, at 1 HZ .
- Teensy has inbuilt SD card slot. Telemetry will be stored in 2GB SD card.

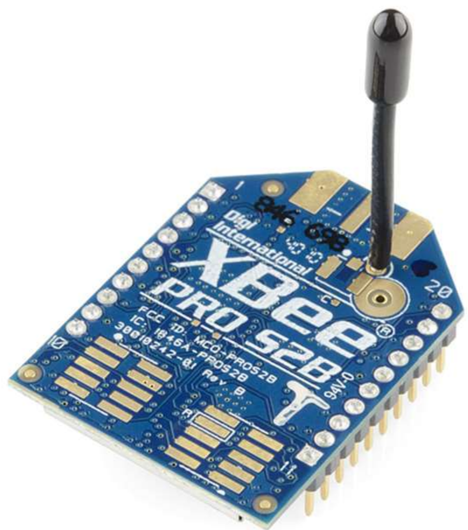


KRANTI

Probe Radio Configuration

ANNUAL CANSAT COMPETITION

- Xbee Radio is used at a frequency of 2.4Ghz
- Xbee at payload and ground station are configured at API mode
- Xbee pro S2B is used which has an indoor range of 60m and outdoor line of sight range of around 2 miles
- Xbee PANID shall be set to team number i.e. , #2610
- Xbee will not be in broadcast mode.
- Data will be converted to packet of string and will be sent to ground station every second starting from the CanSat being powered ON.
- One of the Xbee will be in coordinator mode and the other will be in router mode
- XCTU software will be used to configure Xbee mode, setting destination address, enabling/disabling JV pin, setting PAN ID etc.



Probe Telemetry Format

TEAM ID
MISSION TIME
PACKET COUNT
ALTITUDE
PRESSURE
TEMPERATURE
VOLTAGE
GPS TIME
GPS LATITUDE
GPS LONGITUDE
GPS ALTITUDE
GPS SATELLITES
TILT X
TILT Y
TILT Z

- All Data are separated by ‘,’.
- As per our earlier tests, we concluded that transmission of number without encoding might have some error or losses.
  Ex. If Data = 8 then transmit
  ‘0001100’ instead of ‘0001000’.
- So, We have decided to transmit ASCII encoded data, which is also competition requirement.
  Ex. If Data = 8 then transmit
  ‘11100000’ = ‘8’ .

Probe Telemetry Format

- Telemetry Format is completed by carriage return (\r)
- Telemetry will be transmitted at rate of 1 Hz
- XBEE will be configured at 9600 Baud Rate [Bps]

Sample Telemetry:

<TEAM ID>,<MISSION TIME>,<PACKET COUNT> ,<ALTITUDE> ,<PRESSURE>,<SPEED>,<TEMP>,<VOLTAGE>,<GPSTIME>,<GPSLATITUDE>,<GPS LONGITUDE>,<GPS ALTITUDE>,<GPS SAT>,<TILT X>,<TILT Y>,<TILT Z>,<SOFTWARE STATE>,[<BONUS>]

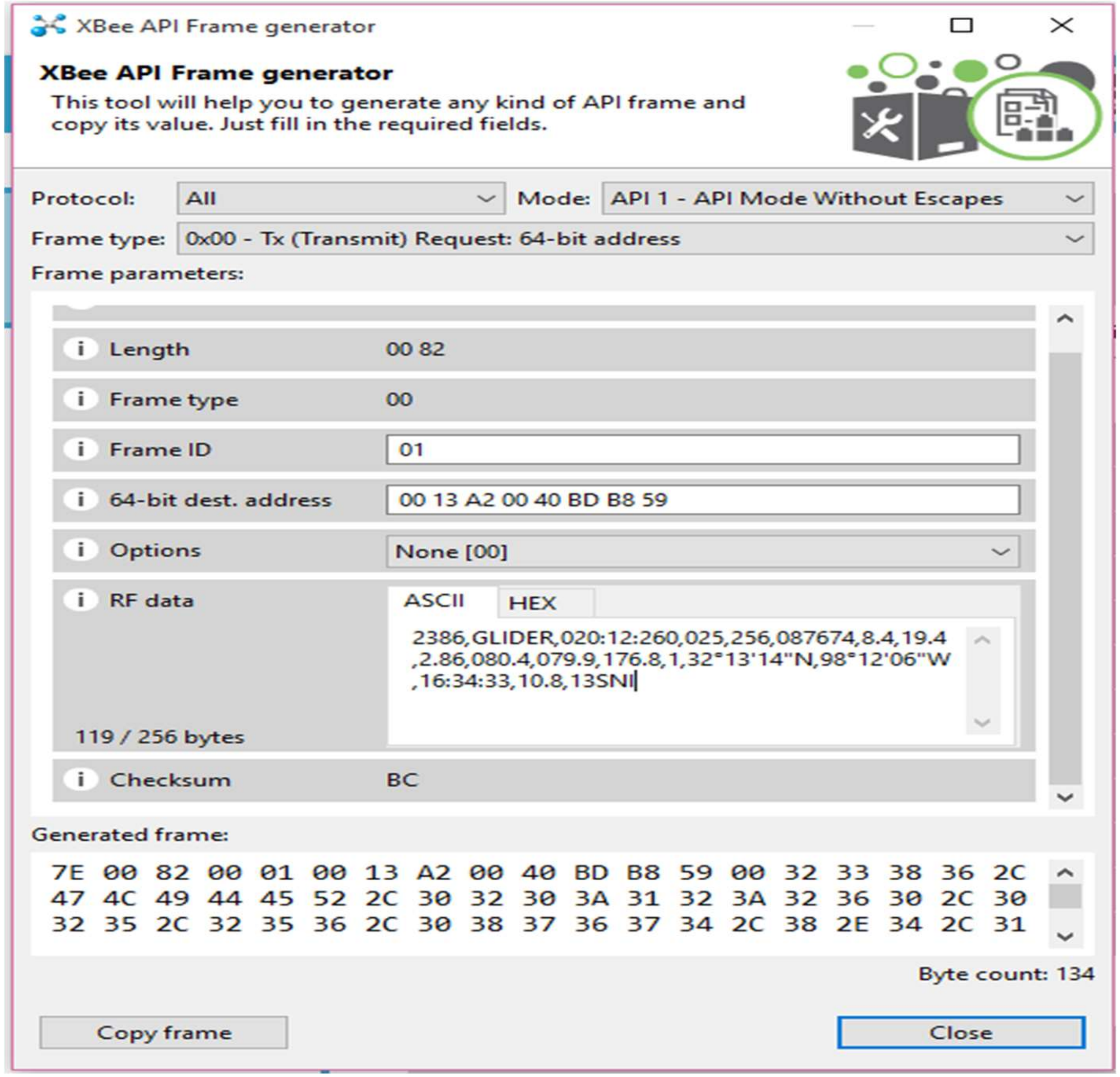
2610 , 020:12:260 , 025 , 256 , 087674 , 3.33 , 19.4 , 5.25 , 1:23:44, 32°13'14" N , 98°12'06"W , 34,3,23,34,156, 10.8 ,\r

- Telemetry Format will be saved in '.CSV' file
- Onboard saving is also going to be in '.CSV' format

Probe Telemetry Format

Glider telemetry example:

2610 , 020:12:260 , 025 , 256 , 087674 , 3.33 , 19.4 , 5.25 , 1:23:44, 32°13'14" N , 98°12'06"W , 34,3,23,34,156, 10.8 ,\r



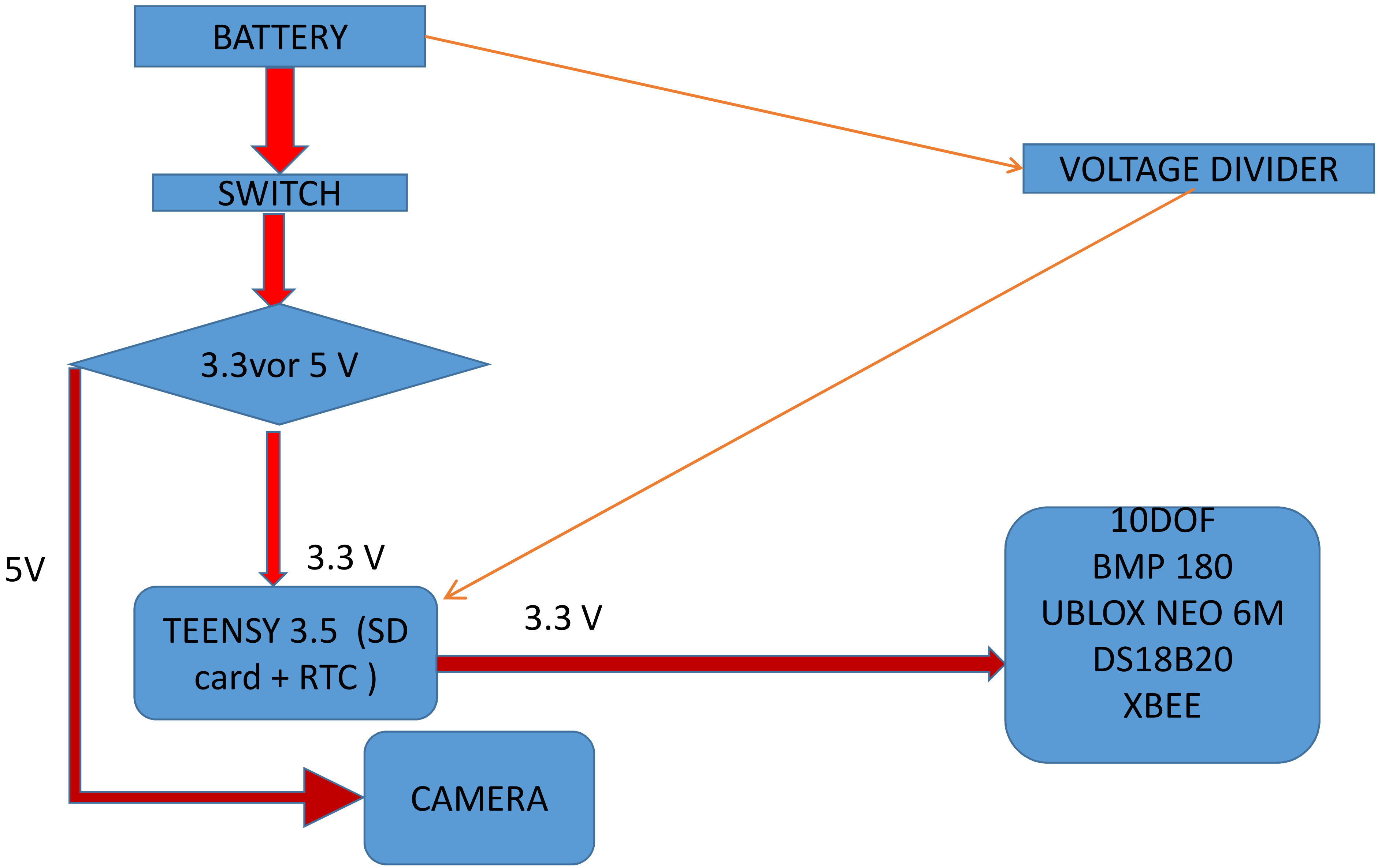
Electrical Power Subsystem (EPS) Design

HARSHIT AGHERA

EPS Overview

Sr. No.	Component	Functionality
EPS01	Coin Cell Battery	Supply energy for Real Time Clock circuit
EPS08	Alkaline Battery	Supply Electrical Energy to run circuit
EPS02	Voltage Regulator	Step down DC voltage to desired level and maintain it constant
EPS03	Voltage Measurement Circuit	Measure Coin Cell Battery Voltage
EPS04	Current Measurement Circuit	Measure Current supplied by Coin Cell Battery voltage
EPS05	ADC Noise Cancellation Circuit	Reduce noise level for ADC peripheral of MCU

EPS Overview



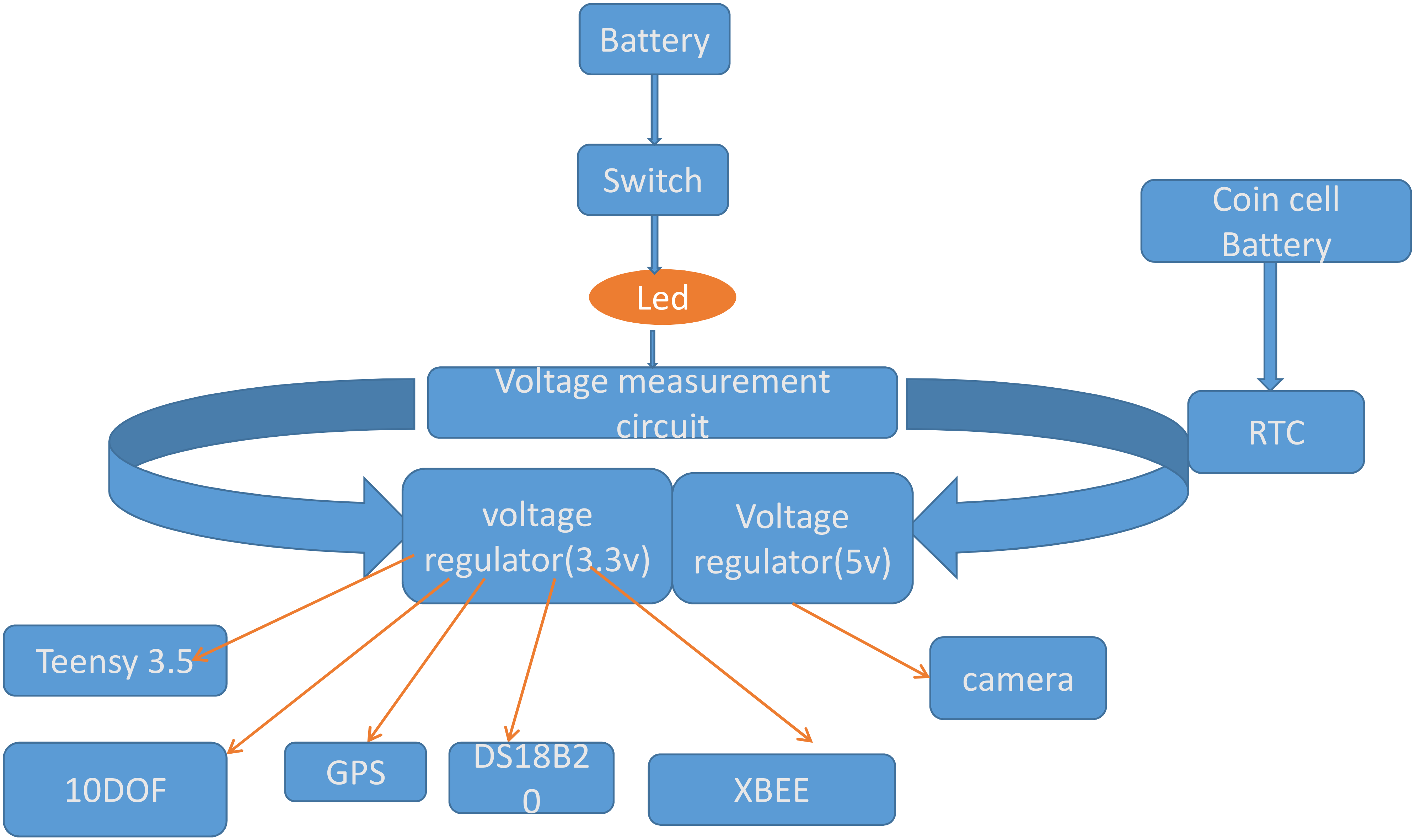
EPS Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
EPS-01	The probe must include easily accessible power switch.	Mission requirement	HIGH	SRS-36		✓		
EPS-02	The probe must include a power indicating device such as LED or sound generating device.	Mission requirement	HIGH	SRS-37		✓		
EPS-03	Li-po batteries shouldn’t be used	Mission requirement	HIGH	--	✓	✓		
EPS-04	Batteries should be alkaline or NI-CAD,NI-MH OR lithium	Mission requirement	HIGH	--	✓	✓		
EPS-05	Spring contacts cannot be used for electrical connections to batteries.	Mission requirement	HIGH	--	✓	✓		
EPS-06	An easily accessible battery compartment must be included allowing the batteries to be installed or remove in less than a minute	Mission requirement	HIGH	SRS-35	✓	✓	✓	

EPS Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
EPS-07	Separate rails of 3.3 v and 5 v shall be maintained	For distribution of power	HIGH		✓			✓
EPS-08	An audio beacon shall be included	Mission requirement	HIGH			✓		✓

Probe Electrical Block Diagram



Probe Power Trade & Selection

Battery	Cost (INR)	Weight (g)	Size (mm*mm*mm)	Supply Voltage (V)	Total Charge (mAh)
Duracell PROCELL	225	45	17.5*26.5*48.5	9	560
Zn-Mg Eveready 1215	100	15	7(d)*50.50 AA	1.5	1110
Varta V4906121414	60	23	AA	1.5	1413

Source: Datasheet

SELECTED : **DURACELL PROCELL**

- Size is compatible.
- It provides a constant output power irrespective of the load.
- It has the required amount of energy that is total charge available is enough.

