Preliminary Design Review (PDR) Outline

Version 01

Team 1516

Ballistic Auto-Gyro Satellite (B.A.G.S)

Presentation Outline (1/5)

Introduction

System Overview – Snigdha Singh

Sensor Subsystem Design – Divya Tiwari

Presentation Outline (2/5)

Descent Control Design – Riyanshu Motalaya

Mechanical Subsystem Design – Bhavya Arya

Presentation Outline (3/5)

Communication and Data Handling(CDH) Subsystem Design - Sourav Bhattacharjee

Electrical Power Subsystem (EPS) Design - Shikhar Makhjia

Flight Software (FSW) Design – Raunit Singh

Presentation Outline (4/5)

Presentation Outline (5/5)

Management – Kshitij Shekhar

Mission Summary (1/2)

General Objectives

- ❖ To design and fabricate an Auto-Gyro Probe (CanSat).
- ❖ The CanSat shall travel through the planetary atmosphere sampling the atmospheric composition during flight and telemetry data in real time to ground station.
- ❖ CanSat consists of two important parts: Container and Payload.
- ❖ The Payload shall descend using a passive helicopter/ auto-gyro mechanism.

Mechanical Objectives

- ❖ Once released from the rocket at the apogee, the parachute shall deploy packed in a height of 25 mm and container shall descend with a velocity of 20 5 m/s till 450 m height above the ground.
- ❖ At 450 meters, the container shall release the payload.
- ❖ Once released, the payload shall descend with the auto-gyro descent control system with a velocity of 10-15 m/s.
- ❖ The CanSat shall weigh 500 10 g and shall fit in a cylinder of length 310 mm having a diameter of 125mm with appropriate clearances.
- ❖ The auto-gyro descent control shall not be motorized. It must passively rotate during descent.

Mission Summary (2/2)

Electronics Objectives

- ❖ Payload shall transmit telemetry consist of sensor data which shall include air pressure, surrounding temperature, altitude, GPS coordinates, pitch, roll, voltage, blade spin and camera direction at the rate of 1 Hz with real-time plots at ground station.
- ❖ The container and payload shall have an audio beacon with minimum sound pressure level of 92 dB, unobstructed to aid in recovery.
- ❖ The container and payload shall include an easily accessible power switch and a power indicator (LED).

Bonus Objectives

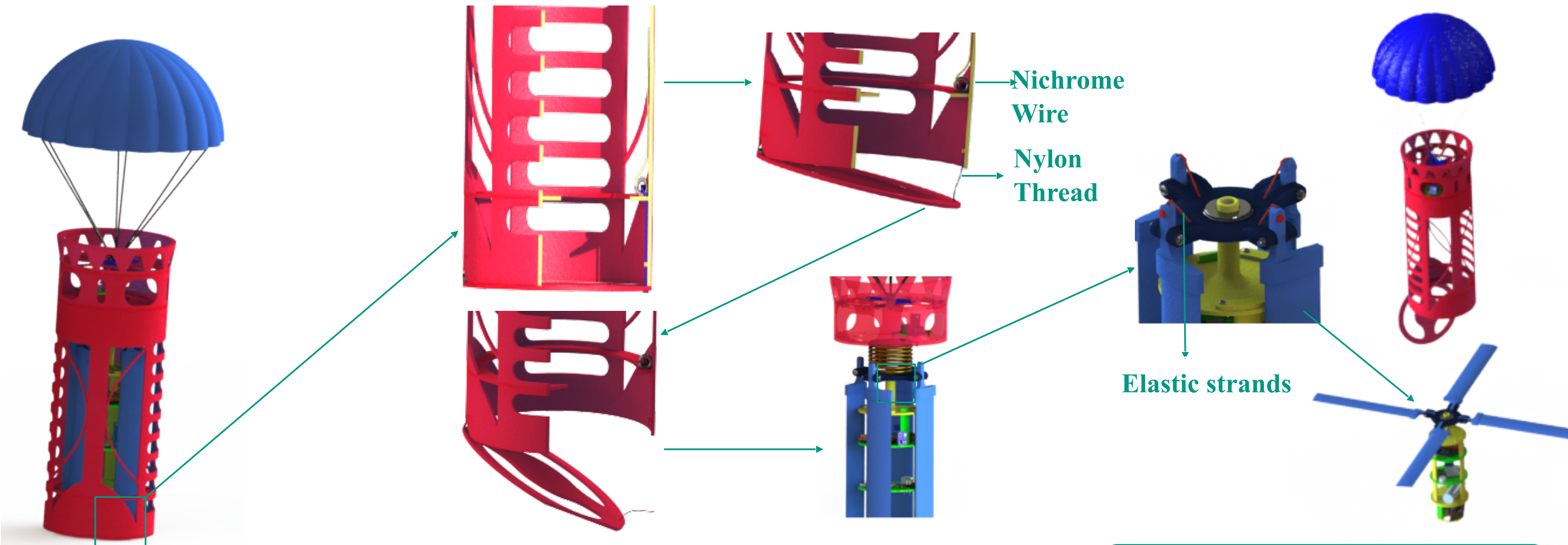
- ❖ Camera of resolution 640 x 480 pixels with 30 fps is used to record the descent after the release of payload from the container.
- ❖ The video is saved in the SD card on the payload.
- ❖ Camera stabilization: It shall point in one direction relative to the earth's magnetic field with a stability of 10 degrees in all directions during descent.

External Objectives

- ❖ Raise funding for travel and CanSat fabrication
- ❖ Display tilt animation of CanSat and payload after release from container.

System Level CanSat Configuration Trade & Selection (1/2)

Design Strategy A: Topologically optimized monocoque container with Clark Z airfoil opening using elastic strands and payload release using nichrome burning setup



Phase 1: Stowed Payload

Payload is kept in the container
In the stowed configuration.

Phase 2: Transition

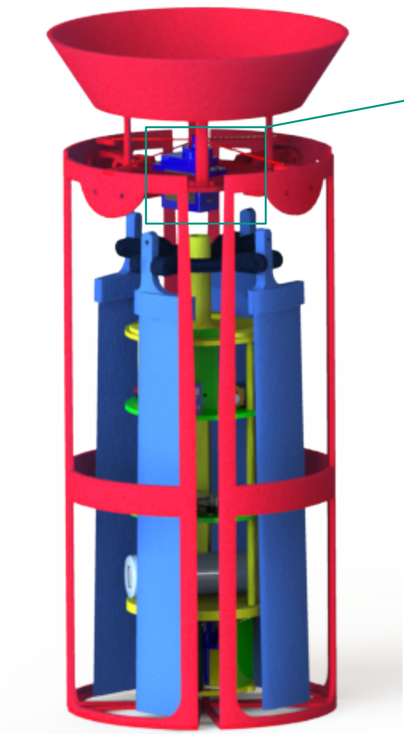
At 450m, the MCU will command the Nichrome burning setup to pass large current (around 2000mA) through the nichrome wire to burn the nylon thread. The nylon thread is attached to a mount on the cylinder and passing through a hole in the hinged lid on the other end. After burning of the nylon thread, the hinged lid will open and the expanded spring and gravity together will force out the payload..

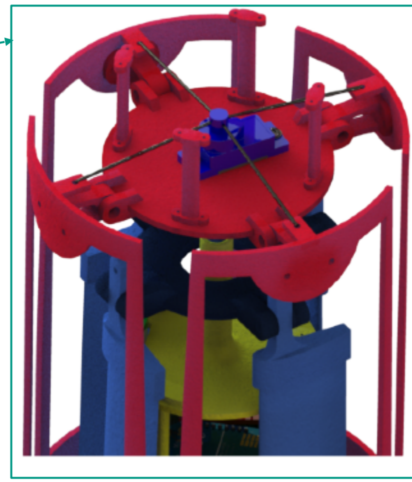
Phase 3: Payload Release And Auto-Gyro in action

Elastic strands and air pressure will force the rotors to open. The rotors will start rotating due to lift forces generated by the downward velocity of the container.

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

Design Strategy B: Space-Frame container with NACA 2415 airfoil opening using neodymium magnets and payload release using servo actuation



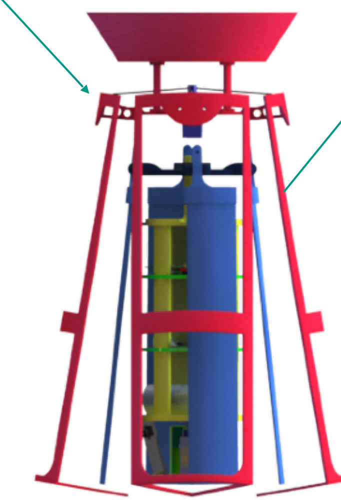


Phase 1: Pre-Deployment

Payload is kept in the container
In the stowed configuration.

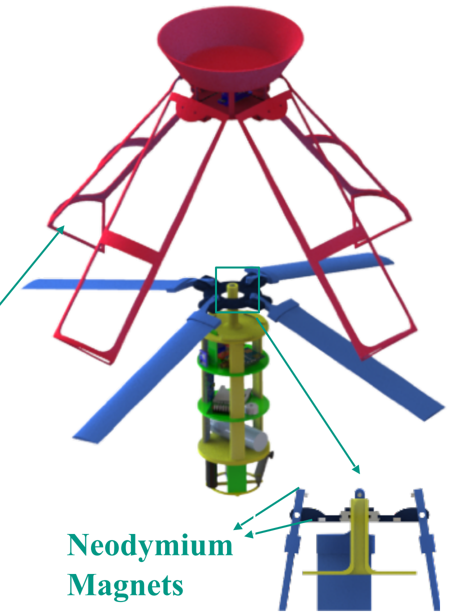
Phase 2: Transition

At 450 m, rotation of 9g servo will cause inward tension in the string in the four directions which in turn will push the 4 hinged flaps out thus opening the container.