Probe Power Trade & Selection

Battery connections and requirements

- Here in the probe power supply we are going to use three batteries that is -
  1)main battery (DURACELL PROCELL)
  2)coin cell battery(inbuilt in RTC)
  3)one backup battery in camera
- But we had given the supply from main battery to all components since it has sufficient and large enough amount of electrical energy.
- The main battery is of single cell type and we don't require any serial and parallel combinations.
- We are using an voltage dividers for separate rails of 3.3 V and 5 V for power supply of different components and sensors etc.
- There are some external probes or connecting wires for the battery to give supply to pcb.

Probe Power Budget

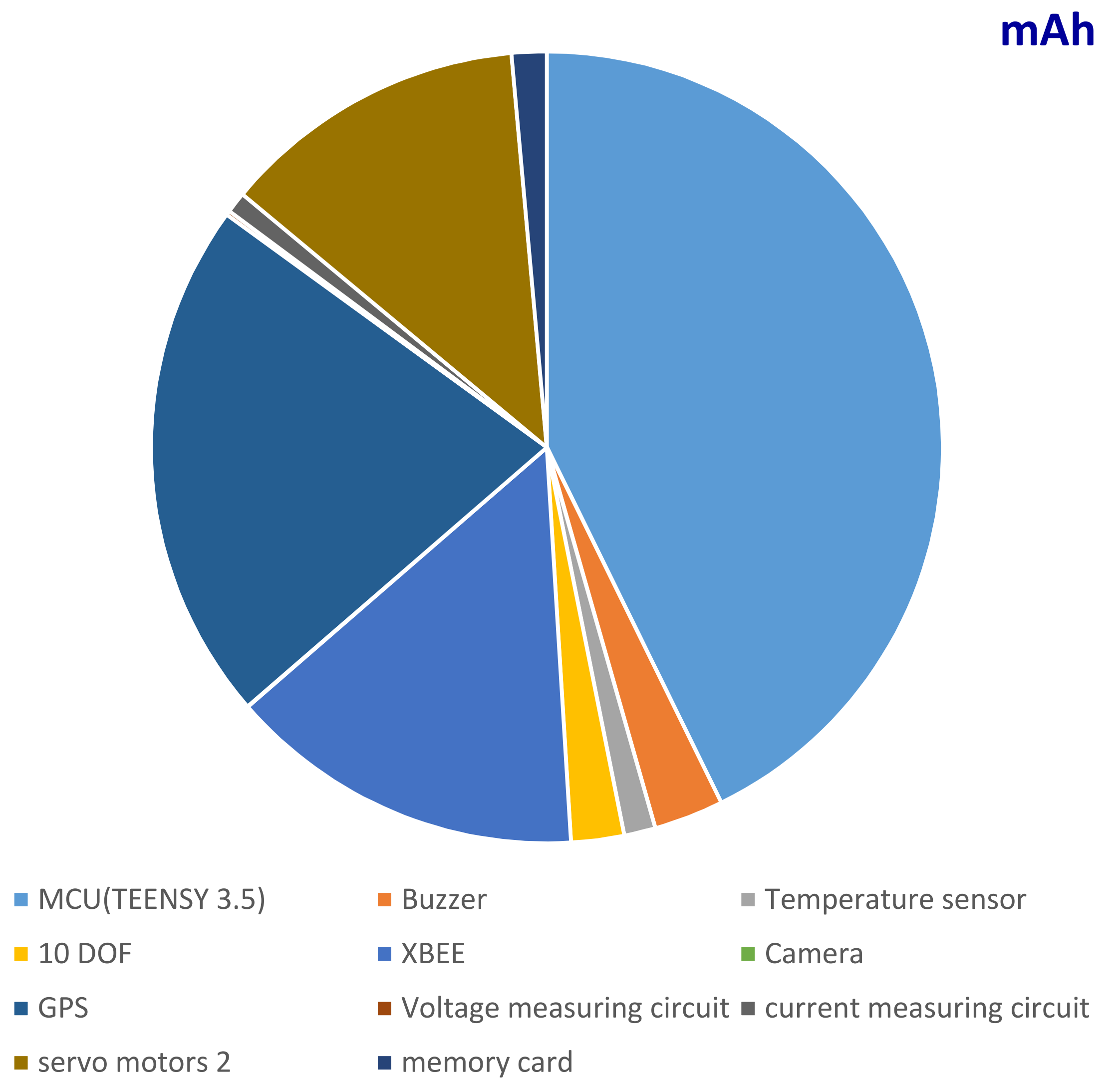
Sr. No	Device	On Time (Minute)	Current (mA)	Charge consumed (mAh)
1	MCU	60	50	50
2	Buzzer	10	20	3.3333
3	Pressure Sensor	60	3.6	3.6
4	Temperature sensor	60	1.5	1.5
5	IMU	10	15.2	2.533
6	Xbee	5	205	17.0833
7	GPS	60	25	25
8	Voltage measuring Circuit	60	0.2	0.2
9	Current Measuring Circuit	60	- -	1

Probe Power Budget

Sr. No	Device	On Time (Minute)	Current (mA)	Charge consumed (m Ah)
10	Camera	60	0.02	0.02
11	SD card	60	1.67	1.67
12	Servo motors -2	2	220	14.666
	TOTAL		542.19	120.6053

Probe Power Budget

PIE DIAGRAM REPRESENTATION



Probe Power Budget

Total energy can be supplied by the battery of the probe = (**charge in mAh)*(voltage supplied)mW**
= 560*9 * 3.6 J
= 18144 J

Energy required by all the components of probe(E) =(**total charge in m Ah)*(average voltage)mW**
= 120.6053 * 3.3 *3.6
= 1432.79064 J

Margin (M) = 15% of energy required (E)
= 15% of(1432.79064 J)
= 214.9186 J

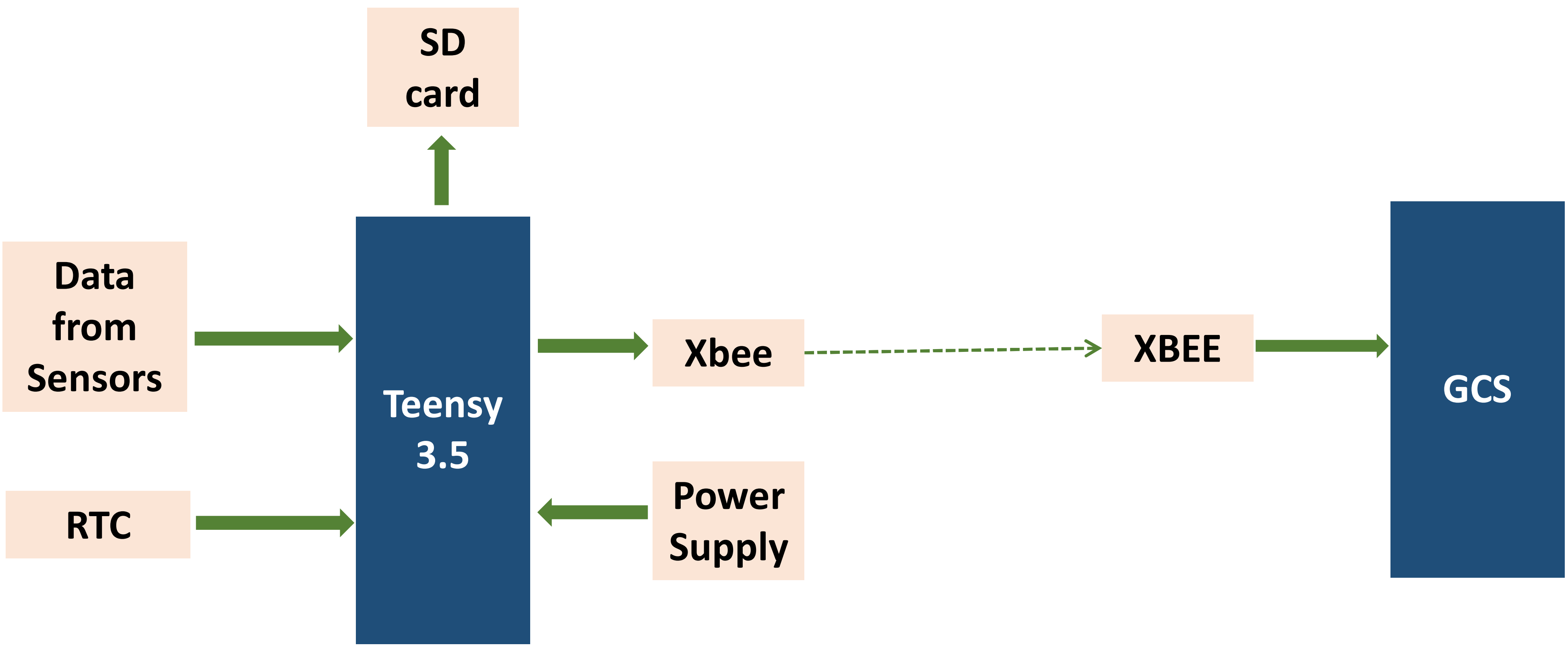
Total energy required by the probe = E + M J
= 1432.79064 + 214.9186 J
= 1647.70928 J

Flight Software (FSW) Design

PANKTI SHAH

FSW Overview

- **Basic FSW architecture:**
  - Sensors provide the required data at the rate of 1 Hz and are used to determine the software state
  - The data obtained is stored in an external SD card along with the software state as well as transmitted vis Xbee at the frequency of 1 Hz
  - In case of rebooting, microprocessor fetches the software state from memory



FSW Overview

- **Programming languages:**
  - Arduino
  - C++
- **Development Environment:**
  - Arduino IDE
- **Brief Summary of FSW tasks:**
  - Receiving data from the sensors at the rate of 1Hz
  - Transmitting all received data to the ground station at the rate of 1Hz
  - Maintaining count of the packets transmitted throughout the mission and in case of rebooting.
  - Storing all data onboard
  - Capturing release of heat shield and the ground in a video and store for retrieval later

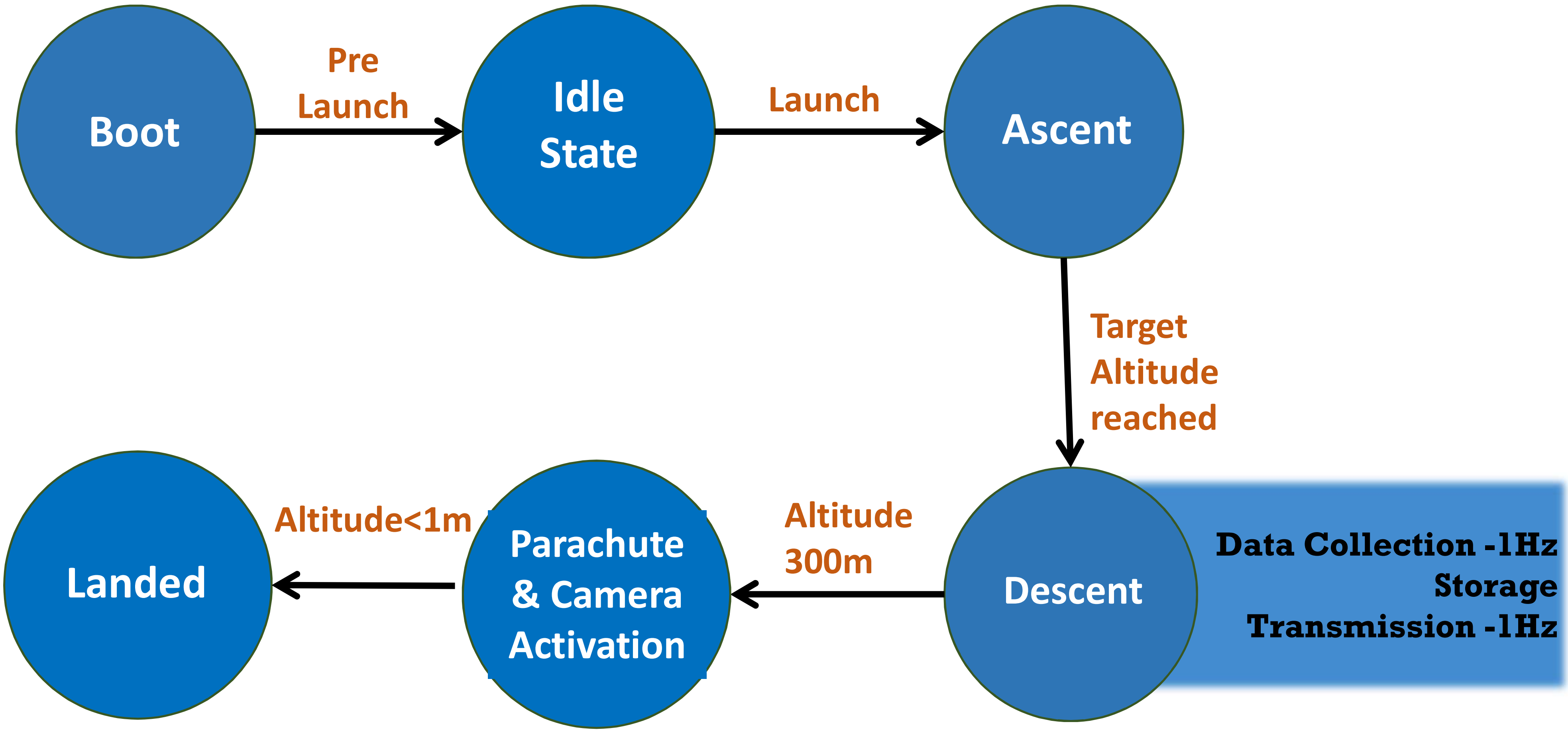
FSW Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
FSW-01	During descent, the probe shall collect air pressure, outside temperature, GPS position and battery voltage once per second and time tag the data.	Mission requirement	HIGH	SRS-21	✓	✓	✓	
FSW-02	A tilt sensor shall be used for validating stability of the probe during descent.	Mission requirement	HIGH	SRS-21	✓	✓		
FSW-03	The count of packets transmitted shall be recorded and incremented with every packet transmitted.	Mission requirement	HIGH	SRS-31	✓			
FSW-04	The probe shall transmit all telemetry at the rate of 1 Hz, either continuously or in bursts.	For real time plotting of telemetry	HIGH	SRS-22	✓	✓		
FSW-05	Telemetry shall include mission time with one second or better resolution.	Allows time tagging of data	HIGH	SRS-25	✓			

FSW Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
FSW-06	Mission time and count of packets transmitted shall be maintained during processor reset.	Mission requirement	HIGH	SRS-31 SRS-25	✓	✓		
FSW-07	Software state shall be maintained throughout the mission to determine the tasks to be performed.	Mission requirement	HIGH	SRS-31	✓	✓		
FSW-08	An audio beacon is required for the probe which shall be powered after landing or operate continuously.	To locate CanSat in the field	HIGH	SRS-30	✓			
FSW-09	A video camera shall capture release of heat shield and the ground during the last 300m of descent.	Bonus Objective	MEDIUM	SRS-39	✓	✓		

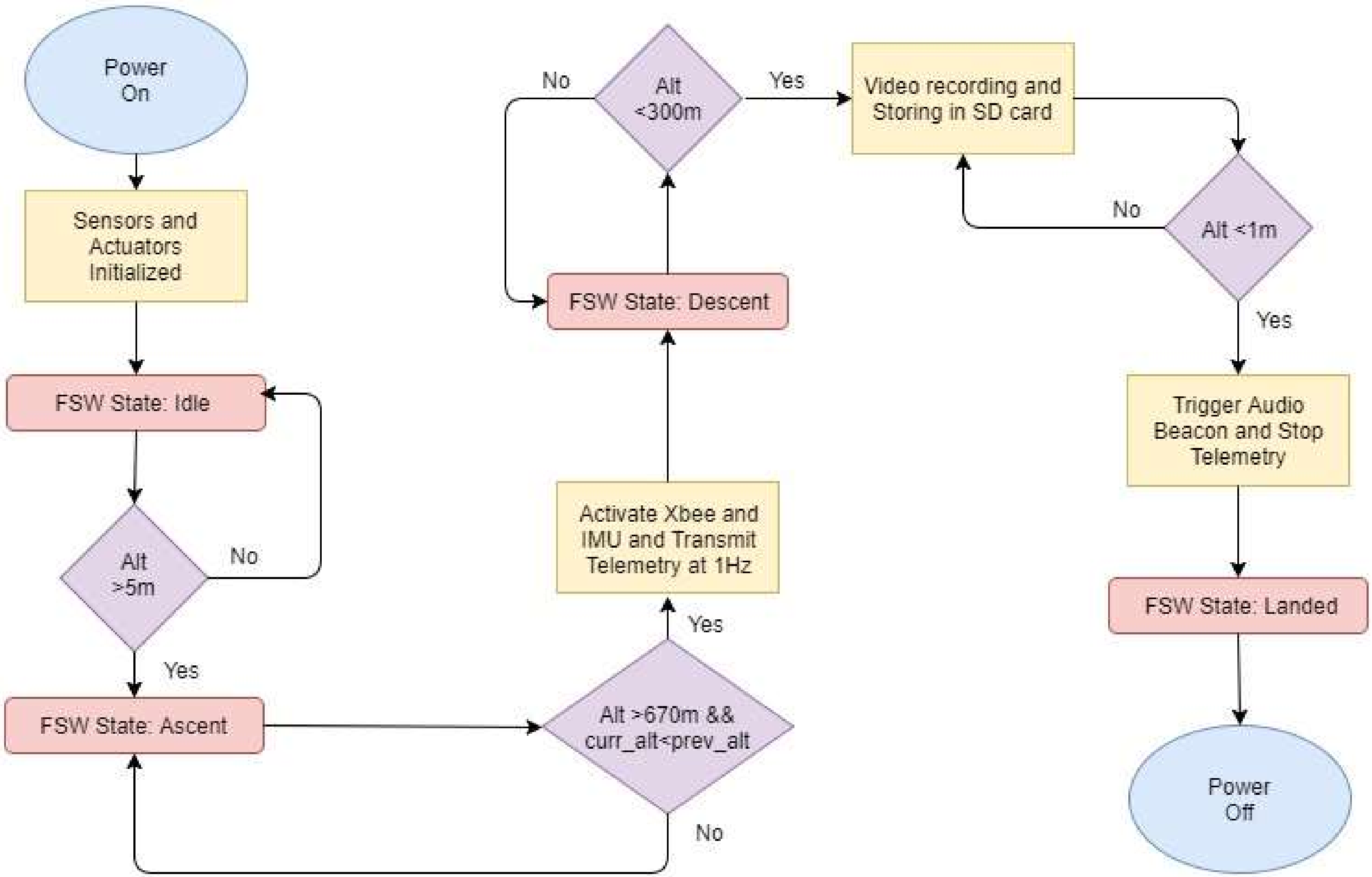
Probe FSW State Diagram



In case of rebooting, information will be fetched from the SD card and the software shall re-enter the necessary state.

The selected sensors will remain in sleep mode until the probe begins it descent and hence, minimum power consumption will be achieved.

Probe FSW State Diagram



Software Development Plan

Phase	Tasks	Status
Phase 1	• Analysis of various sensors required • Selection of suitable sensors which comply with the needs of the mission	Completed
Phase 2	• Interfacing individual sensors with the microprocessor • Building the GUI for real time plotting	Completed
Phase 3	• Integrating various sensors into a single software • Building the final FSW and testing of Xbee transmission	In Progress
Phase 4	• Testing of final FSW and GUI • Debugging the software based on the results	

Software Development Plan

- **Prototyping language and environment**

  Prototyping language is C++ and environment is Arduino IDE

- **Development Team:**

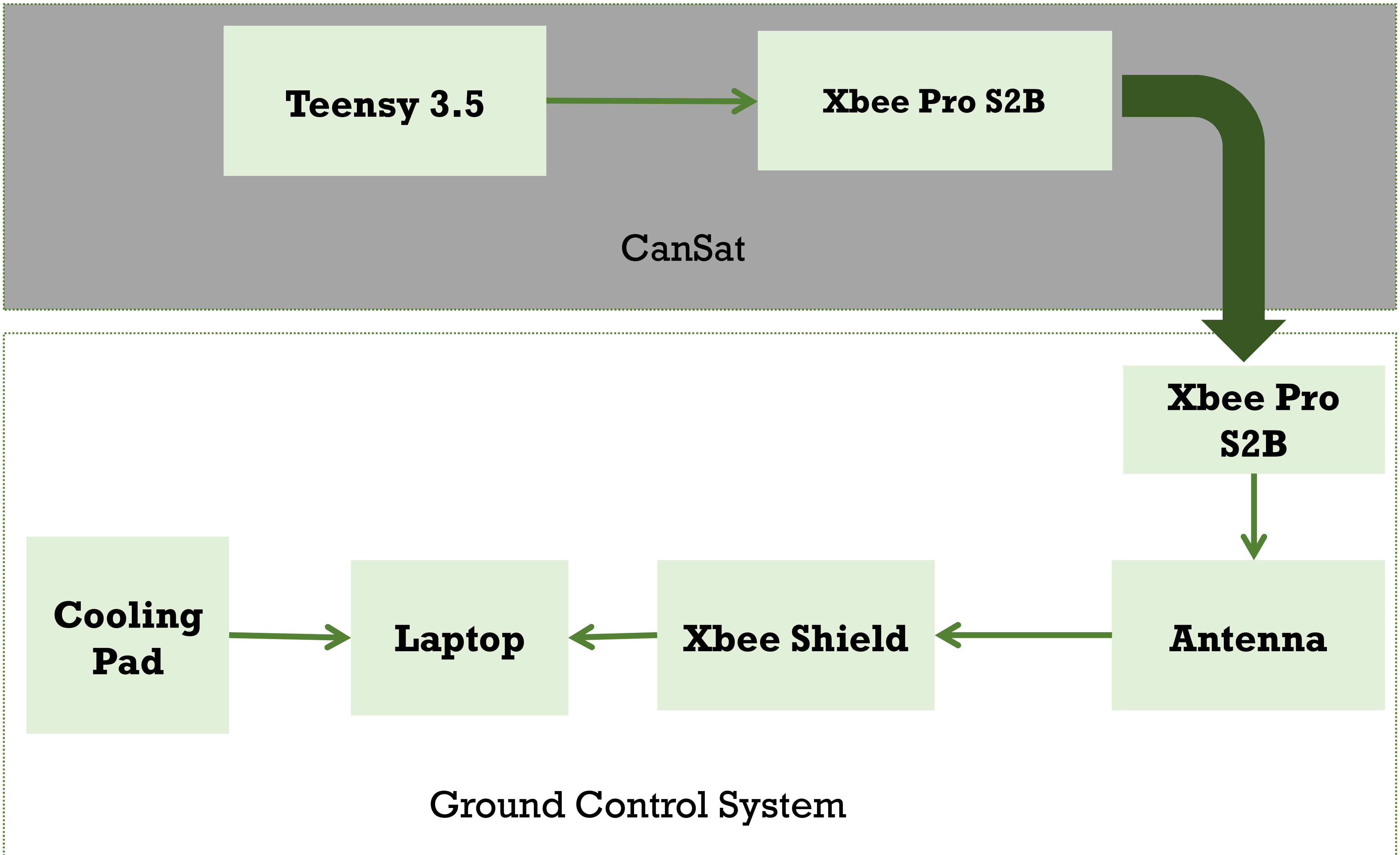
Task	Team	Mentors
Electrical and Electronics Subsystem development, software development, wireless communication handling	Khushal Tamboli Pradeep Manikanta	Kaishavi Umrethwala Harshit Aghera
Generation of GUI, Real time plotting, GCS setup	Pankti Shah	Sanjana Dhiran

- **Test Methodology**
  - Interfacing various sensors and actuators individually and testing
  - Building the GUI for GCS and testing using pseudo data string
  - Designing the integrated software with all required sensors and actuators and testing
  - Testing the final FSW by plotting real time data on the GCS

Ground Control System (GCS) Design

SANJANA DHIRAN

GCS Overview



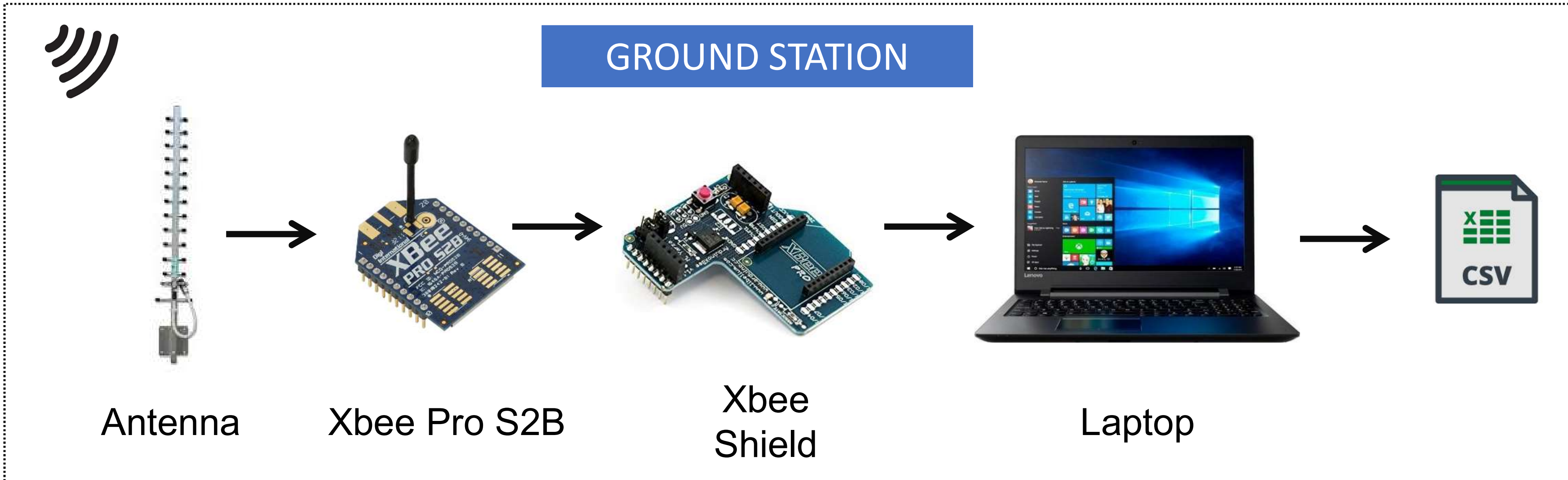
GCS Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
GCS-01	During descent, probe shall transmit all telemetry every second.	Mission requirement	HIGH	SRS-22	✓	✓		
GCS-02	The telemetry shall be transmitted via Xbee either continuously or in bursts.	Mission requirement	HIGH	SRS-22, SRS-26	✓	✓		
GCS-03	Each team shall develop their own ground station.	Mission requirement	HIGH	SRS-27	✓			
GCS-04	All telemetry shall be displayed in real time during descent.	Mission requirement	HIGH	SRS-33	✓	✓		
GCS-05	All telemetry shall be displayed in engineering units.	Mission requirement	HIGH	SRS-33	✓	✓		

GCS Requirements

ID	Requirement	Rationale	Priority	Parent	VM			
					A	I	T	D
GCS-06	Real time plotting of each telemetry data during flight.	Mission requirement	HIGH	SRS-34	✓	✓		
GCS-07	The ground station shall include one l aptop computer with a minimum of t wo hours of battery operation, XBEE radi o and a hand held antenna.	For real time plotting and display of telemetry data	HIGH	SRS-28	✓	✓		
GCS-08	The ground station shall be portable.	Allows positioning of team along flight line	HIGH	SRS-27	✓	✓		

GCS Design

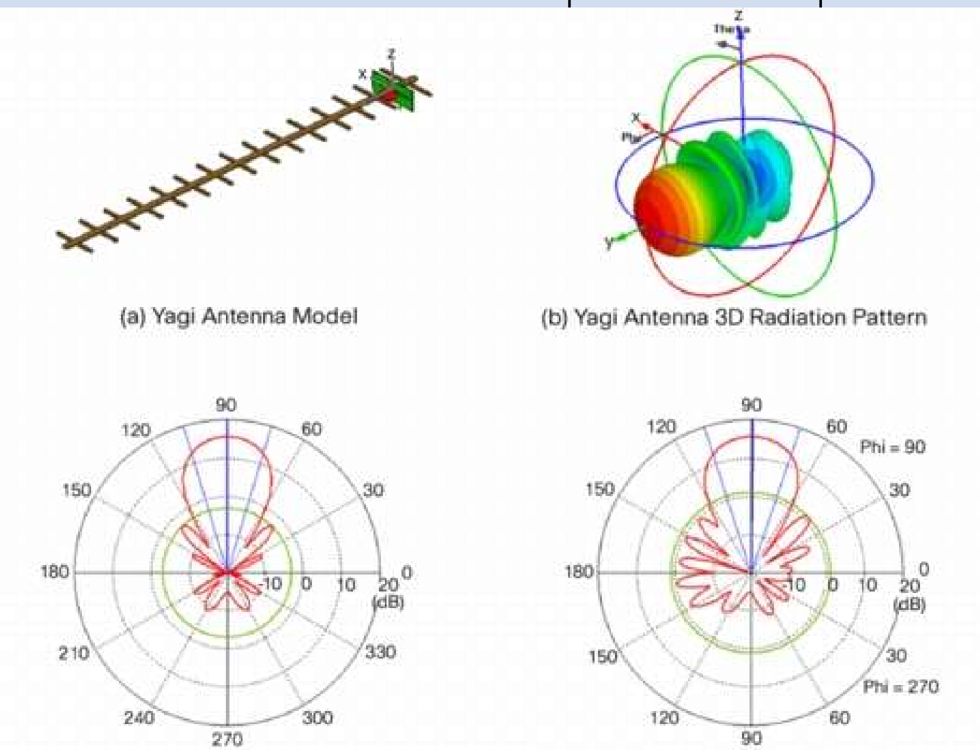


Specifications:

- The laptop used at ground station can operate on battery for upto 5 hours.
- Since laptop will constantly be in use and under the sun, we will use a cooling pad to avoid over heating of laptop.
- The windows auto update function will be disabled during the event.

GCS Antenna Trade & Selection

Antenna	Gain (dB)	Weight (kg)	Length (cm)	Cost (Rs.)	Radiation Pattern
Dipole B0161	18	0.9	68.5	450	Omnidirectional
Yagi	25	1.2	66	900	Unidirectional
Parabolic (LT-ANT2424B)	24	3.5	120	4000	Unidirectional



(a) Yagi Antenna Model
(b) Yagi Antenna 3D Radiation Pattern
(c) Yagi Antenna Azimuth Plane Pattern
(d) Yagi Antenna Elevation Plane Pattern

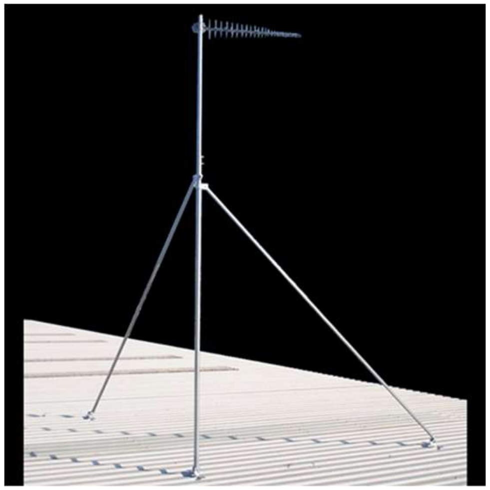
Selected: **Yagi Antenna**

- It has directivity enabling interference levels to be minimised.
- It has high gain.
- The design only receives radiation from a certain direction, thereby eliminating noises from other sources in other direction.

GCS Antenna Trade & Selection

1. Serviceable Mast

- Designed to Collapse (vertical to horizontal) for ease of servicing
- Adjustable height up to 5.5m
- 48 mm (OD) mast base with extendable 42 mm (OD) mast top piece.