Phase 3: Separation

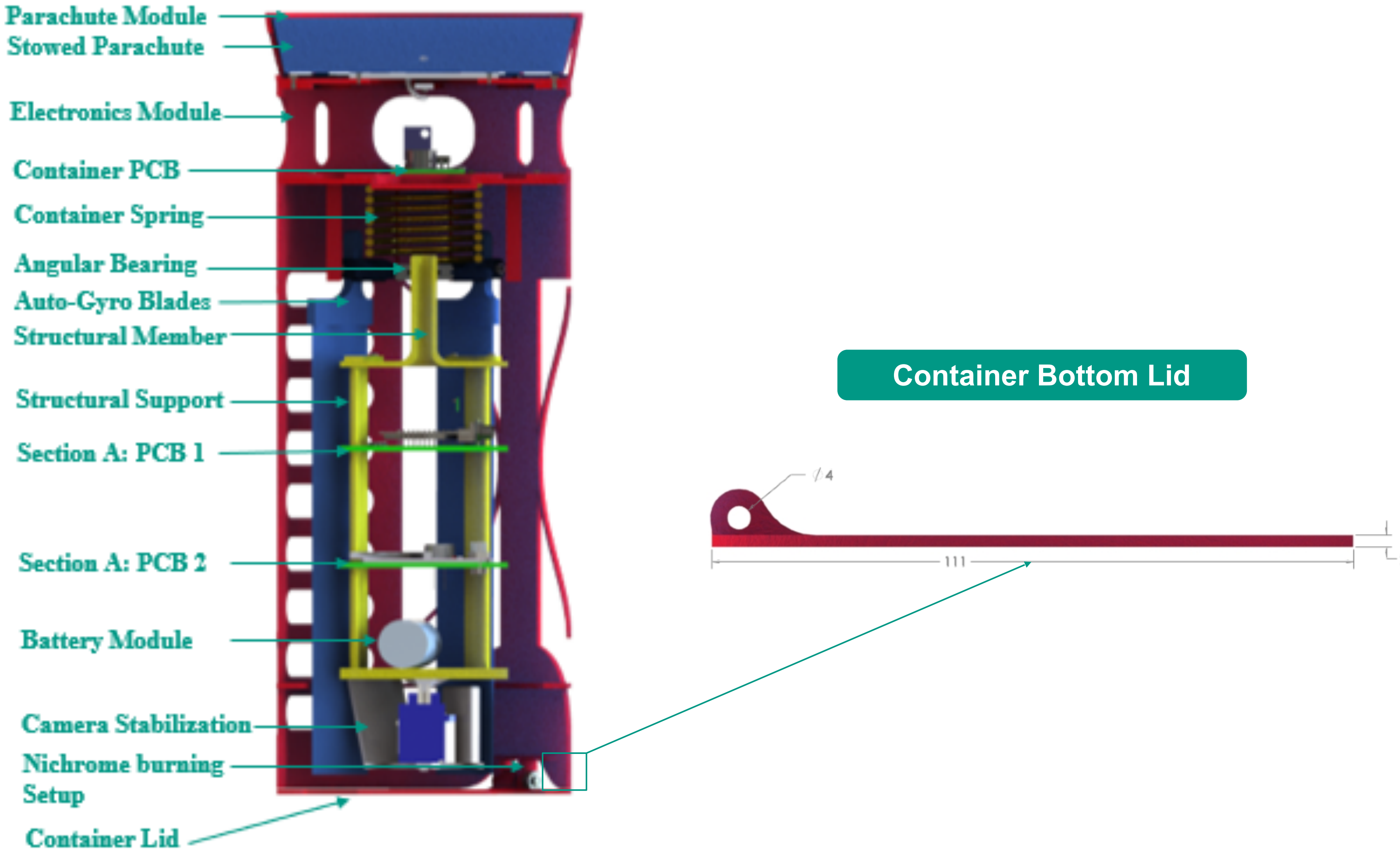
As the flaps start opening out, payload will start coming out,



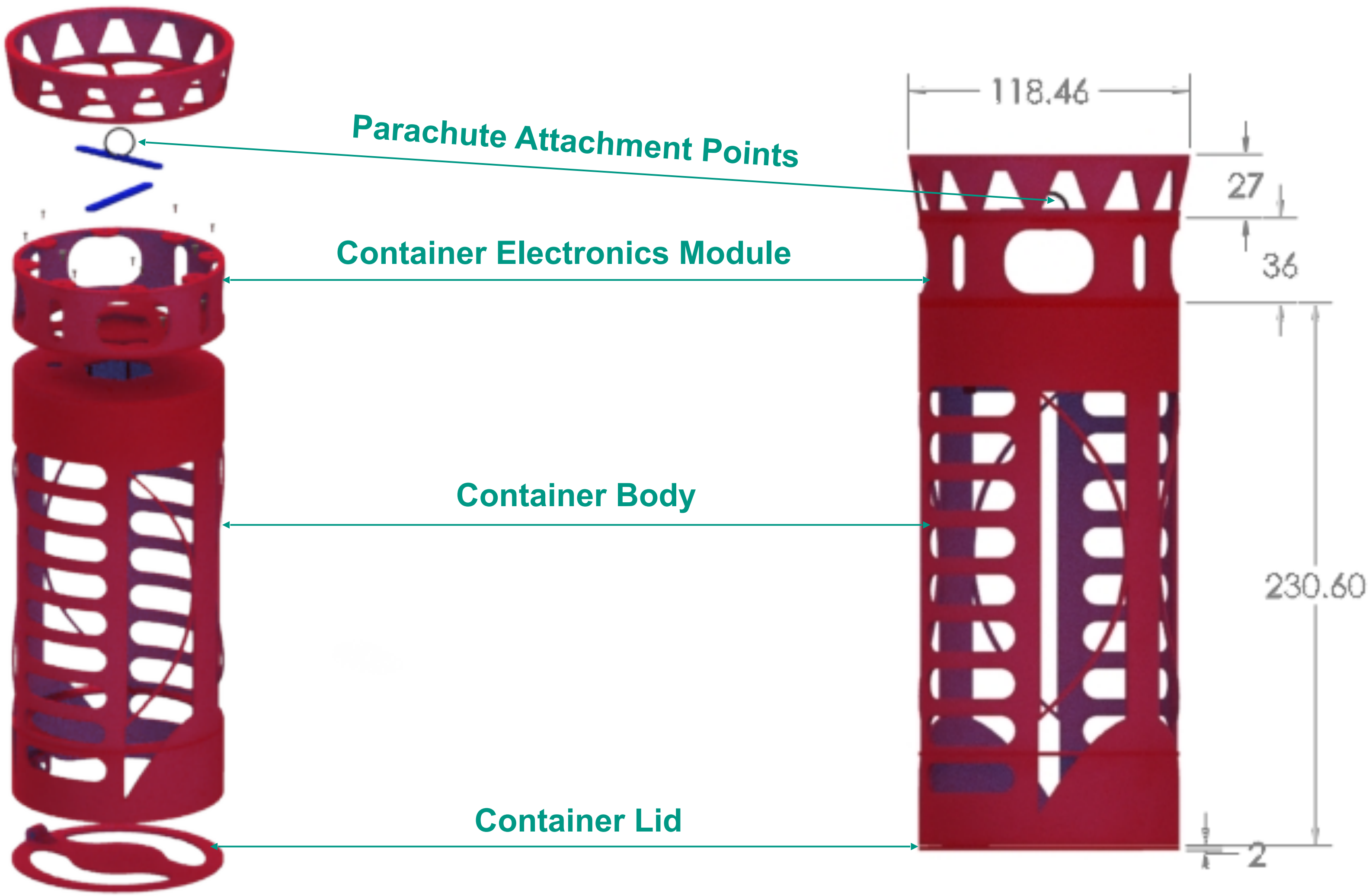
Phase 4: Auto-Gyro in action

The neodymium magnets will start attracting each other and with the container's obstruction gone, these magnets will lock thus opening the blades.

Physical Layout (CanSat)(1/9)