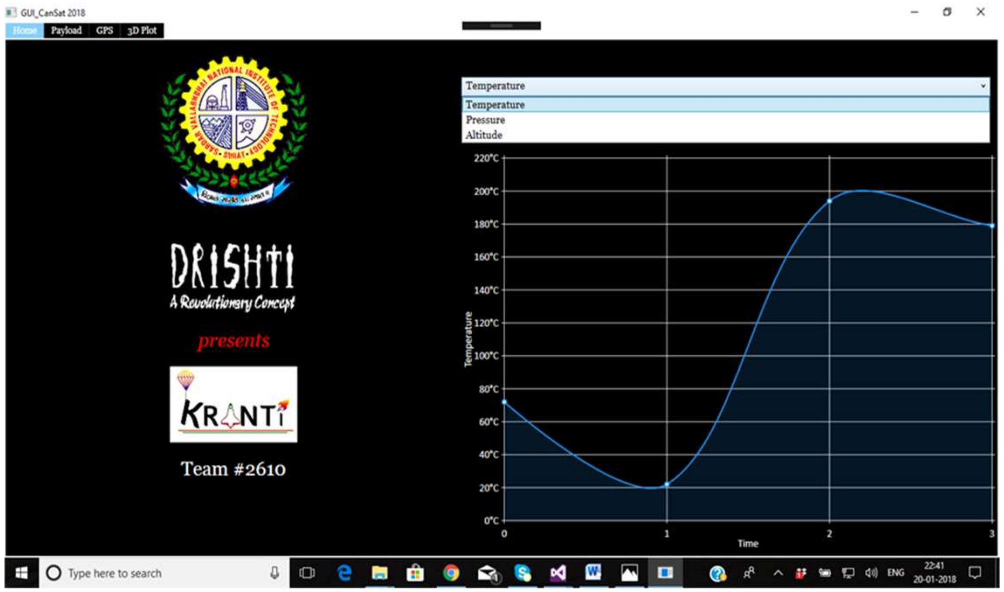


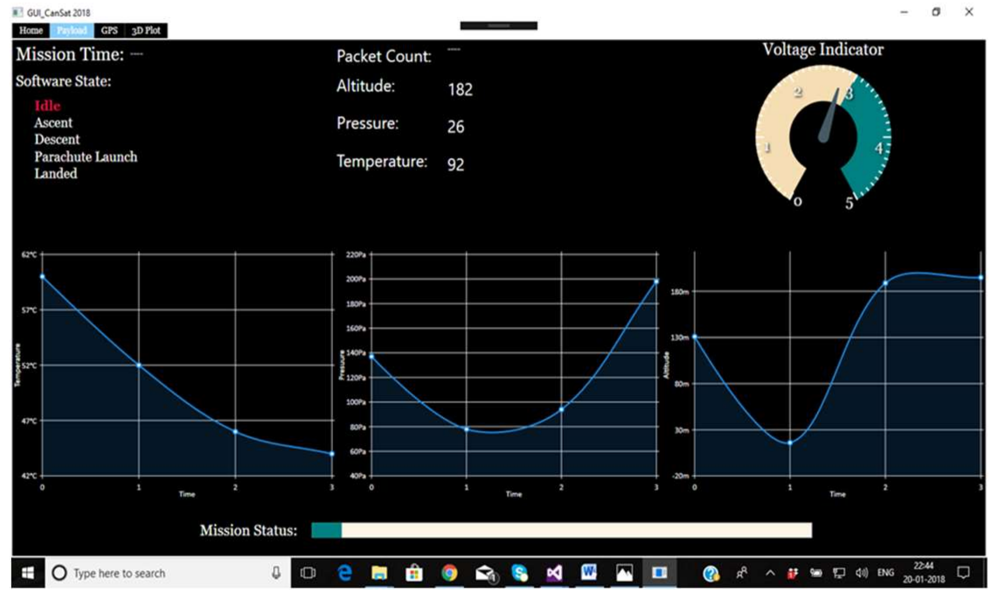
2. Hand Held

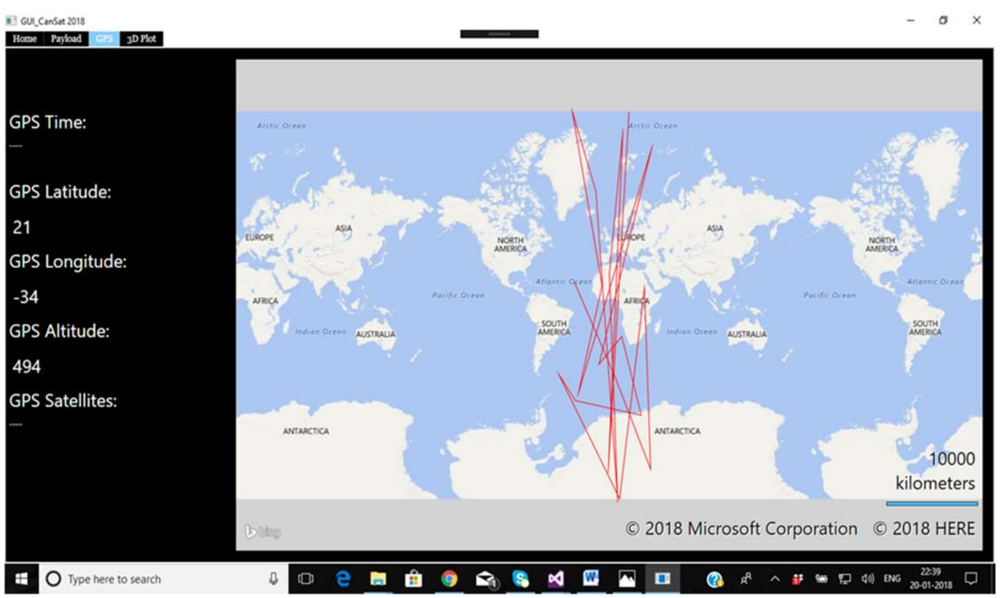
- Antenna held with hand in a holder
- Portable

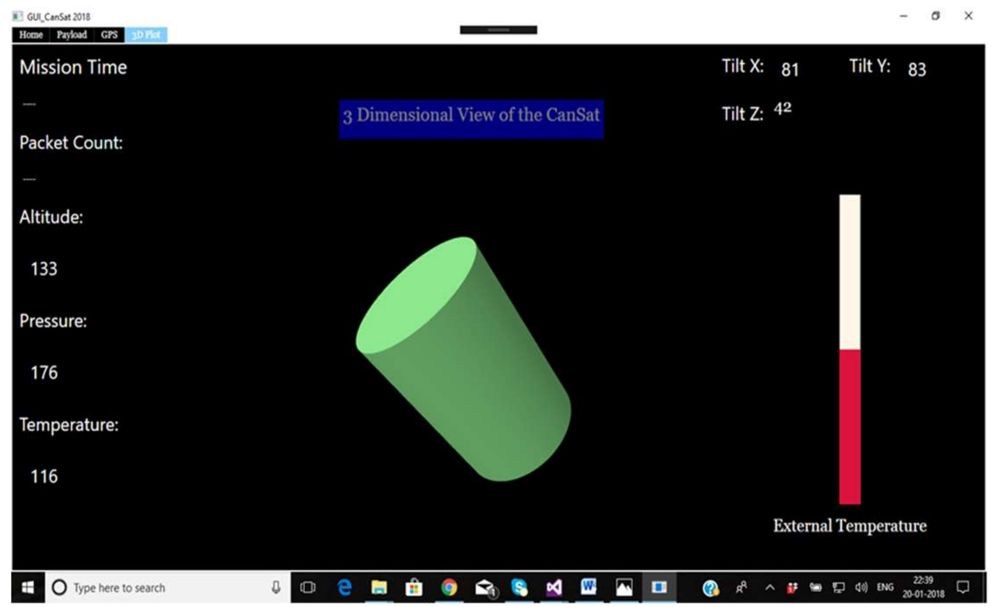
Selected: Hand Held
- Cost Effective
- Can set the direction of antenna according to the position of CanSat obtained in the 3D plot in GUI
- Antenna can be set manually
- This option makes antenna more portable

GCS Software

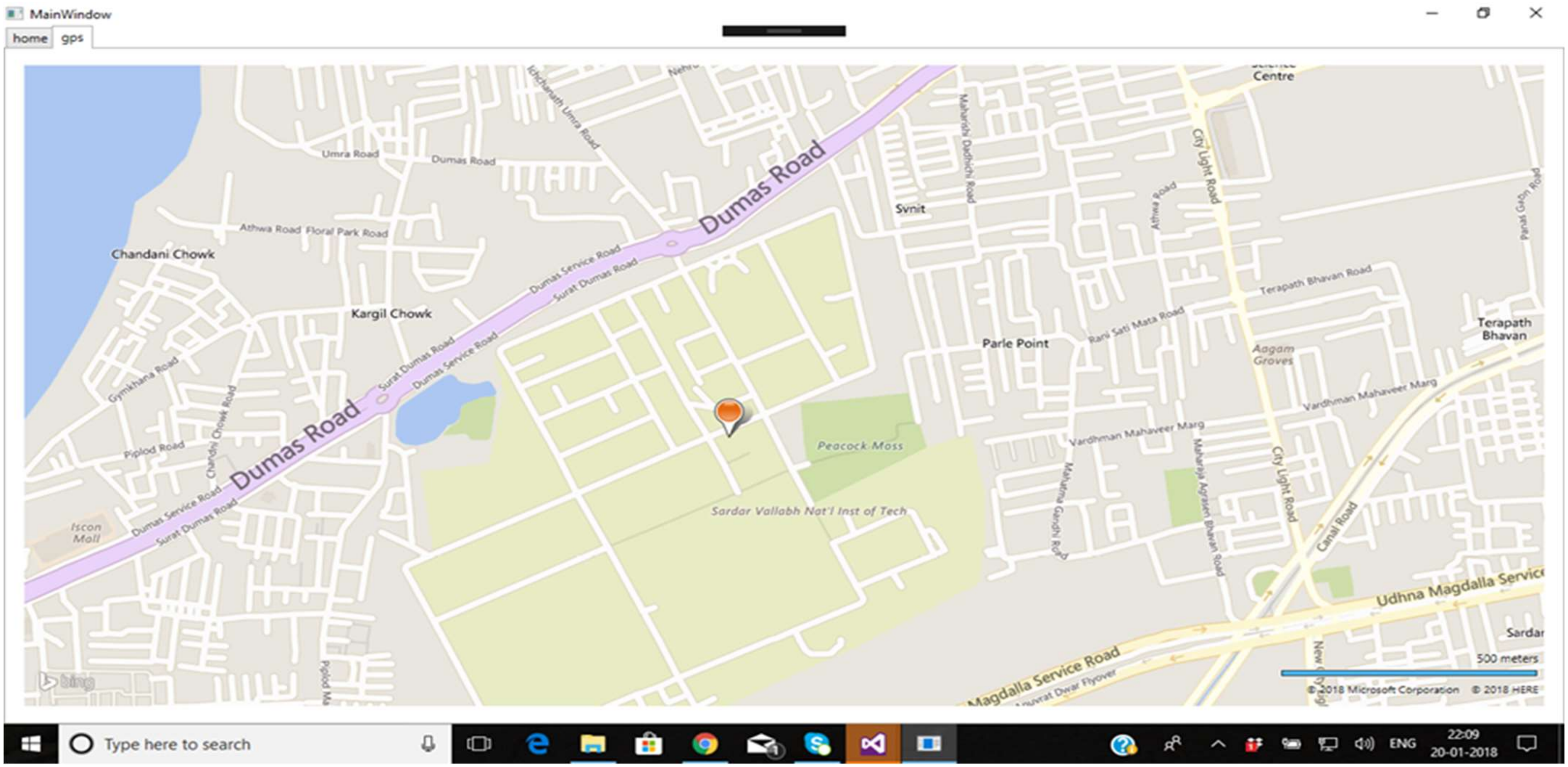








GCS Software

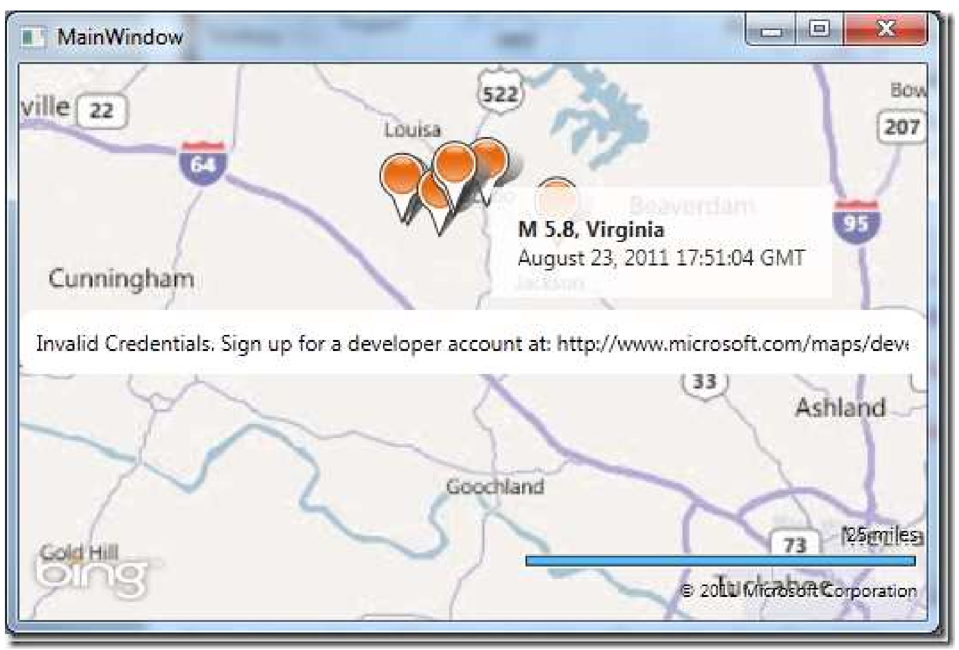


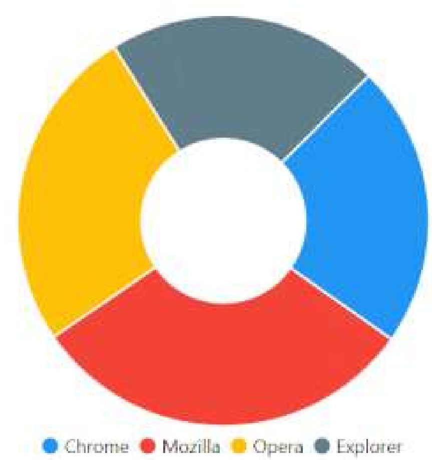
This plot depicts the current position of the CanSat in our GCS software using the GPS data received in the telemetry. In real-time, we will plot the trajectory traced by our CanSat in our GCS software.

GCS Software

Software Packages Used:

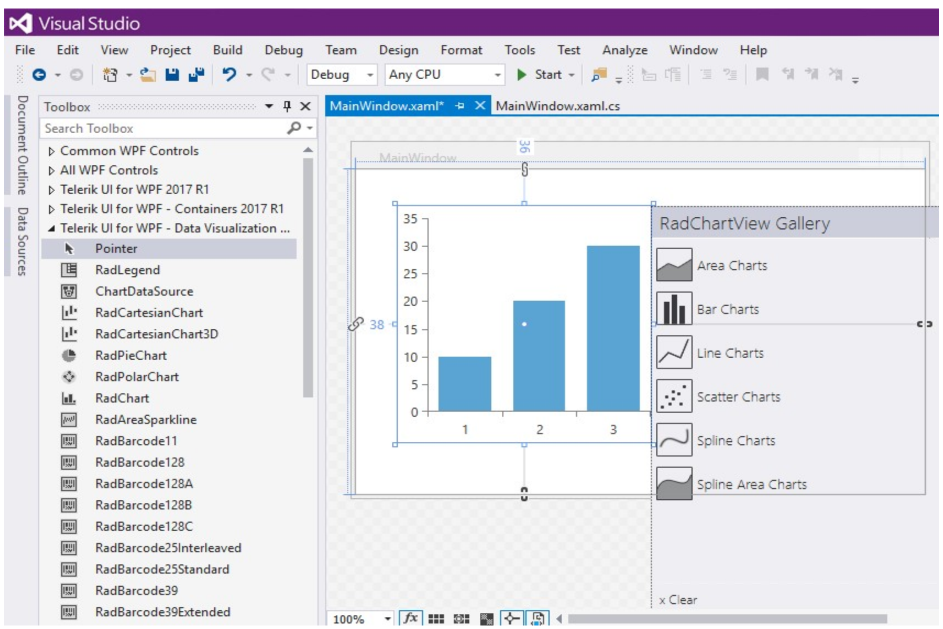
- We used **Live Charts** package to plot real time charts and angular gauges.
- We used **Bing Maps** for plotting GPS position of the CanSat.
- The Bing Maps WPF control uses .NET framework 4.0 and the Windows SDK.





GCS Software Trade

Application	Interface	Memory Requirement	Ease of Debugging	Price (Rs)
LabVIEW	Simple to Build	Resource Heavy	Difficult	16,000
Microsoft's WPF	Simple to Build	Requires lesser memory	Easy to debug	Free
Python (PyQt)	Laborious	Requires less memory	Difficult	Free



Selected: Microsoft's WPF

- Interface easy to build and debug
- Requires optimum amount of memory
- Software packages for several components available readily
- Free of cost

GCS Software

Command Software and Interface:

- GCS software is built using Windows Presentation Foundation in Visual Studio 2015.
- We are using .NET framework for building GUI.
- The front-end language used is Xaml (Extensive Application Markup Language) and the backend language is C#
- Telemetry data will be stored in MS-Excel in .csv file which will be provided to the judges for inspection in a USB.
- File format for .csv file will be as follows:

<TEAM ID>,<MISSION TIME>,<PACKET COUNT>,<ALTITUDE>, <PRESSURE>, <TEMP>,<VOLTAGE>,<GPS TIME>,<GPS LATITUDE>,<GPS LONGITUDE>,<GPS ALTITUDE>,<GPS SATS>,<TILT X>,<TILT Y>,<TILT Z>,<SOFTWARE STATE>

GCS Bonus Wind Sensor

CanSat Probe RF Transmitter [RF wave having frequency as per Wind velocity]

RF Receiver module at Ground Station

ADC

Microcontroller to interpret the data of RF Receiver

USART

Ground Station Laptop

- A self made RF transmitter mounted at CanSat probe generates RF wave of specific frequency depending upon wind velocity.
- RF receiver module located at Ground Station gives analogues output as per value of frequency of received wave.

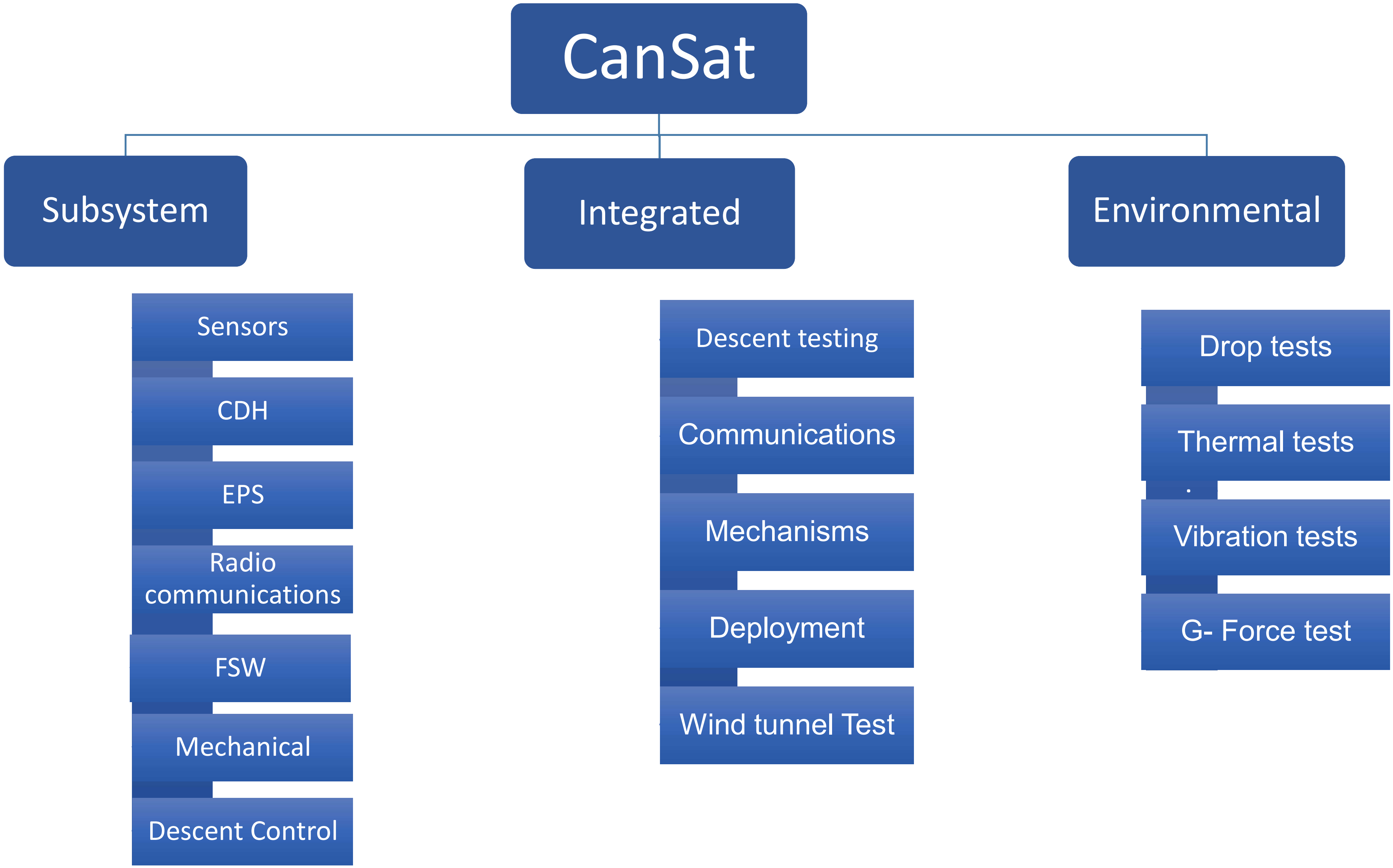
- A microcontroller will be introduced to obtain value of wind velocity from analog signal generated by receiver module.
- Value of wind velocity will be then transmitted by microcontroller to Ground station Laptop via USART communication protocol.

- Wind velocity will be shown graphically on GUI after interpreting the data received from microcontroller.

CanSat Integration and Test

HARSHIL PAREKH
HARSHIT AGHERA

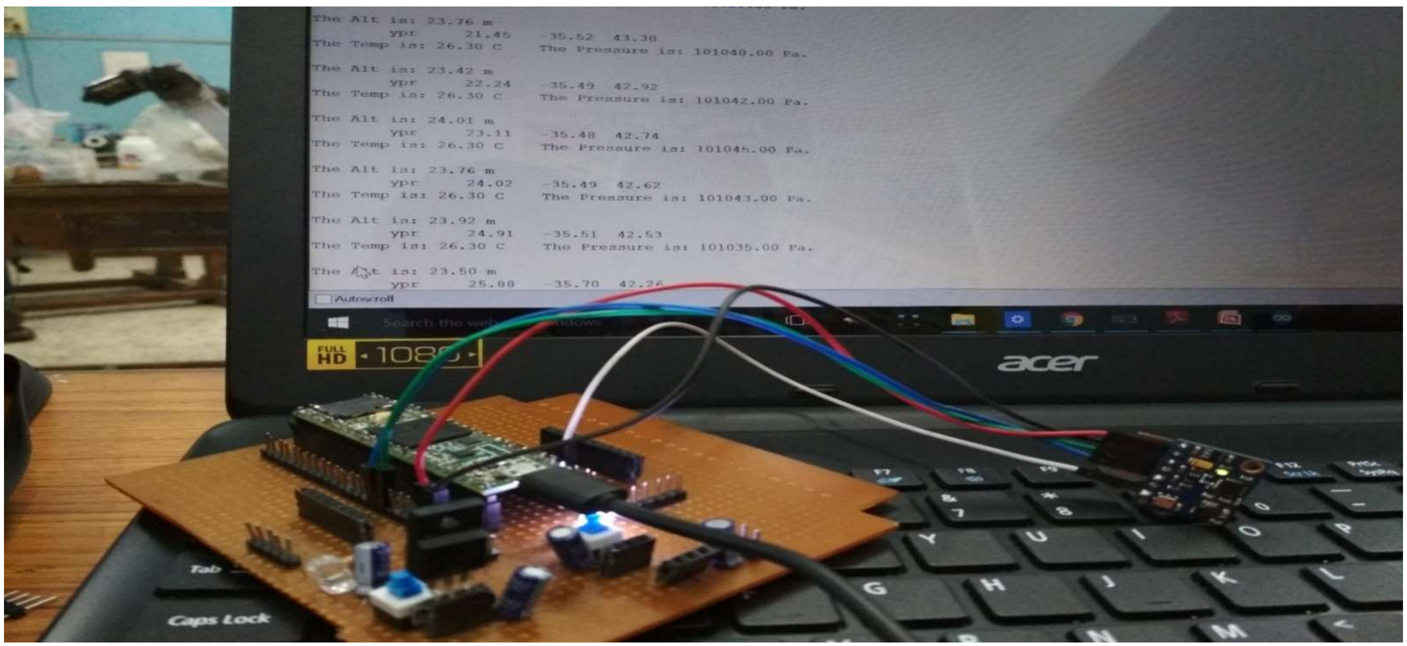
CanSat Integration and Test Overview



Subsystem Level Testing Plan

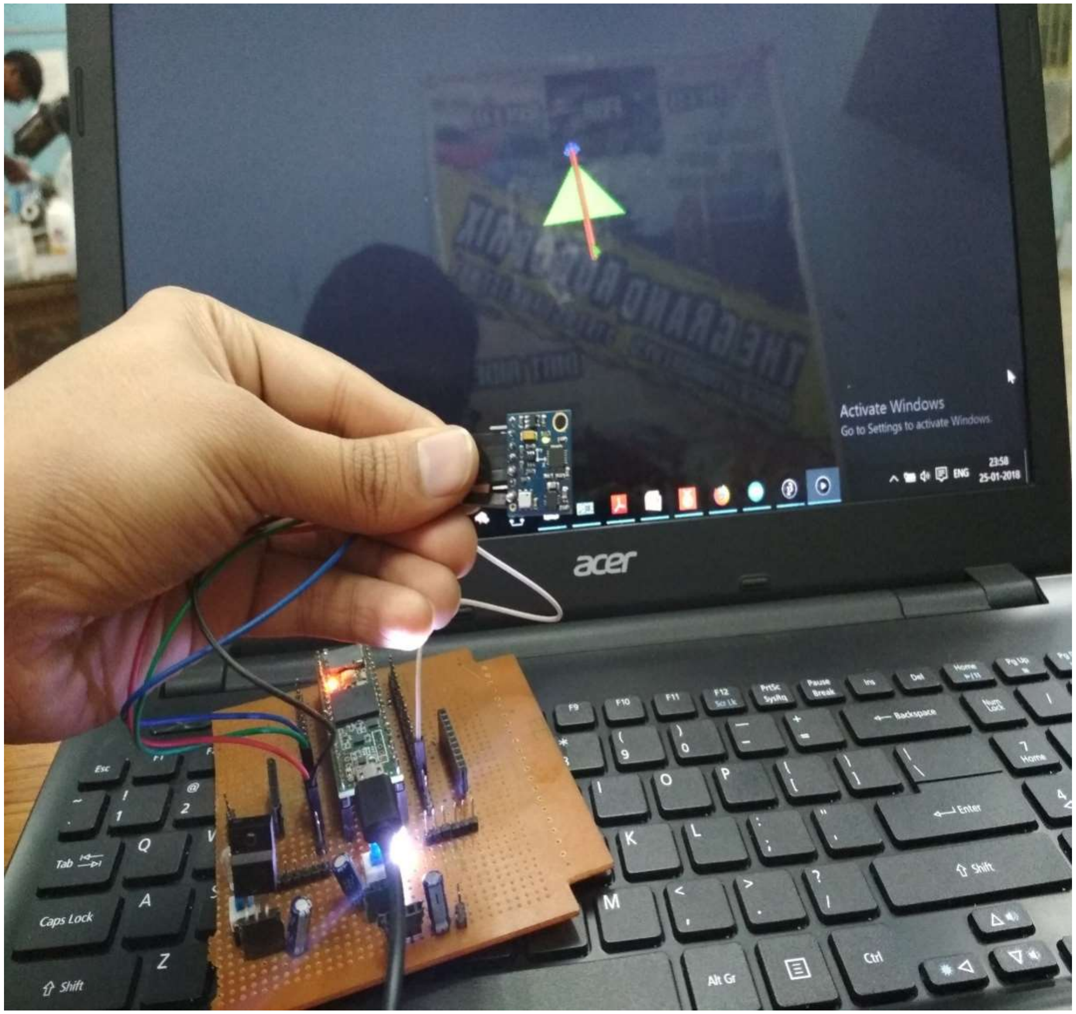
Sensors Testing

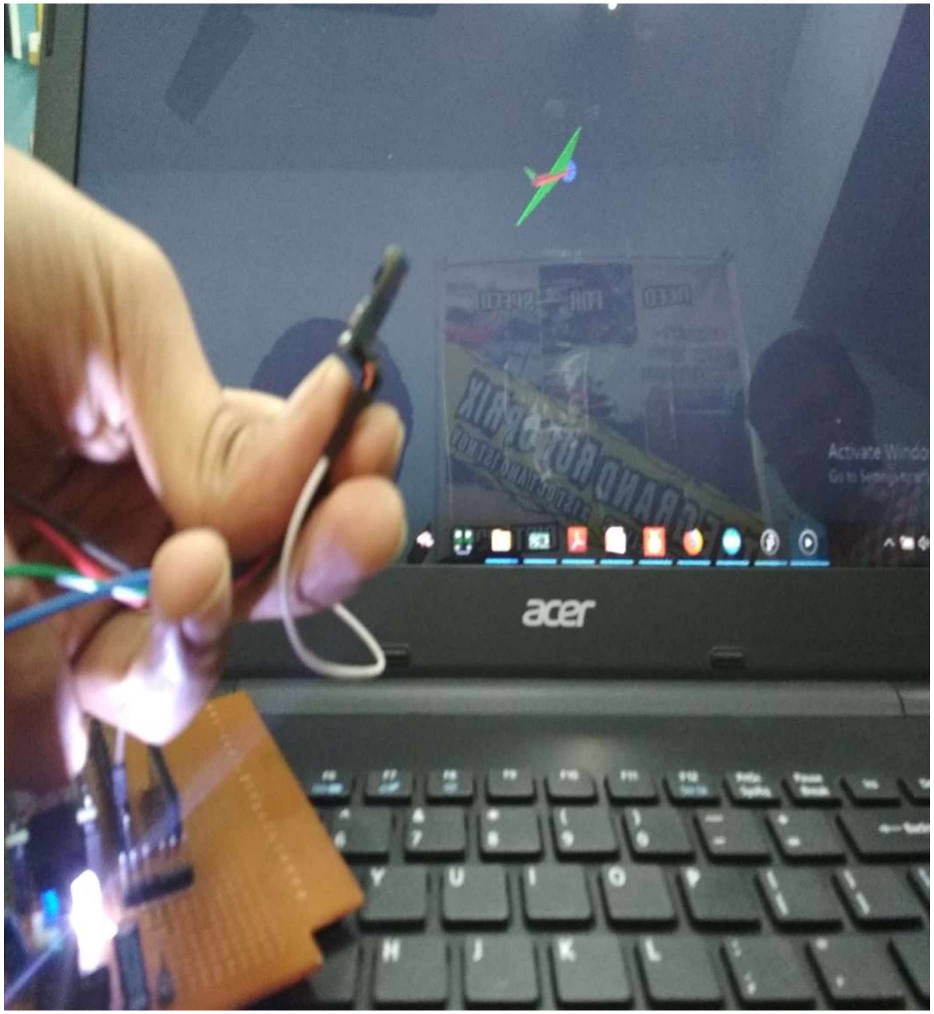
- Configure all sensors individually
- Test two sensors at a time
- Assign pins in the controller to various sensors as per requirement
- **Integrate all sensors; develop and debug the final code**



This photo shows the testing results of BMP180,MPU-6050 on serial monitor for Altitude, Temperature, Pressure and tilt angles. .

Note: Testing videos can be provided upon request





Test results of 3D Simulation of MPU-6050 (tilt sensor)

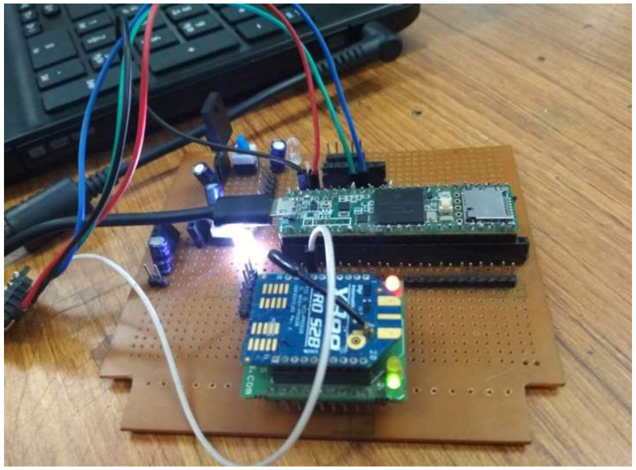
Note: Testing videos can be provided upon request

Subsystem Level Testing Plan

CDH TESTING PLAN

- Checks communication with every sensor and other devices.
- ASCII encoding testing of all sensor's data
- Frame generation of telemetry for API mode of Xbee
- The data then shall be collected from all the sensors (telemetry   data) and sent using radio communication at a frequency of 1 HZ in a required format to the ground station.
- antenna range should be tested using our yagi antenna under different frequency ranges.

XBEE COORDINATOR

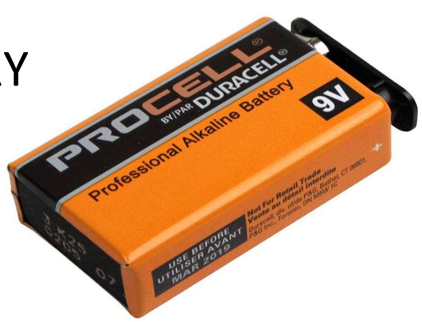


XBEE ROUTER

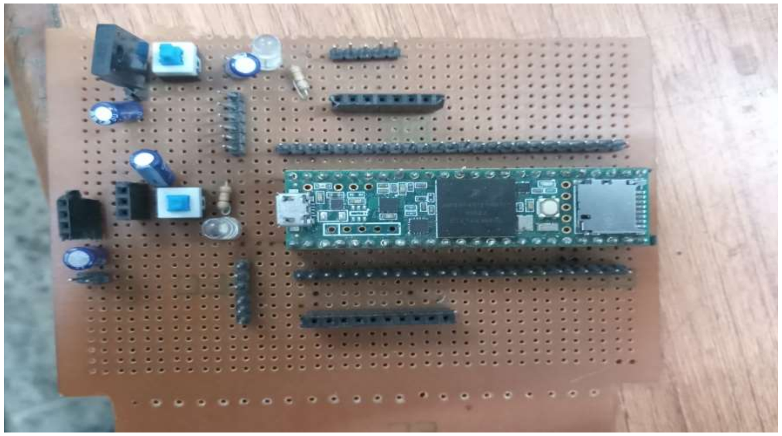
EPS TESTING PLAN

- Calculation of power requirements of each of the components to be powered by 9 V battery (DURACELL PROCELL) .
- Selection of source battery with power output should be 15 % greater than the required amount of power.
- Selection of appropriate voltage regulators.
- Selection of voltage divider circuit to measure battery voltages.
- A circuit should be designed and tested for sustainable power supply.