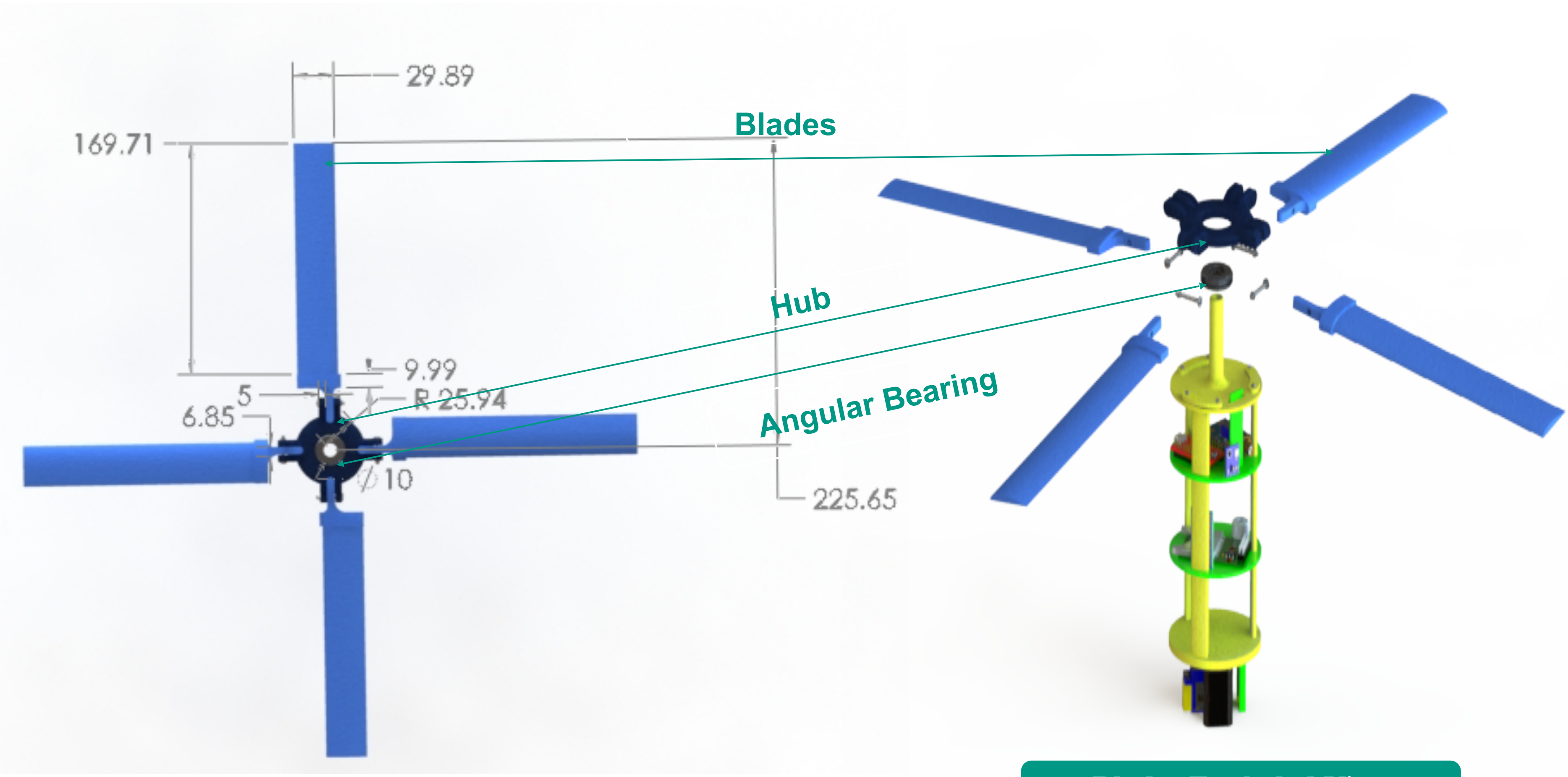


Physical Layout (Container)(2/9)



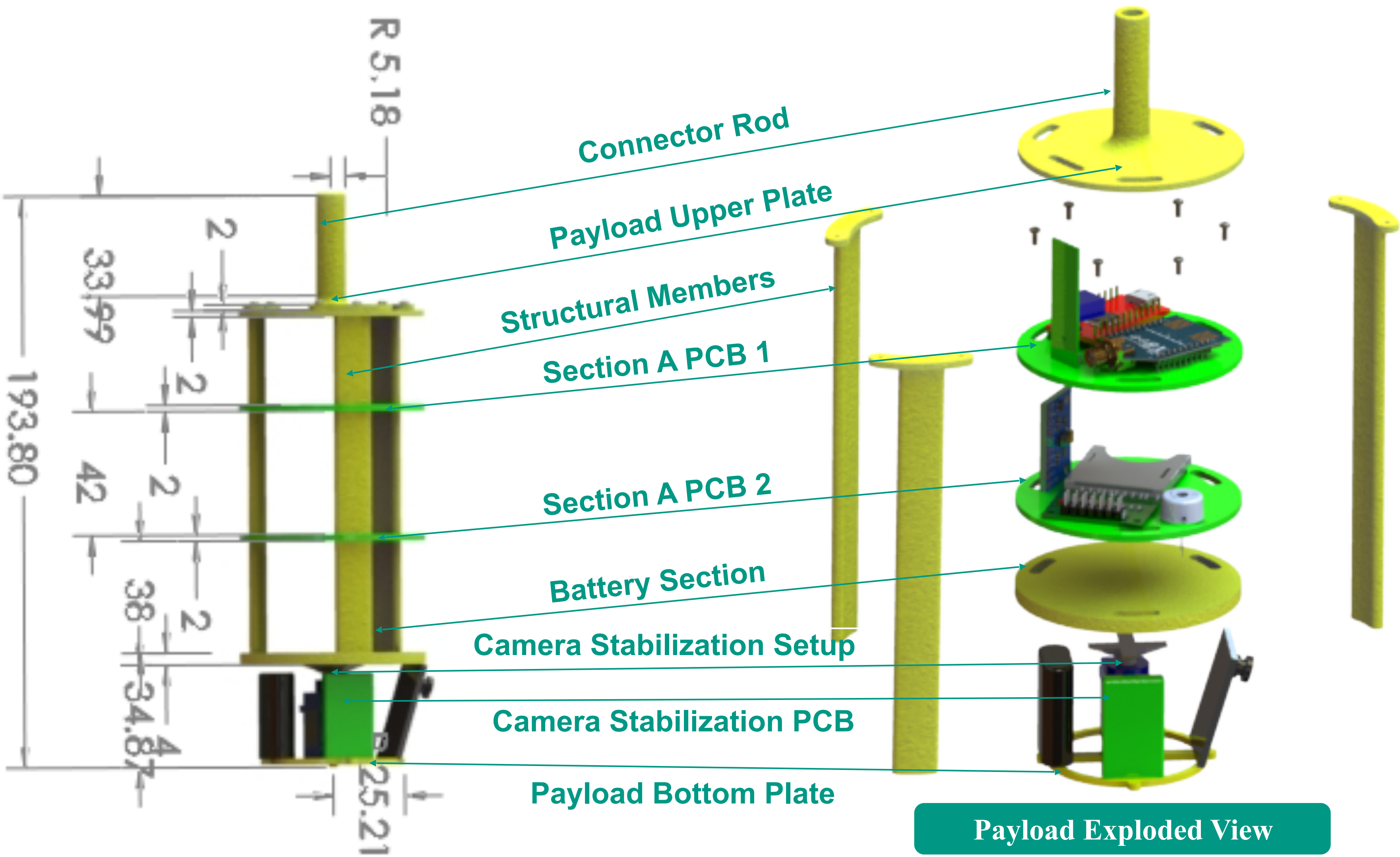
Container Exploded View

Physical Layout (Auto-Gyro)(3/9)

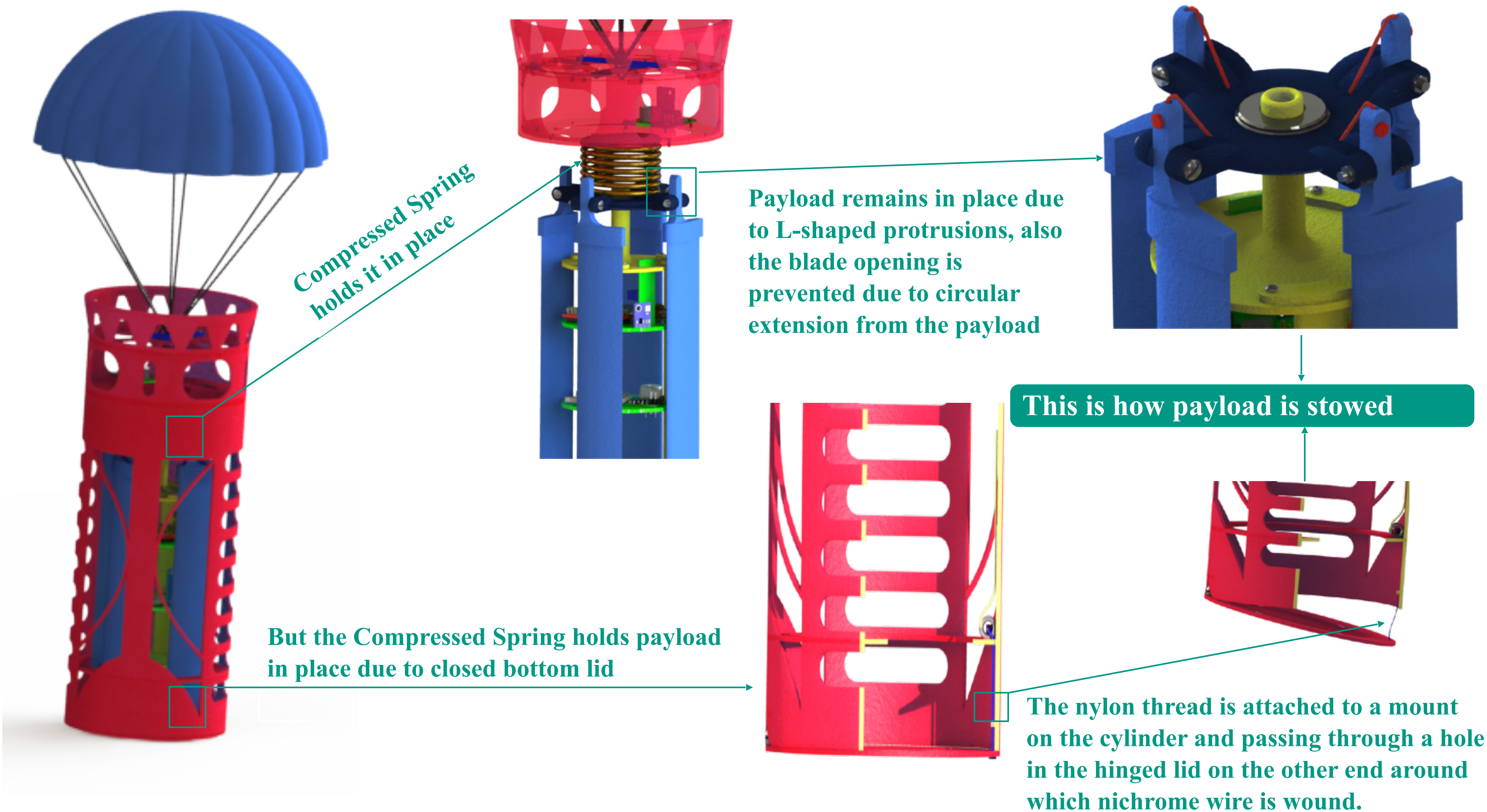


Blades Exploded View

Physical Layout (Payload)(4/9)