BATTERY



ELECTRICAL CIRCUIT OVERVIEW



Subsystem Level Testing Plan

RADIO COMMUNICATION PLAN

- The radio modules for probe being used, XBEE PRO S2B is configured to work in point to point communication mode using API transmission mode.
- We should use two XBEE PRO S2B modules -one will serve as a coordinator and other as a router.
- The coordinator is to be in probe and router is to be at ground station.
- The destination address of coordinator shall be routers MAC address and vice-versa.
- After connections ,the radios will be tested by sending data from coordinator XBEE to router XBEE.

Subsystem Level Testing Plan

Individual Testing

- We have interfaced and debugged each sensor individually.
- We have tested XBEE in API mode.
- GPS module is interfaced with Teensy 3.5.

General Circuit Board Designing

- We have made general circuit board to interface all the sensors together with Teensy 3.5

All Sensor Interfacing on GCB

- We have interfaced all the sensors on general circuit board and debugged the merged code.

Subsystem Level Testing Plan

Printed Circuit Board Designing

- We will design printed circuit board for sensors in Diptrace(software).
- We have already self designed PCB for GPS module.

All Sensors Testing ON PCB

- Final testing of all sensors will be carried out once again in PCB and final code will be debugged..

Subsystem Level Testing Plan

MECHANICAL SUBSYSTEM PLAN

- **Weight Check-** To perform weight checks if total mass is within range.
- **Dimension check-** To perform checks whether payload (Heat shield + Probe) completely fitted within dimension limits and there are no sharp edges in the payload.
- **Mechanism Testing-** Sending a command from a laptop(using XBEE) to develop and deploy the Heat shield. Development mechanism time is tested .
- **Wind tunnel test** -The Payload will be tested in a wind tunnel to check flow patterns and the aerodynamic behaviour.
- **Simulation** on ANSYS
- **G force test** - Container G-test is planned
- **Impact tests** - Impact tests will be done to see the amount of energy the container can resist before fracture.

Subsystem Level Testing Plan

DESCENT CONTROL SYSTEM PLAN

- **Decent control mechanism-** The complete CanSat payload along with the sensor subsystem electronics will be tested using a Helium Balloon and Quad-copter to perform Descent Test from heights up to 400-500m.

- **Development mechanism-** Loading the payload i.e. integrating heat shield and probe and then sending a command from a laptop(using XBEE) to develop the heat shield.

- **Parachute**- Deploying CanSat Payload along with parachute from a multi storeyed building.

Integrated Level Functional Test Plan

DESCENT TESTING

Heat Shield

- Release Payload horizontally from a small height (10-15 m) with simulated mass of electronics test flight pattern and velocity .
- Release Heat shield vertically, nose down, from a small height (10-15 m) with probe and electronics to test deployment system .
- Repeat tests from a greater height (30-400m) in various configurations such as nose down, nose up, nose inclination at possible angle of attack to test longer-term flight pattern, velocity, attitude sensors and stability.

RESULTS-
Velocity of Heat shield = 6m/s.

DESCENT TESTING

Parachute

- Release the parachute with mass equal to Payload and calculate time and distance required to develop.
- Velocity is also calculated and dimensions of parachute are adjusted.

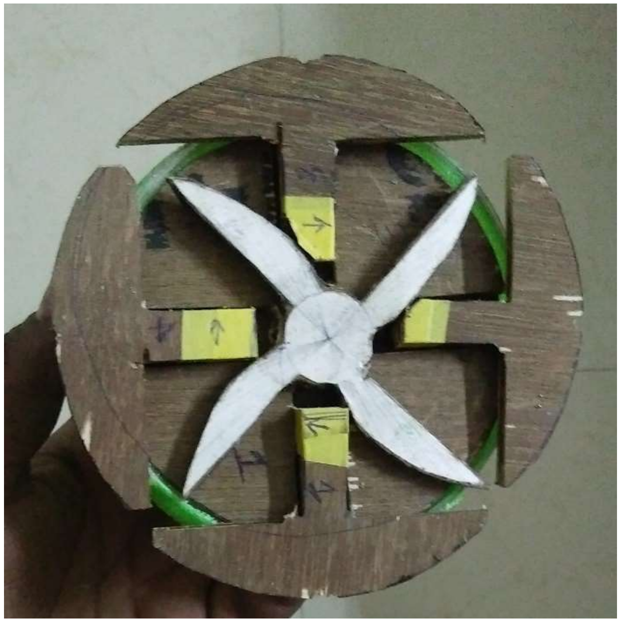
RESULTS-
Velocity of Parachute = 4.5m/s.

Integrated Level Functional Test Plan

MECHANISM TESTING

Heat shield Mechanisms

- The heat shield is developed using Cam mechanisms, which is activated by servo motor. Maximum torque that servo can handle is tested with dynamometer.
- The smooth function of hinges is necessary, which is examined repeatedly.
- The time required for development of heat shield is observed.



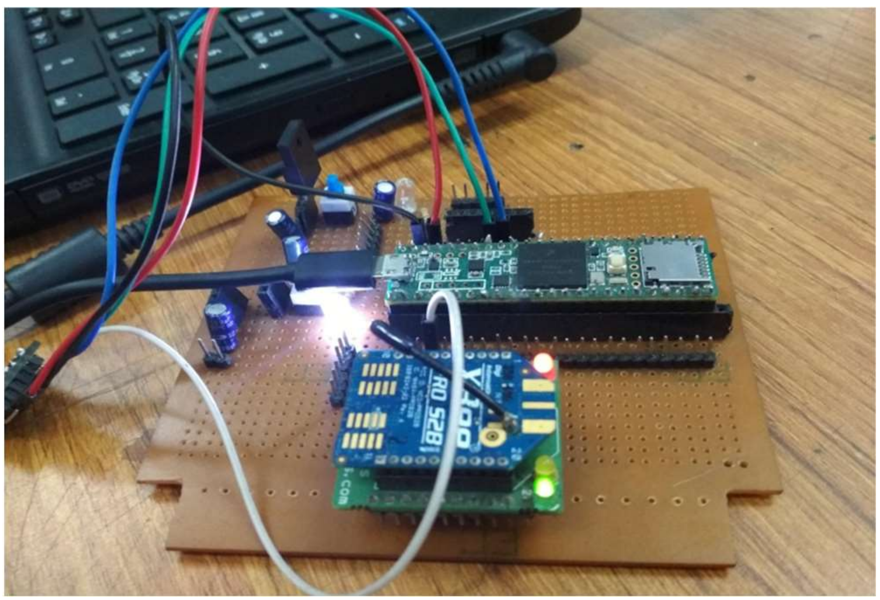
Parachute release mechanism

- The parachute release is operated by servo motor. Servo calibration with altitude sensor is tested..

Integrated Level Functional Test Plan

COMMUNICATIONS TESTING

- Xbee transmission is tested in laboratory by receiving data from various sensors in XCTU.
- The range of Xbee and antenna will be tested in open ground.
- GUI will be tested to receive and plot data.



Integrated Level Functional Test Plan

DEPLOYMENT TESTING

- The heat shield deployment mechanism (Gripper) is tested by releasing payload and allowing parachute to open immediately and hence detachment of heat shield is observed.
- For longer testing, the payload is deployed from height greater than 100m and then with the help of altitude sensor the parachute is opened at 75m and deployment is examined.
- Parachute ropes tension test to see whether ropes are attached securely.
- The Payload will also be tested in the wind tunnel to assure it can undergo the force of the wind before deployment and after deployment.

Integrated Level Functional Test Plan

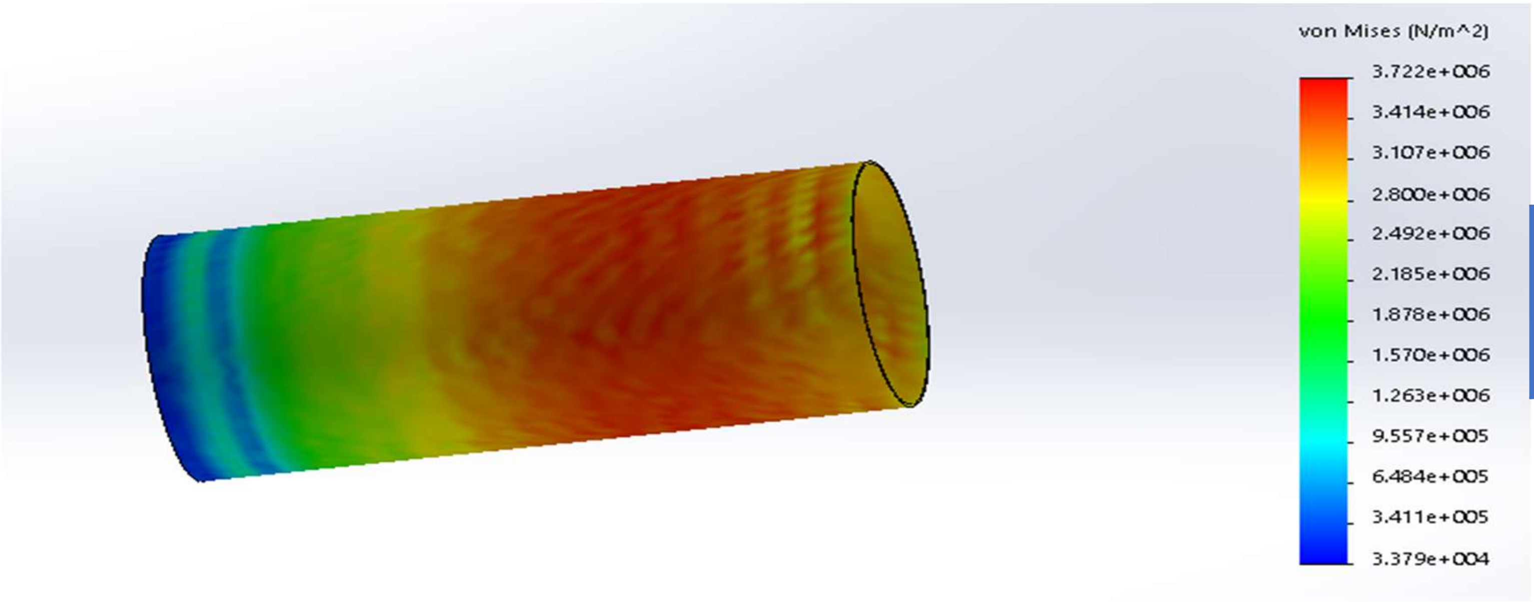
WIND TUNNEL TESTING

A simulation of Payload-CAD model was run in ANSYS.
The manufactured heat shield was tested in WIND TUNNEL to observe and verify the lift and drag produced

Environmental Test Plan

DROP TESTS

- One end of a cord is tied to the ceiling and the other end is secured to the parachute attachment point.
- The Payload is raised to a height of 120cm in line with the cord to attend velocity of 5m/s.
- The cord is released and the Payload is allowed to free fall.
- Observe the results of the drop test. Did the parachute attachment point fail? Did the Heat shield release from the probe.
- Remove the glider from the container and inspect for any damage.
- The drop test was also conducted by elevating Payload to approximately the height stipulated by the competition with drones and weather balloons and released to see their performance.



RESULTS
Max. Stress
= 37 N/m^2

Environmental Test Plan

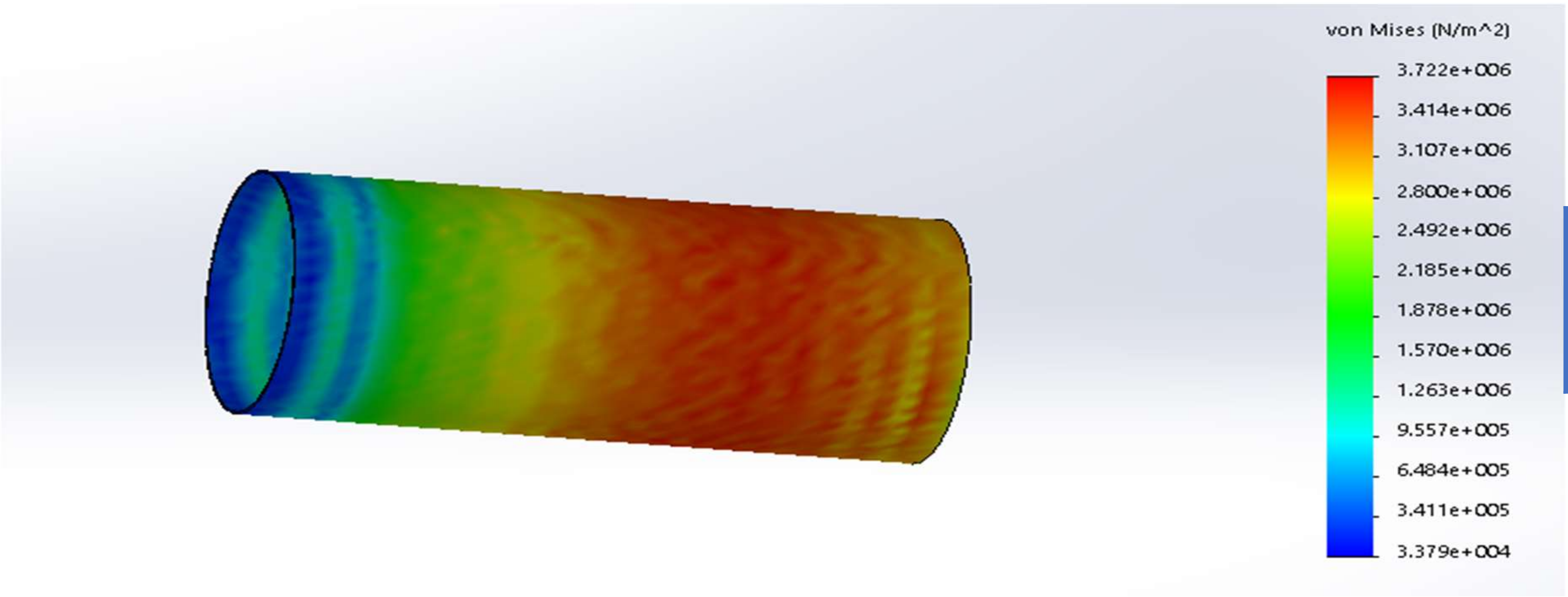
VIBRATION TEST

- The CanSat is securely mounted on the vibration Table.
- The Table powered up to full speed, for 2 seconds and turned off.
- As soon as the table stops moving, the processes is repeated until one minute is completed.
- The CanSat is removed from test and inspected it for any damage.
- A full functional test is performed and the results are noted.

Environmental Test Plan

G-FORCE TEST

- One end of a cord is tied to the ceiling spring balance which is tied to ceiling and the other end is secured to the parachute attachment point.
- The Payload is raised to a height in line with the cord.
- The cord is released and the Payload is allowed to free fall.
- Observe the results of the spring balance . If the force calculated on spring balance is F, let W be weight of CanSat then shock force is given as S= F-W.
- Repeat the procedure by changing the length of cord and observe the highest shock it can sustain.