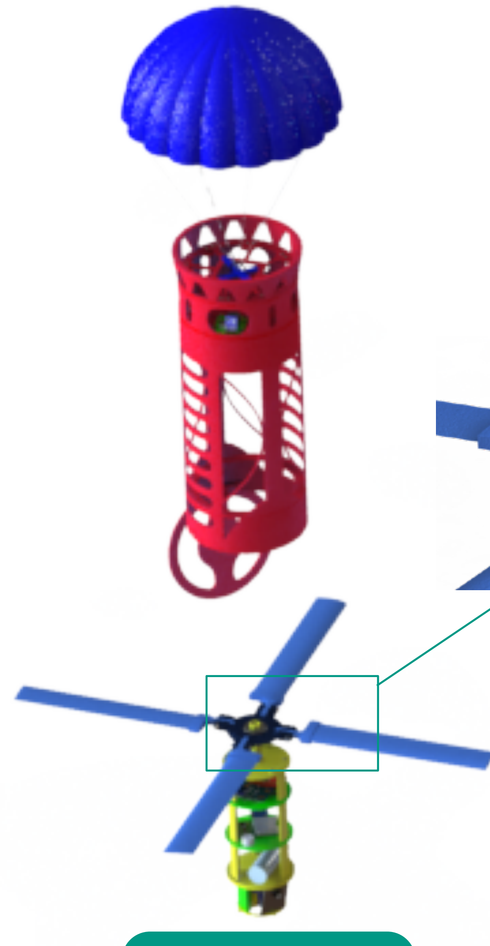
Physical Layout (Stowed Configuration) (5/9)



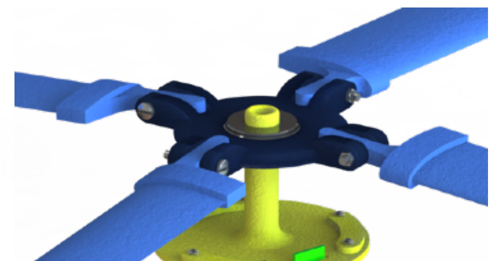
Physical Layout (Deployed Configuration) (6/9)

Parachute Deployment at launch

Transition from Stowed to Deployed

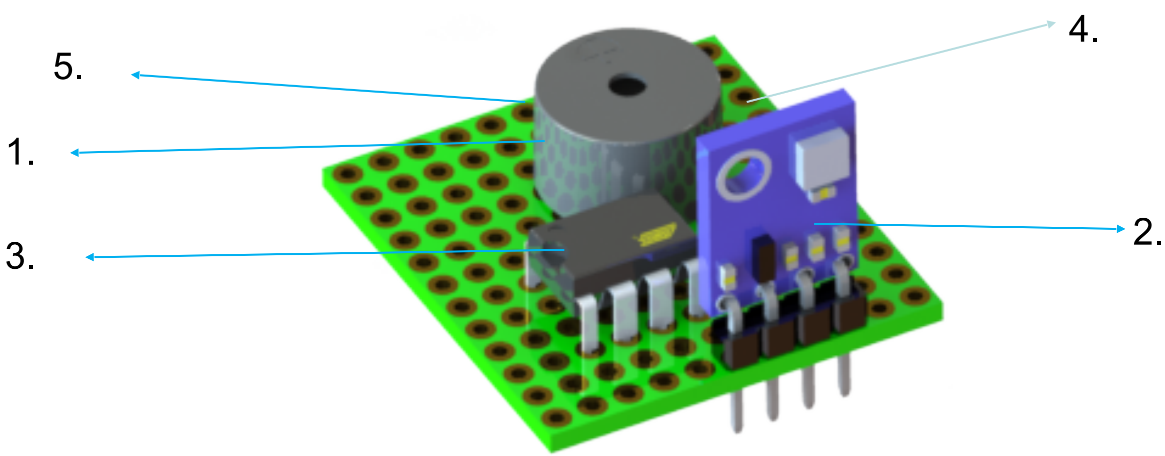


Payload Release



Auto-Gyro Close-Up

Container Electronics



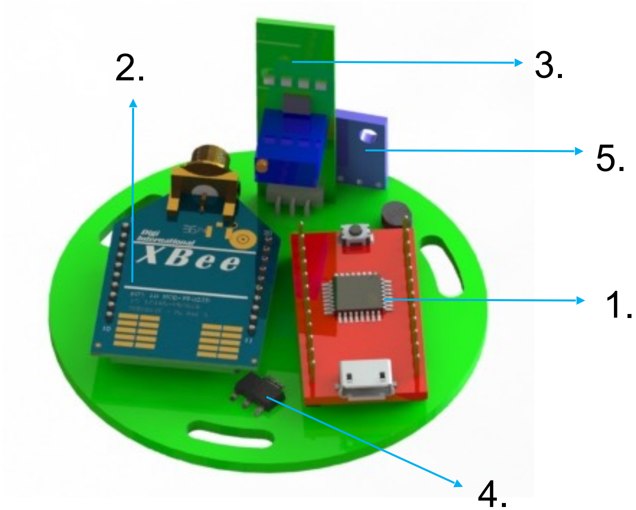
S.No	Part	Dimensional Layout (mm³
1	ATtiny85	9.27 x 6.35 x 3.40
2	BMP280	19 x 18 x 3
3	Buzzer	23.6 x 16
4	TIP120 BJT	16.5 x 10.6 x 4.8
5	LM1117 LDO	7.3 x 6.7 x 1.7

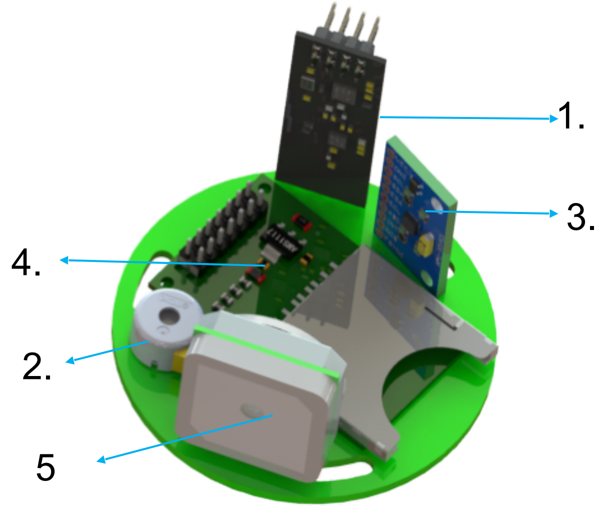
Physical Layout (Payload Electronics) (8/9)

Payload PCB 1

SECTION – A

Payload PCB 2





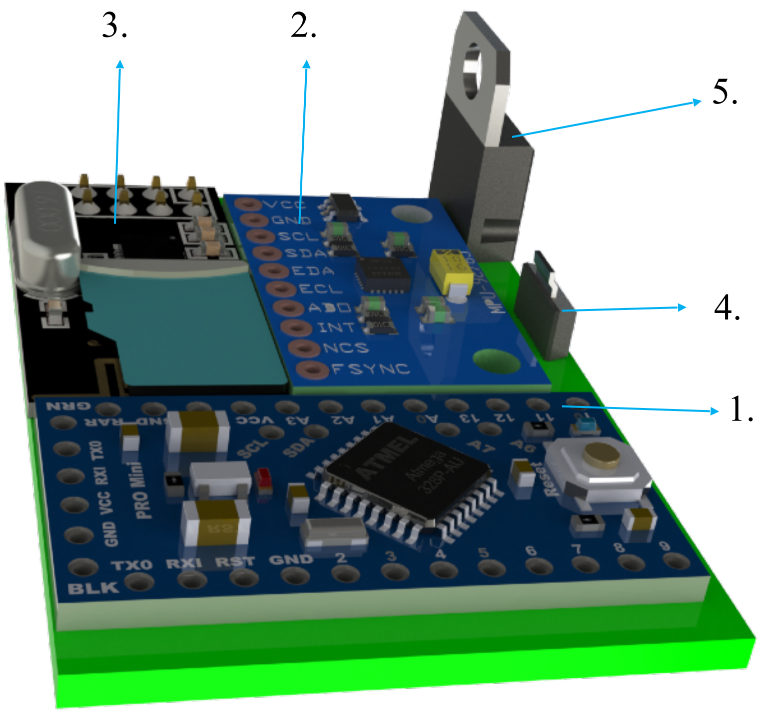
S.No	Part	Dimensional Layout
1	Sparkfun SAMD21 Mini	18 x 33
2	Xbee-Pro S2C	27.61 x 24.38
3	AH44E	11.3 x 35.5
4	LM1117 LDO	7.3 x 6.7
5	BMP280	19 x 18

S.No	Part	Dimensional Layout (
1	NRF24L01	28 x 15
2	Buzzer	23.6 x 16
3	MPU9250	22 x 17
4	SD Card Shield	25 x 24
5	GPS UBLOX-NEO6m	22 x 30

Physical Layout (Payload Electronics) (9/9)

SECTION – B (Camera Stabilization)

Camera Section PCB 1



S.No.	Part	Dimensional Layout (mm²)
1	Arduino Pro Mini	18 x 33
2	MPU9250	22 x 17
3	NRF24L01	28 x 15
4	LM1117 LDO	7.3 x 6.7
5	LM7805 LDO	16.5 x 10.6

Payload is divided into 2 sections, Section A: Telemetry Section and Section B: Camera Stabilization Section

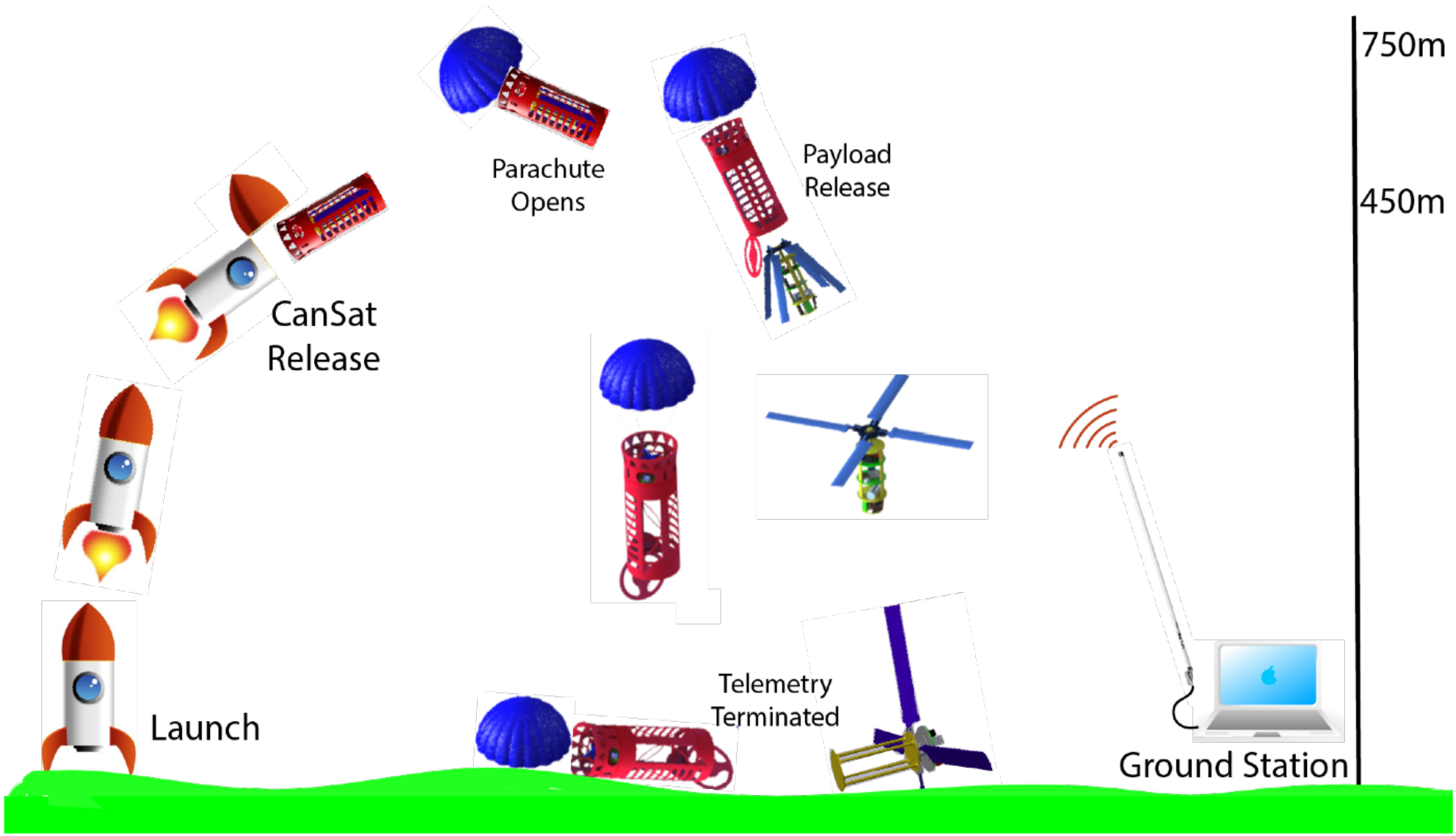
System Concept of Operations (1/3)

Pre-Launch	Launch	Rocket Separation+ Parachute Deployment	Payload Release
• All mechanical parts are checked • All circuits are checked • Functioning of sensors and telemetry is checked • CanSat body is checked for protrusions or damages	• CanSat electronics is switched ON • CanSat is placed safely in the rocket payload section. • A final system check is done	• The CanSat starts sending telemetry data • The FSW is active and logging data • At apogee, the rocket separates violently and parachute is deployed.	• At 450 m, payload is released using nichrome burning setup • The payload orients itself downwards leading to stable equilibrium using auto-gyro design.

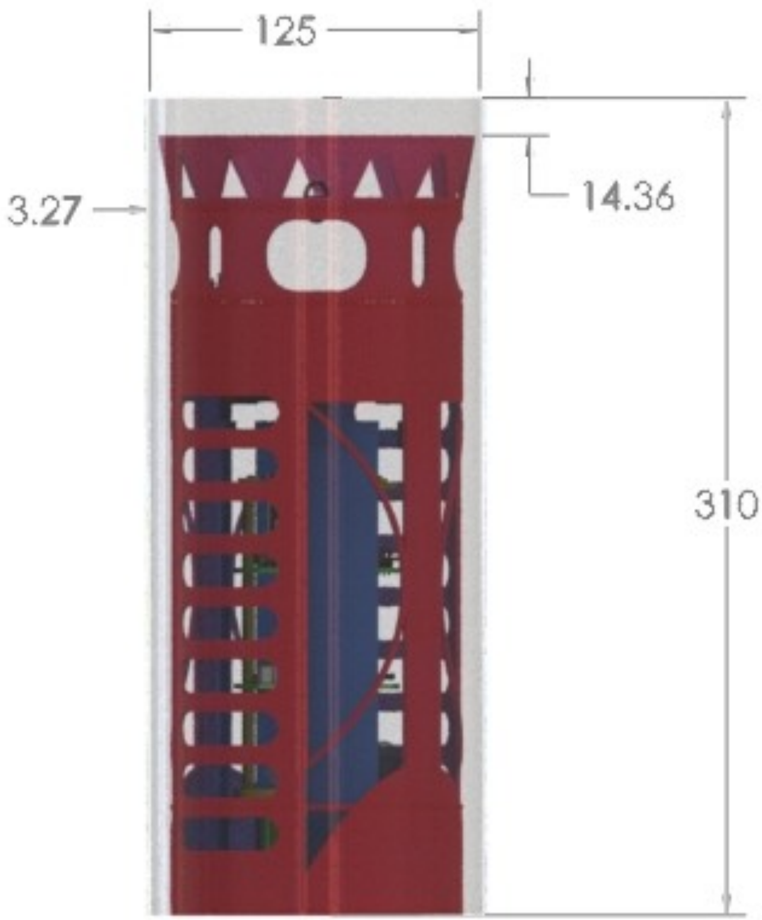
System Concept of Operations (2/3)

Payload Descent with Auto-Gyro	Container Descent with Parachute	Landing	Recovery + PFR
• Auto-Gyro and camera are operational. • The payload sends telemetry data for descent • Velocity tending to terminal is obtained between 10 – 15 m/s.	• Container descends with parachute • The velocity tending to terminal is obtained between 5 – 10 m/s.	• The payload telemetry is stopped and the audio beacons on both container and payload are activated to aid in recovery at < 5m.	• The container and payload are located and the data card is retrieved from the camera • The data is saved in the desired format at the GCS • The PFR is prepared and presented

System Concept of Operations (3/3)



Launch Vehicle Compatibility



*** All dimensions are in mm.**

	Height (mm)	Width (mm)
Cylindrical Envelope	310	125
CanSat (Payload + Container)	295.64	118.46
Tolerance	14.36	6.54

- ❖ CanSat and payload will be tested by performing during rocket testing.
- ❖ Height clearance to accommodate parachute at the top which requires a packing of 25 mm.
  (Total height of parachute module = 27 mm)
- ❖ No sharp protrusions.
- ❖ Fit Test is yet to be done.

Sensor Subsystem Design

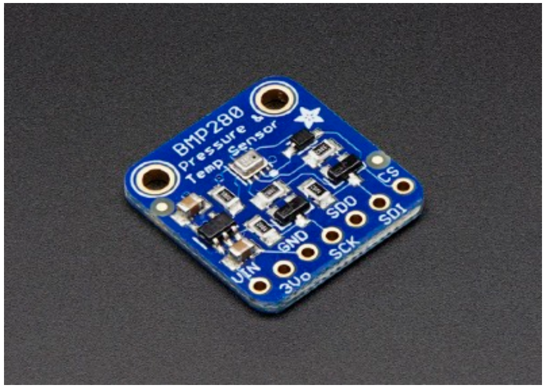
Divya Tiwari

Sensor Subsystem Overview

S.No.	Sensor Name	Purpose	Sensor Utilized	Quantity	Description
1	Pitch and Roll Sensor	To measure pitch and roll of the CanSat.	**MPU-9250**	x2	Returned values include: accelerometer and gyroscope readings in x, y and z axis. Second one is used for camera stabilisation setup.
2	Air Pressure Sensor	To measure air pressure, and Altitude of Cansat	**BMP - 280**	x2 (Science Payload + Container)	Calculation of altitude using the relationship between pressure and altitude. While pressure and temperature served as raw data by sensor.
3	Temperature Sensor	To measure temperature	**BMP - 280**	x1 (Science Payload)	Calculation of external temperature.
4	GPS Sensor	To obtain GPS data.	**U-blox NEO-6M**	x1 (Science Payload)	Returned values include: Time, latitude, longitude, altitude and number of satellites
5	Auto-Gyro Blade Spin Rate Sensor	To obtain blade spin rate	**Hall Sensor AH44E**	x1 (Science Payload)	Calculation of spin rate by summation of gauss entries above threshold.
6	Voltage Sensor (ADC + Voltage Divider)	To measure battery voltage	**Resistor Network + 12 bit ADC**	N.D. (Science Payload)	To obtain the current system battery voltage.
7	Camera Sensor	Video recording	**Piqancy Ultra HD Camera**	x1 (Science Payload)	Bonus requirement: To video record the flight recording.