RESULTS
Max. Stress at impact = 37 N/m^2

Environmental Test Plan

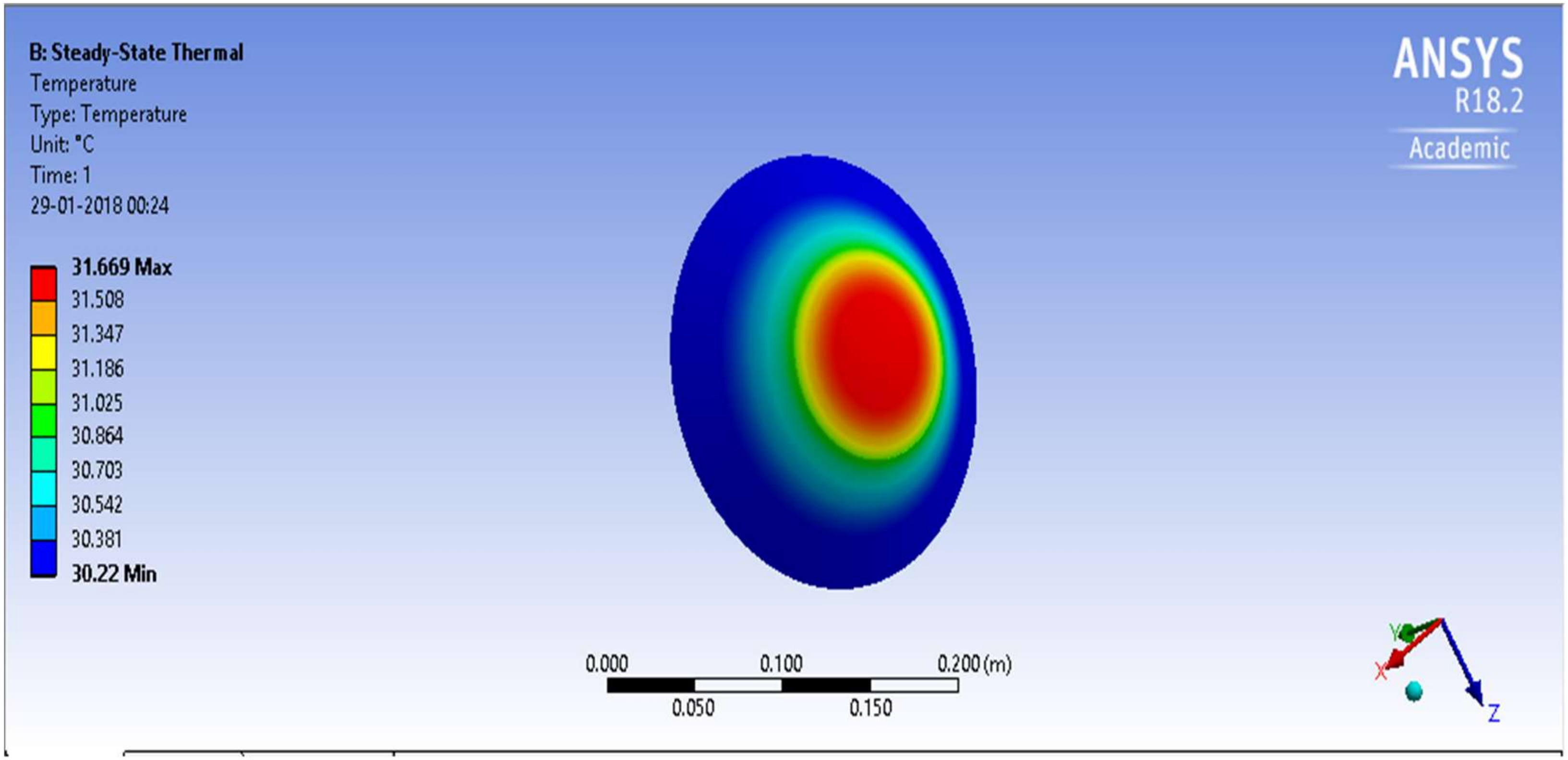
THERMAL TESTS

- The CanSat is turned on and placed into a thermal chamber and sealed.
- The heat source is turned on and monitored till it reaches 60°C.
- This temperature is maintained for 15 to 20 minutes
- The heat source is turned off and the CanSat is visually and functionally inspected.
- With the CanSat still hot, all mechanisms and structures will be inspected to make sure the integrity has not been compromised.
- All epoxy joints and composites are inspected and all results are noted.

Environmental Test Plan

Thermal Analysis for Different Configuration

Nylon + Kapton



Assumption made:

- Mean temp.-25°C
- Density of air-1.124kg/m3
- Heat flux-1.28W/m2

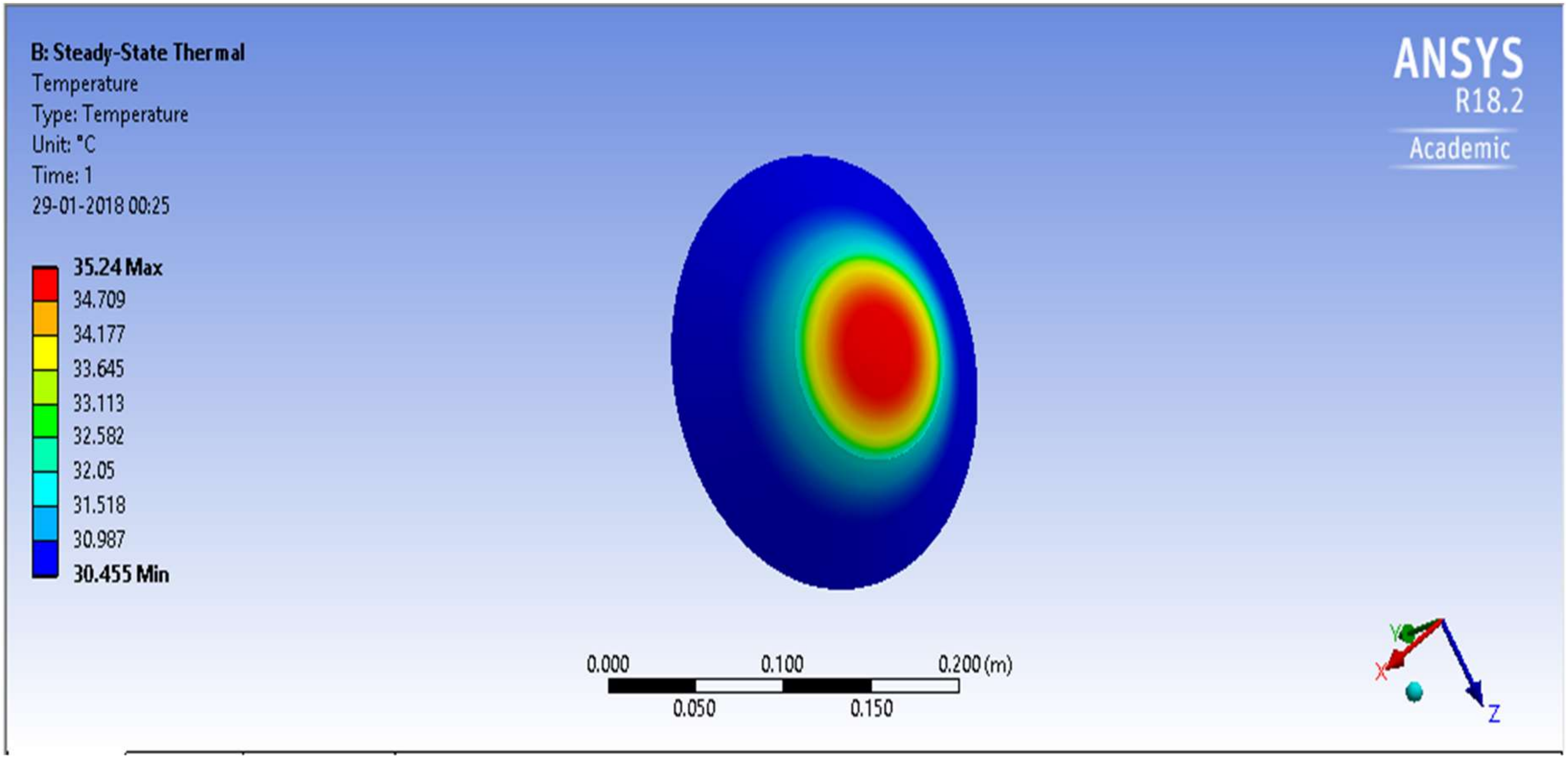
From the result of the simulation the max temperature that can be attained is calculated.

➢ **T_{max} = 31.669°C**

Environmental Test Plan

Thermal Analysis for Different Configuration

Nylon + Kevlar



Assumption made:

- Mean temp.-25°C
- Density of air- 1.124kg/m3
- Heat flux- 1.28W/m2

From the result of the simulation the max temperature that can be attained is calculated.

➢ T_{max} **= 35.24°C**

Environmental Test Plan

Thermal Analysis for Different Configuration

- **The configuration selected is also backed by the thermal analysis carried on the model where following observation and conclusions were made:**

➢ The maximum temperature attained in the 60 degree model which is selected is less compared to other model.

➢ Temperature being less, the material used can have lower materialistic property

Mission Operations & Analysis

DHRUV PATEL

Overview of Mission Sequence of Events

Team Member Roles and Responsibilities

Mission control officer
- Dhruv Patel

Ground Station crew
- Sanjana Dhiran
- Kaishavi Umrethwala
- Pankti Shah

Recovery crew
- Ajinkya Zalte
- Sanket Ambedkar
- Harshil Parekh

CanSat Crew
- Harshit Aghera
- Khushal Tamboli
- Pradeep Manikanta

Overview of Mission Sequence of Events

Arrival

- Weight check of the CanSat.
- Verification of communication between CanSat and Ground Control Station.
- Final Check for Sensors.

Whole Team

CanSat Assembly

- Check for Mechanical Damage in the CanSat structure.
- Detachment and development mechanism check.
- Assembly of full payload.

CanSat crew

Ground Station Setup

- Antenna Assembly and Ground Station Settings.

Ground station crew

Flight Preparations

- Power On re-entry container electronics.
- Integration of CanSat into Rocket Payload.
- Launch.

CanSat crew

Overview of Mission Sequence of Events

Mission

- Telemetry transmission from re-entry container to the ground station.
- Deployment of aero braking heat shield.
- Heat shield detaches and parachute opens at 300m.
- Land(3)

Recovery

- Recovery Crew to enter the field and search for CanSat
- Localization of the Field Judge and delivering of score card
- Retrieval of re-entry container and the CanSat
- Submission of the telemetry data file for inspection

Recovery crew

Analysis

- Collection of data acquired by camera
- Analysis of obtained data
- Mission assessment and preparation of the post flight review
- Delivery of the presentation on the next day

Whole Team

The Development Process

This includes various checklist for the initial ground station setup, pre-launch preparation, launch preparation and recovery of probe and heat shield

Manual Major Components

Pre-launch Checklist	**Structural tests** • Development of the heat shield • Heat shield release mechanism • Parachute release mechanism • Final visual check up of parachute. **Electronics Test** • Check battery connection. • Verify functionality of all sensors. • Check camera trigger.
Payload and GCS setup checklist	• Initial start up of the program • Configure the GCS and begin data receiving
Payload assembly test	• Installation of egg module into the probe. • Proper attachment of the heat shield to the probe.
Integration	• Integrate the Payload into the rocket cavity.
Recovery	• Recovery crew will be ready to retrieve the heat shield and probe.

CanSat Location and Recovery

- The recovery crew will be split into two teams, one in search for the probe and other for the container.

Probe recovery	• The probe will be visually spotted during its descent by parachute. • Both probe and parachute will be painted fluorescent orange to increase the visibility. • The audio beacon will aid in locating the container.
Heat shield recovery	• Heat shield will be painted fluorescent orange • The heat shield develops and hence increases visibility.

CanSat Location and Recovery

- The Heat shield and Probe will possess the following information written on them to aid identification.

Team Name
Team Leader Name and Number
Contact Details
Email Address

Requirements Compliance

Kaishavi Umrethwala

Requirements Compliance Overview

The following design comply to the required :

- Mechanical Subsystem :
  - ➢ CanSat complies the dimensions requirements.
  - ➢ CanSat complies the mass requirements.
  - ➢ Heat-Shield protects all the components and complies the velocity range (10 to 30 meters/sec) in ANSYS fluent analysis.
  - ➢ Parachute produces the sufficient drag so that it can maintain the velocity 5 meters/sec.
  - ➢ Egg module is tested by creating similar situation considering forces.

- Electronics Subsystem
  - ➢ As of now, all sensors and GPS are configured and tested against various possible failure.
  - ➢ Schematic for CanSat circuitry is finalized along with Battery potential measuring circuit and different power supply scheme for individual component.
  - ➢ GUI fabrication ant Ground station is completed and analysed for possible received data string.
  - ➢ Integration of Communication circuit with rest circuitry is yet to be designed.
  - ➢ PCB layout adoption from schematic for entire circuit of CanSat is left and have most priority among other compliances.
  - ➢ GUI testing with actual XBEE received data string is still in progress.

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
1	Total mass of the CanSat (probe) shall be 500 grams +/- 10 grams.	Comply	7,45,83,123	
2	The aero-braking heat shield shall be used to protect the probe while in the rocket only and when deployed from the rocket. It shall envelope/shield the whole sides of the probe when in the stowed configuration in the rocket. The rear end of the probe can be open.	Comply	95,80	
3	The heat shield must not have any openings.	Comply	7,21,96	
4	The probe must maintain its heat shield orientation in the direction of descent.	Comply	7,67	
5	The probe shall not tumble during any portion of descent. Tumbling is rotating end-over-end.	Comply	7,45,156	
6	The probe with the aero-braking heat shield shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	Comply	7,28,80,19	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
7	The probe shall hold a large hen's egg and protect it from damage from launch until landing.	Comply	7,118,121	
8	The probe shall accommodate a large hen's egg with a mass ranging from 54 grams to 68 grams and a diameter of up to 50mm and length up to 70mm.	Comply	7,113	
9	The aero-braking heat shield shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	Comply	7,31	
10	The aero-braking heat shield shall be a florescent colour; pink or orange.	Comply	8,53	
11	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	8	
12	The rocket airframe shall not be used as part of the CanSat operations.	Comply	8	
13	The CanSat, probe with heat shield attached shall deploy from the rocket payload section.	Comply	8	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
14	The aero-braking heat shield shall be released from the probe at 300 meters.	Comply	8,108,109	
15	The probe shall deploy a parachute at 300 meters.	Comply	5,56,111,112	
16	All descent control device attachment components (aero-braking heat shield and parachute) shall survive 30 Gs of shock.	Comply	9	
17	All descent control devices (aero-braking heat shield and parachute) shall survive 30 Gs of shock.	Comply	9	
18	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Comply	9,20,79	
19	All structures shall be built to survive 15 Gs of launch acceleration.	Comply	11	
20	All structures shall be built to survive 30 Gs of shock.	Comply	11	
21	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	10	
22	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	10,83	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
23	Mechanisms shall not use pyrotechnics or chemicals.	Comply	10,83	
24	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	Comply	10	
25	During descent, the probe shall collect air pressure, outside air temperature, GPS position and battery voltage once per second and time tag the data with mission time.	Comply	6,11,31,33,34,35,36,126,156,177,178	
26	During descent, the probe shall transmit all telemetry. Telemetry can be transmitted continuously or in bursts.	Comply	11,127,139,156,164	
27	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.	Comply	12,127,156,164	
28	XBEE radios shall be used for telemetry. 2.4 GHz Series 1 and 2 radios are allowed. 900 MHz XBEE Pro radios are also allowed.	Comply	12,127,137	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
29	XBEE radios shall have their NETID/PANID set to their team number.	Comply	11,127,137	
30	XBEE radios shall not use broadcast mode.	Comply	14,127,137	
31	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Comply	9	
32	Each team shall develop their own ground station.	Comply	27,164	
33	All telemetry shall be displayed in real time during descent.	Comply	14,164	
34	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	14,164	
35	Teams shall plot each telemetry data field in real time during flight.	Comply	27,164	
36	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand held antenna.	Comply	13,165	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
37	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	Comply	12,165	
38	Both the heat shield and probe shall be labelled with team contact information including email address.	Comply	10,84	
39	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	Comply	14,156	
40	No lasers allowed.	Comply	8	
41	The probe must include an easily accessible power switch.	Comply	15	
42	The probe must include a power indicator such as an LED or sound generating device.	Comply	15	
43	The descent rate of the probe with the heat shield deployed shall be between 10 and 30 meters/second.	Comply	13,45	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
44	The descent rate of the probe with the heat shield released and parachute deployed shall be 5 meters/second.	Comply	13,46,76	
45	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Comply	13,84,145,157	
46	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.	Comply	15,144	
47	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.	Comply	15,144	
48	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	9	
49	A tilt sensor shall be used to verify the stability of the probe during descent with the heat shield deployed and be part of the telemetry.	Comply	7,40,177	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
50	Add a colour video camera to capture the release of the heat shield and the ground during the last 300 meters of descent. The camera must have a resolution of at least 640x480and a frame rate of at least 30 frames/sec. The camera must be activated at 300 meters.	Comply	15,41, 24,46	
51	Wind sensor	Partially Comply	172	Difficulties in transmitting the wind velocity readings by varying frequency.