Payload Air Pressure Sensor Trade & Selection

Model Number	Interface	Pressure range (hPa)	Size (mm^3)	Weight (gm)	Resolution (hPa)	Supply Voltage (V)	Price ($)
BME 280	I2C, SPI	300-1100	19 x 18 x 3	1.2	± 1	1.6 - 3.6	25
MPX 4115	I2C	150-1150	10.7 x 10.7 x 3	4	± 1.5	4.85 - 5.35	22.58
BMP 280	**I2C**	**300-1100**	**19 x 18 x 3**	**1.3**	**± 1**	**1.71 - 3.6**	**3.5**



BMP - 280

Selected Air Pressure Sensor, BMP280, as it offers:

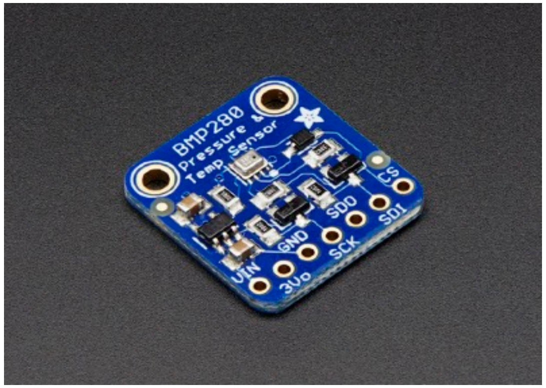
1. Works at 3.3V, optimal for the design framework.
2. High Resolution and low weight, at low cost.
3. Offers sleep mode, reduction in power in pre-launch state.

Payload Air Temperature Sensor Trade & Selection

Model Number	Interface	Range (°C)	Size (mm^2)	Weight (g)	Accuracy (°C)	Supply Voltage (V)	Price ($)
BMP 280	**I2C**	**(- 40) – (+ 85)**	**19 x 18**	**1.3**	**± 1**	**1.71 - 3.6**	**3.5**
BMP 085	I2C	300 – 1100	16.5 x 16.5	1.6	± 2.5	1.6 - 3.6	19.95
LM 35	Analog	(- 55) – (+ 150)	4.69 x 4.69	1	± 0.5	4 - 30	0.65

Selected Air Temperature Sensor, BMP280, as it offers:

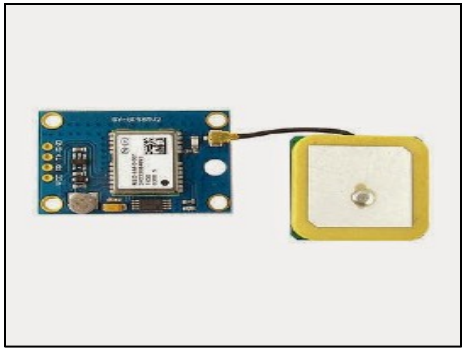
1.Optimal operation voltage to framework.
2. LM 35 not utilised as the job of pressure and temperature can be clubbed in one device, thus reducing weight, cost and total pins utilised.



BMP - 280

GPS Sensor Trade & Selection

Model	Interface	Size(mm³)	Weight(g)	Accuracy (m)	Power Ratings	Other	Cost($)
BN-220	UART	22 x 20 x 6	5.3	0.1	5mA-5.0V	Cold Start : 26s Warm start : 25s	9.11
Quectel MC60	UART	18.7 x 16 x 2.1	1.3	0.4	1.2mA-5V	Cold Start:35s Hot Start:1s	8.35
U-Blox Neo-6M*	**UART**	**22 x 30 x 4**	**12**	**2.5**	**47mA – 3.3v**	**Cold Start: 27s Hot Start: 1s**	**11.09**



U-Blox Neo-6M

Selected GPS Sensor: U-blox NEO-6M
1. Very easy to use.
2. Easily available.
3. Separate antenna relaxes PCB design.

***GPS receiver will be used in NMEA 0183GG format**

Payload Power Voltage Sensor Trade & Selection

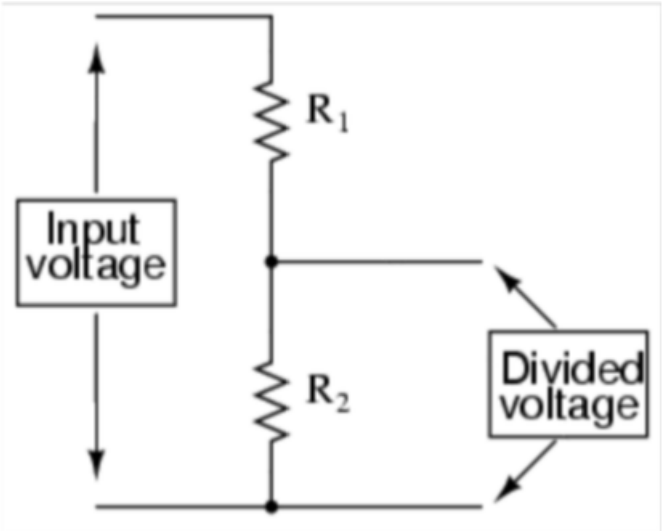
Sensor	Interface	Resolution (mV)	Weight (g)	Size (mm²)	Cost ($)
Voltage divider circuit	**ADC port**	**1.61**	**Negligible**	**2 x Resistor Size**	**1**
M A X 1 7 0 4 3 G+U	I2C	1.25	1g	2 x 3	3

Reasons for selection of Voltage Divider Circuit:

1. Negligible implementation cost.
2. Utilises internal ADC of SAMD, which offers resolution of 12 bits.
3. Easier implementation.

$$V_{obs} = \frac{R_2}{R_1 + R_2} V_{bat}$$

$$R_1 R_2 \textit{are chosen such that} V_{obs} \leq 3.3V$$



Pitch and Roll Sensor Trade & Selection

Model Number	Interface	Acceleration Range (g)	Size (mm2)	Weight(g)	Accuracy	Operating Voltage (V)	Price ($)
BNO055	I 2 C , UART	±16	10x13	3	+/- 3 °/sec	2.4-3.6	11.81
ADXL335	Analog	±3.6	9x11	2.8	+/- 7 °/sec	1.8-3.6	3.19
MPU-9250	**I2C**	**±16**	**17x10**	**1.5**	**+/- 5 °/sec**	**2.4–3.6**	**2.83**

MPU-9250

Reasons for selection of **MPU 9250**:

1. DMP (Digital Motion Processor): Clubs accelerometer and gyroscope data to minimize error inherit in each.
2. Digitally-programmable low-pass filter
3. Low Sleep mode current

Size. interface, res

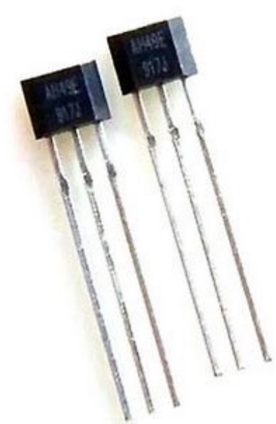
Sourav Bhattacharjee
Done

Blade Spin Rate Sensor election (1/2)

		Size (mm2)	Interface	Resolution (°)	Weight(g)	Cost($)
AH44E	**Hall Sensor IC**	**3.10 x 4.17**	**Digital**	**90**	**<1**	**1.54**
PT333-3C	Infra-red Sensor (Photo-transistor)	5.9 X 5.9	Digital	90	<1	0.70

Reasons for selection of **AH44E**, hall sensor:

1. Low Noise Output, thus virtually eliminates the need for filtering.
2. Extremely fast response time (200ns).
3. Current consumption of 3.5mA at Vcc, 5V, thus lower power requirements.

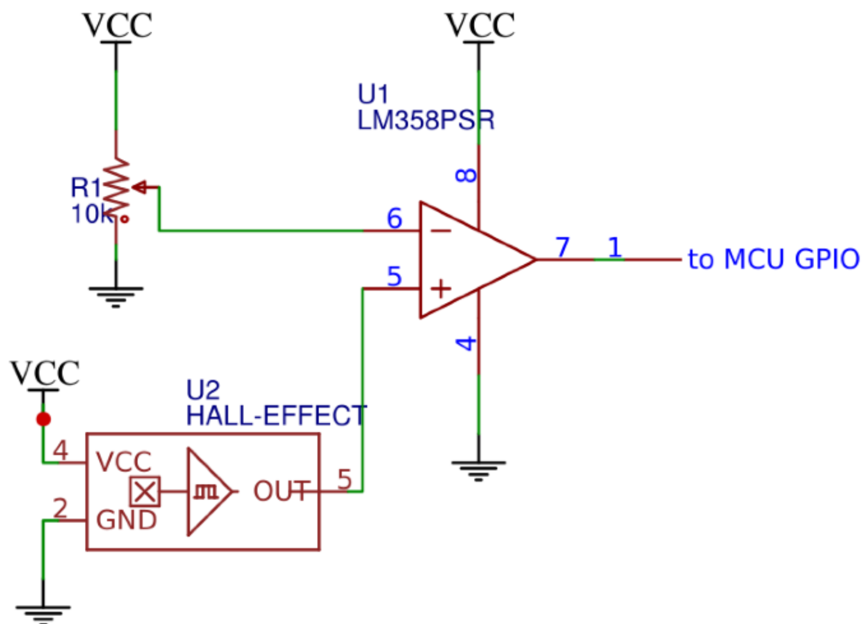


AH44E

Auto-gyro Blade Spin Rate Sensor Trade & Selection (2/2)

- A magnet is attached to each wing of the auto gyro.
- The hall sensor is mounted just below the magnets.

Hall sensor being used to measure blade spin rate



Schematic of hall sensor as Auto Gyro Blade Spin Rate Sensor

- The circuit generates a pulse each time the magnet passes over the sensor.
- The MCU counts these pulses and calculates RPM of the Auto Gyro.

Bonus Camera Trade & Selection

Name	Weight(g)	Power	Resolution	FPS	Interface	Supply Voltage (V)	Price($)
Miniature TTL Serial JPEG Camera	26	75 mA x 5 V	640 x 480	30	TTL	3.3	15.76
Pixy CMUCam5	27	140 mA x 5 V	1280 x 720	50	I2C, SPI, UART	5	40.7
OV7670	25	20 mA x 3.3 V	640*480	30	I2C	2.45-3.0	4.09
Piquancy Ultra HD Camera	**20**	**20 mA x 3.3 V**	**1280 x 720**	**30**	**N D (Write)**	**3.3**	**11.21**

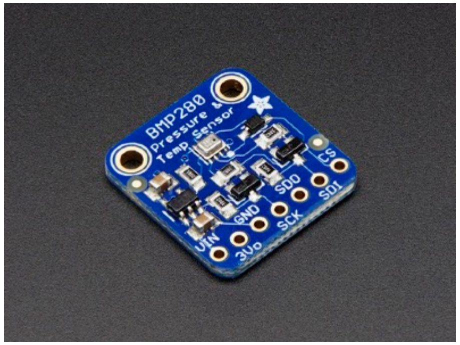
Reasons for selection of **Piquancy Ultra HD Camera**:

1. Simple interface
2. Light camera with high resolution
3. Resolution and megapixel values are suitable for the competition requirements
4. Integrated SD card

Piquancy Ultra HD Camera

Container Air Pressure Sensor Trade & Selection

Model Number	Interface	Pressure range (hPa)	Size (mm³)	Weight (g)	Accuracy (hPa)	Supply Voltage (V)	Price ($)
BMP 280	**I2C**	**300-1100**	**19 x 18 x 3**	**1.3**	**+/-0.12**	**1.71-3.6**	**3.5**
BME 280	I2C and SPI	300-1100	19 x 18 x 3	1.2	±1	1.6-3.6	25
MPX 4115	I2C	150-1150	10.7 x 10.7	4	±1.5	4.85-5.35	22.58



BMP - 280

Selected Air Pressure Sensor, BMP280, as it offers:

1. The very low offset temperature coefficient results in a low temperature drift making it highly precise.
2. Built in IIR filter minimizes short term disturbances in the output data.
3. Multiple modes of operation make this sensor highly flexible for saving energy and providing precise measurements.

Descent Control Design

Riyanshu Motalaya

Descent Control Overview (1/2)

Descent Control System

Descent control system consists of three phases:

Combined descent of Container and Payload

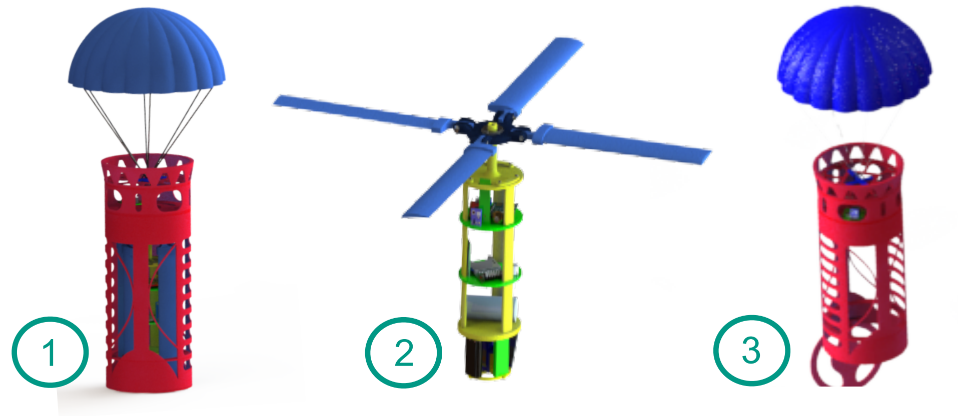
Post separation from the rocket payload and container descent together and it is controlled by the parachute. It should reach a terminal speed of 20 5 m/s

Descent of Payload post separation

Post separation auto-gyro comes into action and the descent is controlled mainly by autorotation of the blades and it should achieve a terminal speed of 10-15 m/s

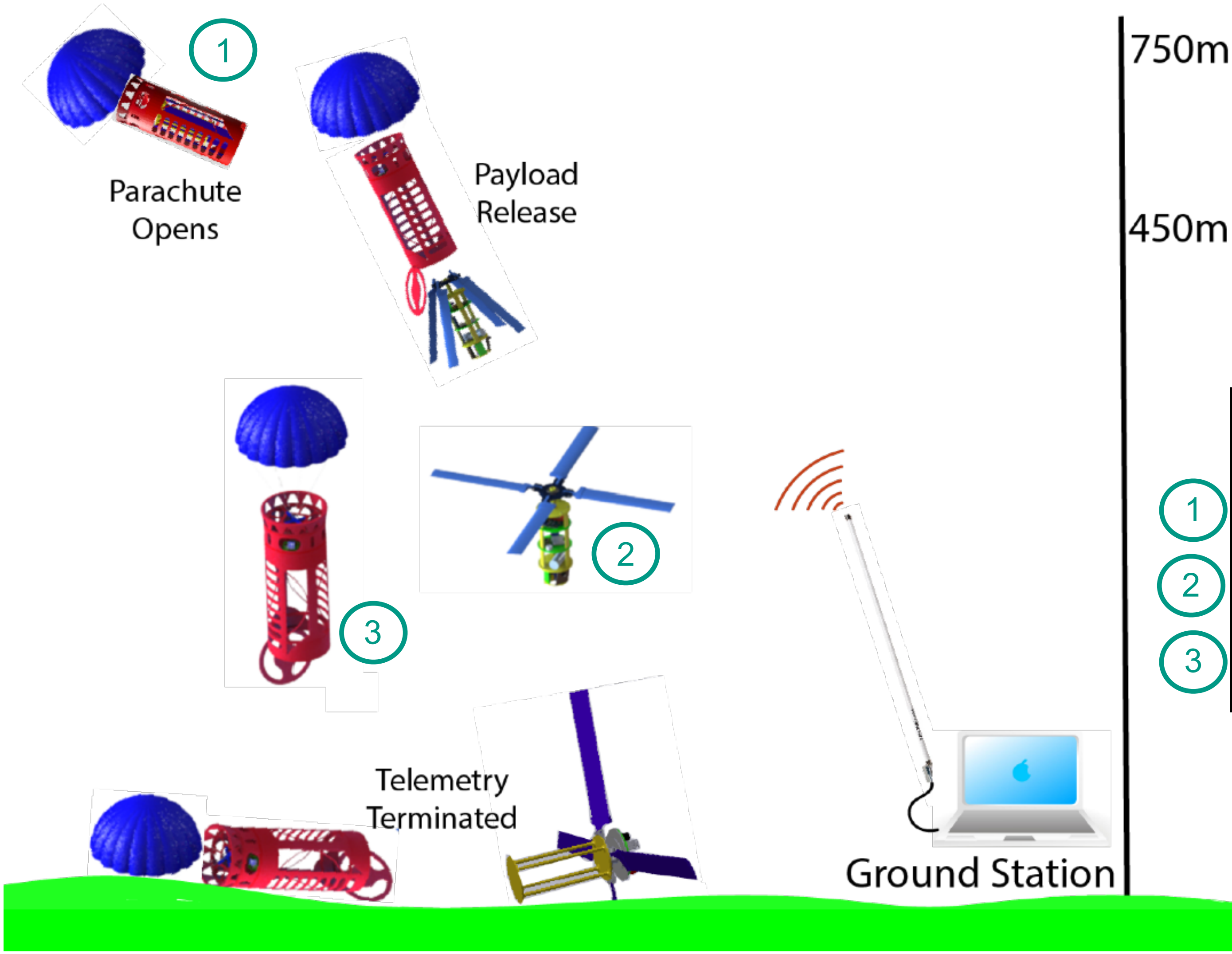
Descent of Container post separation

Parachute controls the descent of container post payload separation



Descent Components	Position
Parachute	Top of CanSat (when in nadir direction)
Parachute Tab	To connect O-ring with the parachute mount
O-ring	To connect all parachute shroud lines
L-shaped protrusions	Container main body top to restrict payload movement inside container
Circular Ring	Inside container to prevent payload flapping in stowed configuration
Angular bearing	Payload Top

Descent Control Overview (2/2)