Management

KAISHAVI UMRETHWALA

CanSat Budget – Hardware

Mechanical Sub-System

Component		Model	Quantity	Unit Price	Total(Rs.)	Determination
Probe Material		ABS	1	1500	1500	Estimated
Heat-Shield	Nose	Teflon	1	560	560	Estimated
	Cloth	nylon	1	100	100	Actual
	Container	ABS	1	2500	2500	Actual
Mechanism	Development	Cam-balsa	4	125	500	Estimated
	Deployment	Nylon threads	16	20	320	Actual
		ABS gripper	2	80	160	Estimated
Parachute		Ripstop nylon	1	990	990	Actual
Servo Motor		-	2	189	378	actual
Strings	Parachute	Nylon	9 meters	10	90	Actual
	For balancing	nylon	1 meter	20	20	Actual

CanSat Budget – Hardware

<table>
<tr><th colspan="2">Component</th><th>Model</th><th>Quantity</th><th>Unit Price</th><th>Total(Rs.)</th><th>Determination</th></tr>
<tr><td colspan="2">Rods</td><td>Carbon rod</td><td>4</td><td>228</td><td>912</td><td>Actual</td></tr>
<tr><td colspan="2">Hinges</td><td>ABS</td><td>2</td><td>80</td><td>160</td><td>Actual</td></tr>
<tr><td colspan="2">Wooden Plates</td><td>Balsa Wood</td><td>2</td><td>595</td><td>1190</td><td>Actual</td></tr>
<tr><td rowspan="2">Egg Module</td><td>Container</td><td>Plastic</td><td>1</td><td>50</td><td>50</td><td>Estimated</td></tr>
<tr><td>Bubble Rape</td><td>Plastic</td><td>3</td><td>20</td><td>30</td><td>Actual</td></tr>
<tr><td colspan="5">TOTAL</td><td colspan="2">9460($150)</td></tr>
</table>

CanSat Budget – Hardware

Electronics Sub-System

Component	Model	Quantity	Unit Price	Total(Rs.)	Determination
Microcontroller	Teensy 3.5	1	1595	1595	Actual
Communication module	XBEE pro S2B	1	1900	1900	Actual
GPS MODULE	UBLOX NEO 6M	1	899	899	Actual
PRESSURE,ALTITUDE &TILT	10 DOF	1	999	999	Actual
CAMERA	MEMORE KEYCHAIN CAMERA	1	385	385	Actual
AUDIO BEACON	PIEZO BUZZER	1	50	50	Actual

CanSat Budget – Hardware

Component	Model	Quantity	Unit Price	Total(Rs.)	Determination
CIRCUIT BASED BOARDS	PCB	1	2000	2000	Estimated
CIRCUIT TEST BOARDS	GCB	1	1000	1000	Estimated
SD CARD	SANDISK 2GB	1	125	125	Actual
RTC	M276 DS3231	1	105	105	Actual
VOLTAGE REGULATOR 3.3 V	LD33V	1	65	65	Actual
VOLTAGE REGULATOR 5V	7805	1	50	50	Actual
TEMPERATURE	DS18B20	1	100	100	Actual
TOTAL				9273($146)	

CanSat Budget – Other Costs

Ground Station Cost

Component	Model	Quantity	Unit Price	Total	Determination
Antenna	Yagi Antenna	1	900	900	Actual
Communication Module	XBEE pro S2B	1	1900	1900	Actual
Others	-	-	2000	2000	Estimated
TOTAL				4800($76)	

CanSat Budget – Other Costs

Other Costs

Type	Cost	Determination
Competition Fee	6674($100)	Actual
Test facilities and Equipment	3000	Actual
Flights	1000000	Estimated
Meal	40000	Estimated
Accommodation	55000	Estimated
Transport	25000	Estimated
TOTAL	1129674($17931)	

CanSat Budget – Other Costs

Total Expenditure

Category	Cost
Mechanical Sub-System	**9460**
Electronics Sub-System	**9273**
Ground Station	**4800**
Other	**1130000**
TOTAL	**1153533 ($18126)**

Source of Income : As a part of DRISHTI, a technical hobby club of our college, technical resources required for competition are funded by college itself. For other costs like travelling fees and accommodation, we are currently in search for sponsorship.

Program Schedule

- Competition started in **September '17** with the formation of team by selecting students based on their interest and their ability to contribute to the Team. The focus was to understand the problem statement properly, analysing different ideas and working on minor details to complete the task in the given timeline.
- In **October '17** different designs for development and deployment of heat shield were analysed, along with the materials to be used and research on sensors complying to the competition requirement was started.
- In **November '17** different designs for the probe were discussed and CAD modelling for different configuration was started.
- In **December '17**, after completion of the **End Semester Exam** we started on the development of the FSW algorithm along with the analysis of the CAD model and the simulation on software.
- In **January '18**, the team was registered and an appropriate design was chosen to build the prototypes which underwent full flight testing along with the testing of sensors. The work on **PDR** started.
- The **PDR** was complied by **25 January 2018**, and mailed by **31 January 2018**.

Program Schedule

- In **February '18**, fabrication of the probe and heat shield shall begin along with the building of the electronic circuits. By the end of the month we intend to complete the drop test, and other final test on the model along with the testing of the circuit and decide on the modifications.

- By **March '18**, our **Mid Semester exams** will begin following which work on the CDR will begin with the completion of compilation by 25th March 2018 for the final review.

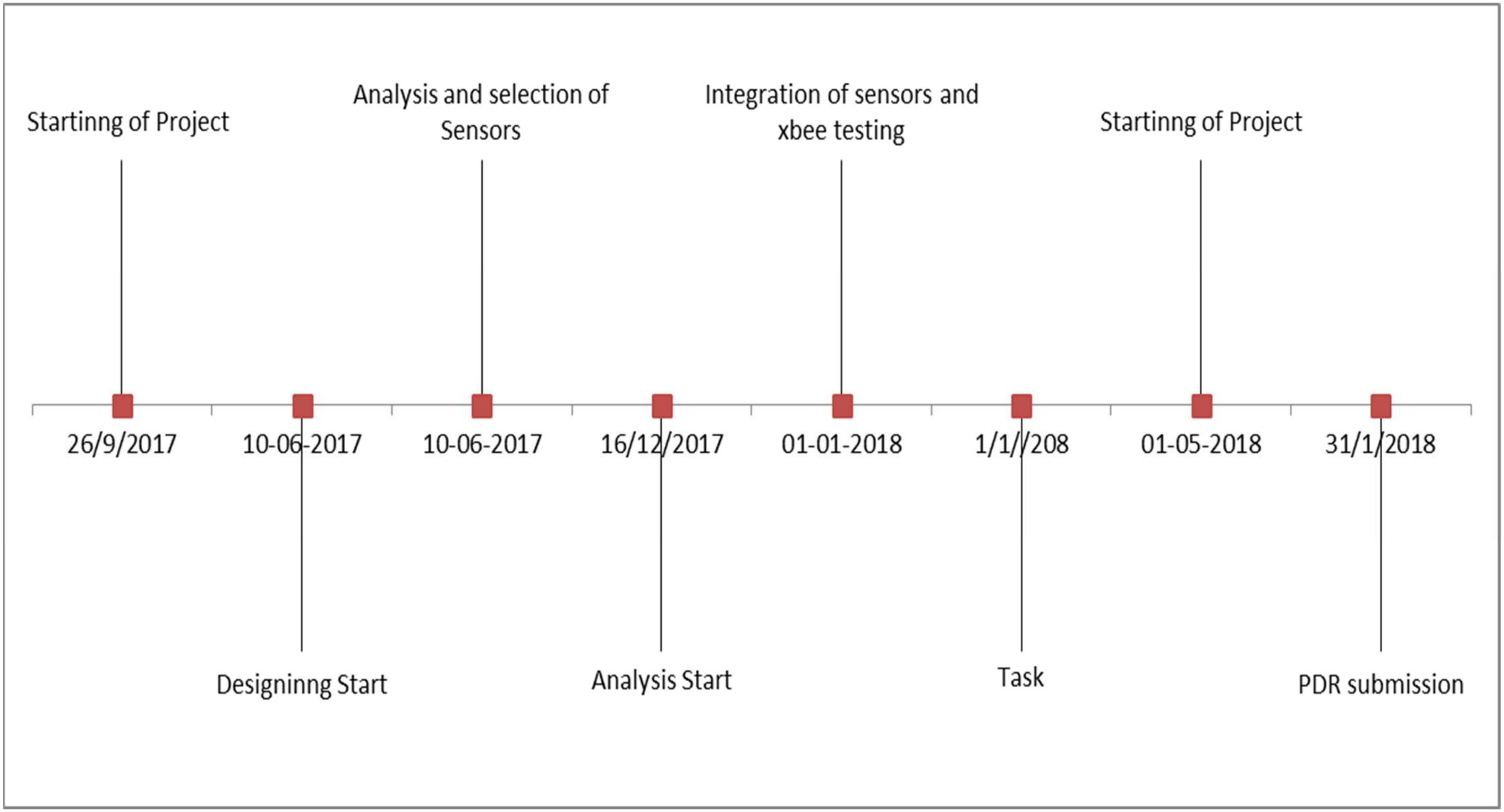
- CDR will be submitted on **29th March '18.**

- In **March '18**, we will start the final fabrication of the probe and the heat shield, drone drop tests from the height of 300 metres to ensure the proper functioning of all components.

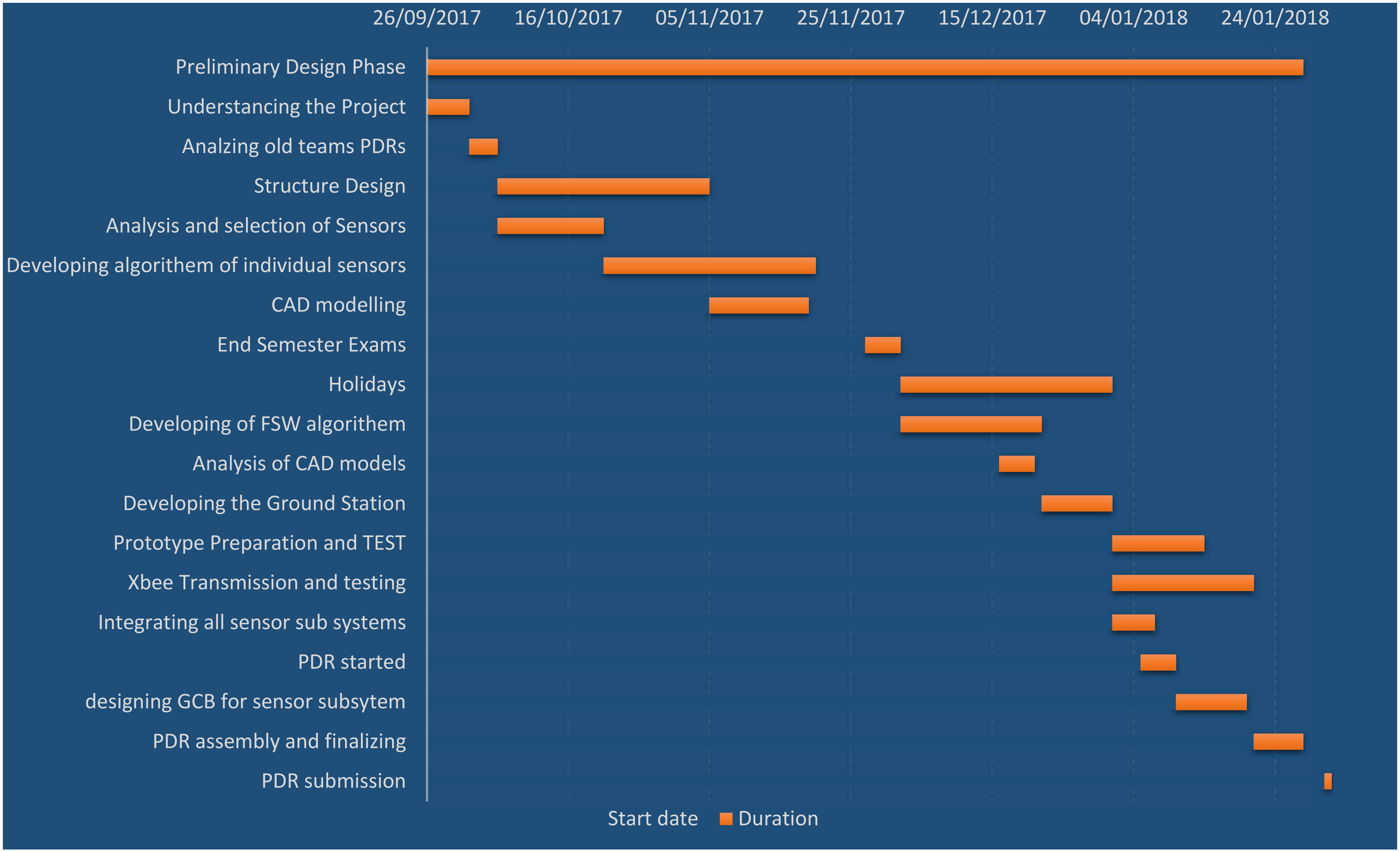
- Any shortcomings to the above conducted test would lead us to make some modification to the design.

Program Schedule

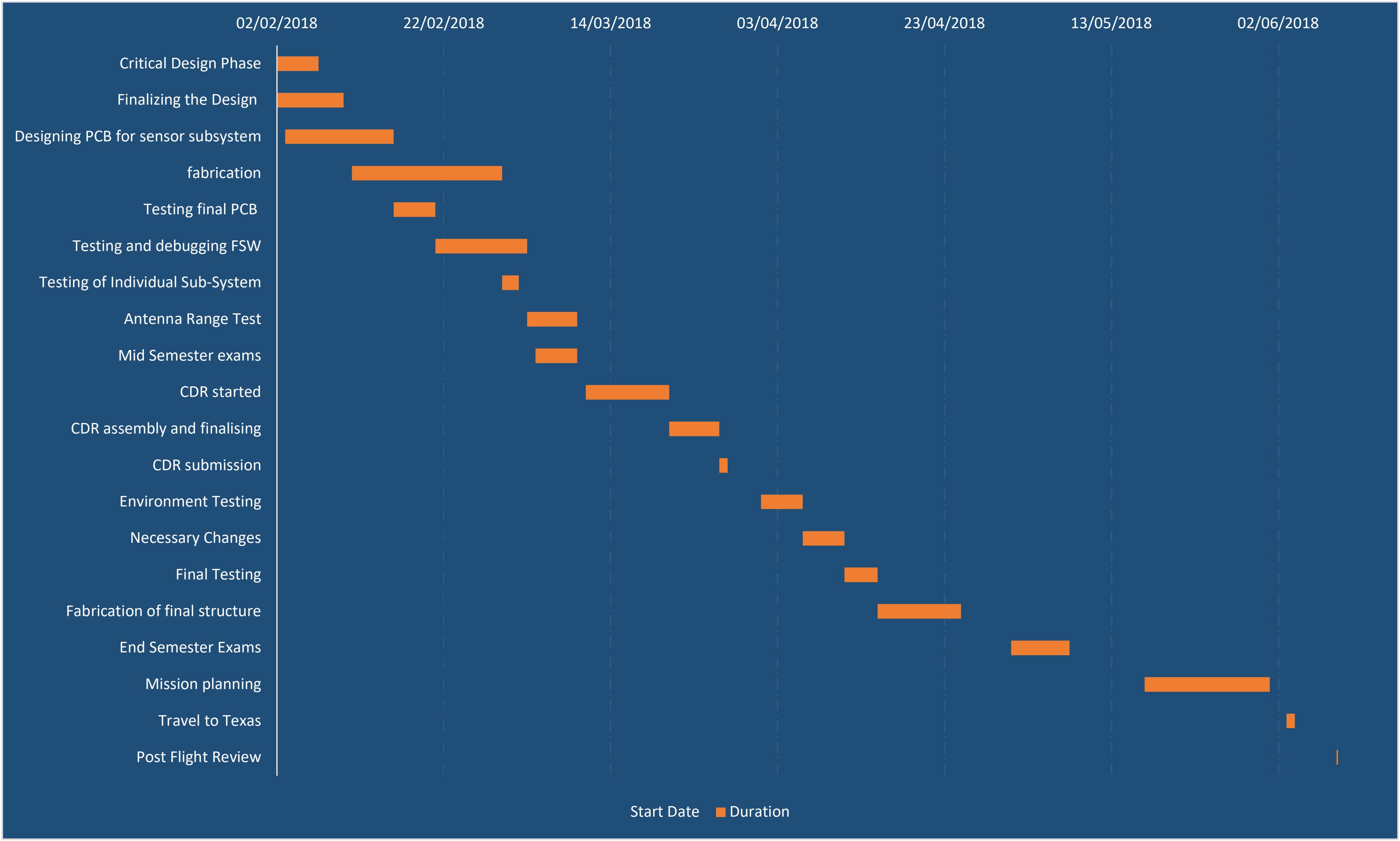
Milestones in CanSat Preparation



Program Schedule



Program Schedule



Conclusion

Accomplishments

- Recognition and divisions of tasks
- Material selection
- Designing and analysis of Heat shield and parachute is completed
- Successfully tested parachute and heat shield
- Designing of container and drop test is successfully completed
- Fabrication is started for container and heat shield both
- Integration of mechanical parts and electronics parts are running

- Selection of Individual Sensors, Communication modules and Power modules
- Separate interfacing of all sensors and communication devices
- GCB based testing of Electronics circuitry testing
- Development and testing of GCS GUI
- Camera selection

Conclusion

Unfinished Work

- Still working on deployment mechanism of heat shield
- Conducting all over performance of CanSat by rocket test
- Weight reduction of system

- Development of prototype of transmitter for Wind sensor
- PCB designing of Electronics circuits
- Configuration and testing of Camera

Future Development Plans

- Development and testing of deployment and development mechanism for heat shield.
- Performance measurement of both mechanical and electronics subsystem by rocket test.

- Development and testing of prototype of transmitter for Wind sensor.
- Designing of PCBs as per mounting space availability.
- Real time GUI testing with actual data being received from CanSat Probe.