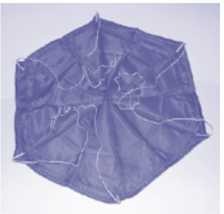


	Velocity (m/s)	Time of Flight (s)
1	16.75	22.08
2	13.29	32.12
3	9.76	46.77

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

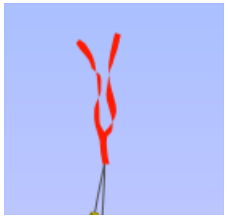
Pre-Payload: Passive Stowed Payload Descent Rate Control from Apogee to 450 m

Shape	Diameter (cm)	Drag Coefficient	Mass (g)	Price ($)	Descent Rate (m/s)
Hexagonal	**22.86**	**0.8**	**16**	**$21**	**16.75**
Flat Round Canopy	24	0.45	35	$30	15.21
Parachute (with 5% spill hole)	23.43	0.85	38	$34	15.89
Streamers	40	0.6	40	$25	12.23



Hexagonal

Hemispherical



Streamers

Flat Round Canopy

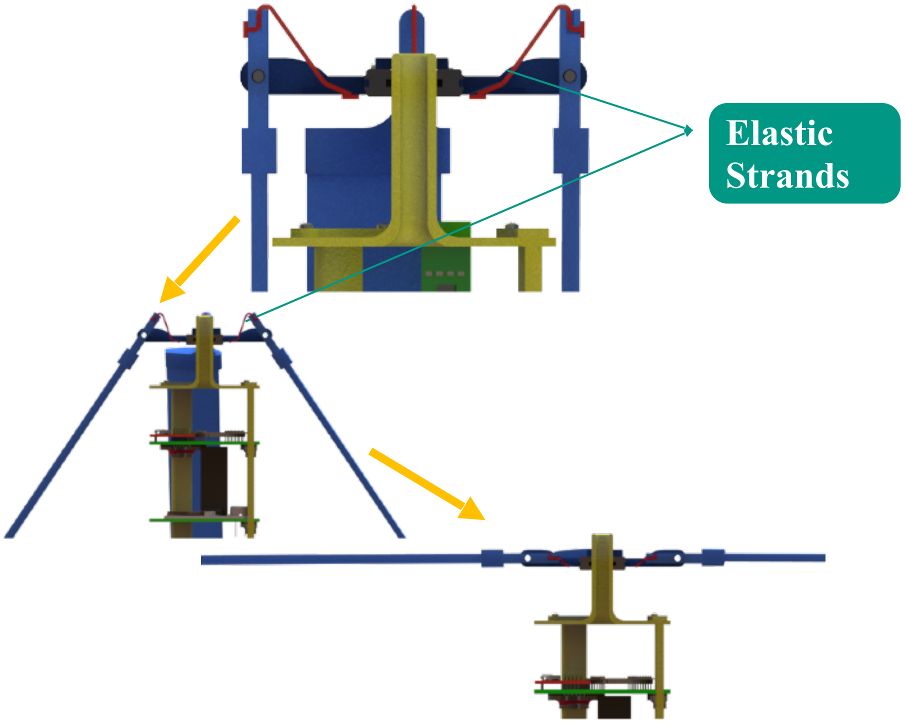
Requirements for Passive Stability:

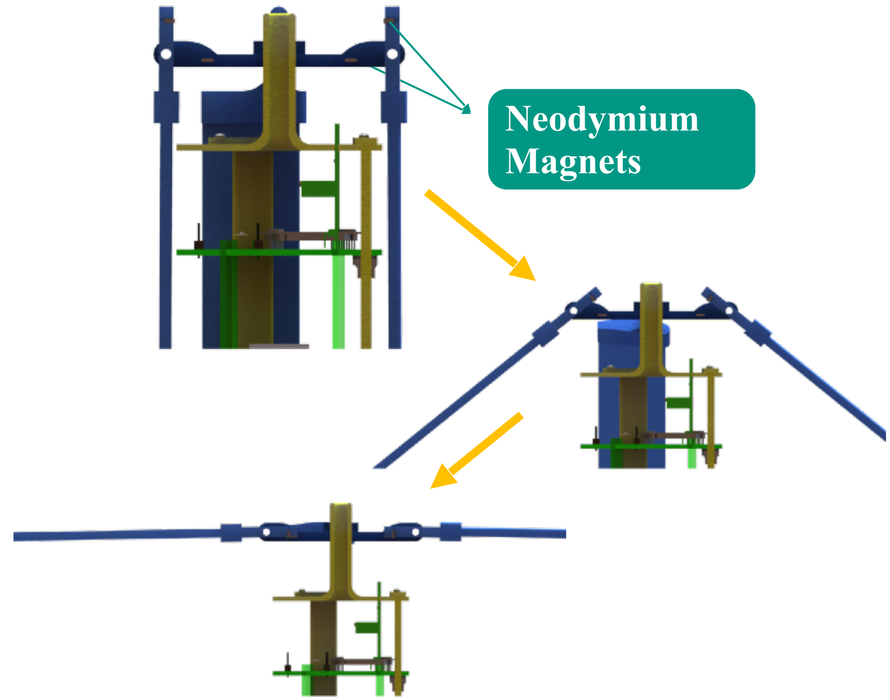
Optimal Drag: Higher Drag Coefficient
Lower Total Mass
Lower Work Force
Optimal speed (16.75 m/s) to reduce stress and wind drift potential
Compact: Less space for packing
Controllable

We have selected hexagonal parachute as it meets all the requirements in the left.

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

Post-Payload: Passive Deployed Payload Descent Rate Control from 450 m to ground





Design Strategy A: Blade Opening using Elastic Strands

Elastic strands and air pressure will force open the blades

Design Strategy B: Blade Opening using Neodymium Magnets

During separation from payload, the neodymium magnets will lock each other due to strong magnetic attraction and force open the blades.

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

Passive Deployed Payload Descent Rate Control from 450 m to ground

	Design Strategy A: Blade Opening using elastic strands	Design Strategy B: Blade Opening using neodymium magnet
Pros	• Self-sustainable action: Elastic strands will force open the blades whatever maybe the direction of release of payload • More reliable • Cost-effective	• Neodymium magnets will ensure good locking and no flapping.
Cons	• Excessive temperature on launch day can affect the elasticity of the strands.	• More weight • Hall sensor magnets can interfere with magnetic field lines of neodymium magnets.

Design Strategy	Quick Action	Self-sustainable action	Blades Flapping	Weight	Cost	Total (50)
A	8	9	6	8	9	40
B	7	7	9	6	7	36

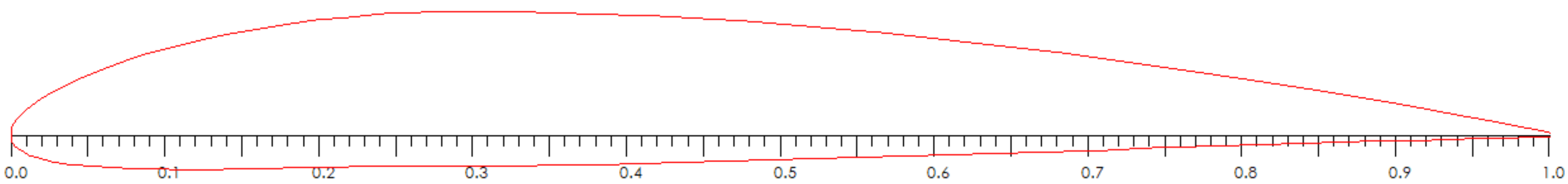
Reasons for selection of **Design Strategy A**, Blade opening using elastic strands :

1. More reliability due to self-sustainable action
2. Light-weight and cost-effective

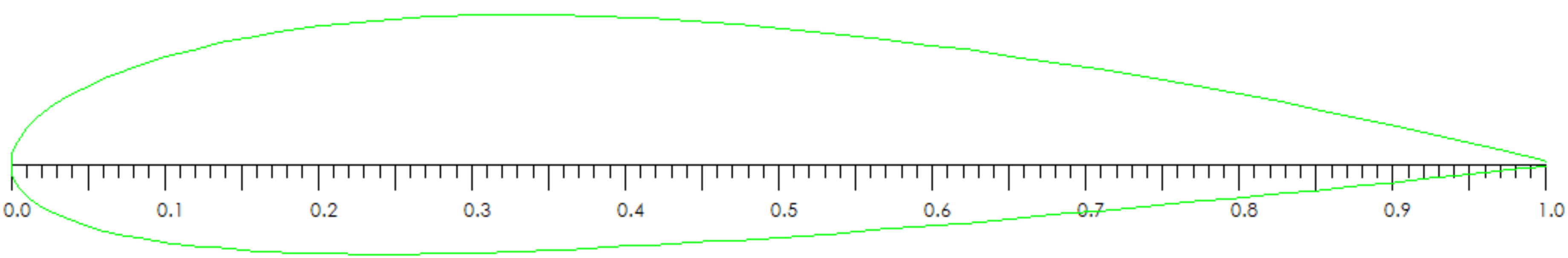
(0 to 10)
0-Least, 10-Most

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

Passive Deployed Payload Descent Rate Control from 450 m to ground (Airfoil Design)



Design Strategy A: Clark Z



Design Strategy B: NACA 2415

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

Passive Deployed Payload Descent Rate Control from 450 m to ground (Airfoil Design)

	Design Strategy A: Clark Z	Design Strategy B: NACA 2415
Pros	❖ Less rotational drag ❖ High stalling point ❖ Due to flat bottom, better easy of manufacturability ❖ Low pitching moment	❖ Thick airfoil (more structural strength)
Cons	❖ Thin airfoil (Weak, can break)	❖ High pitching moment ❖ Difficult to manufacture ❖ Low stalling point

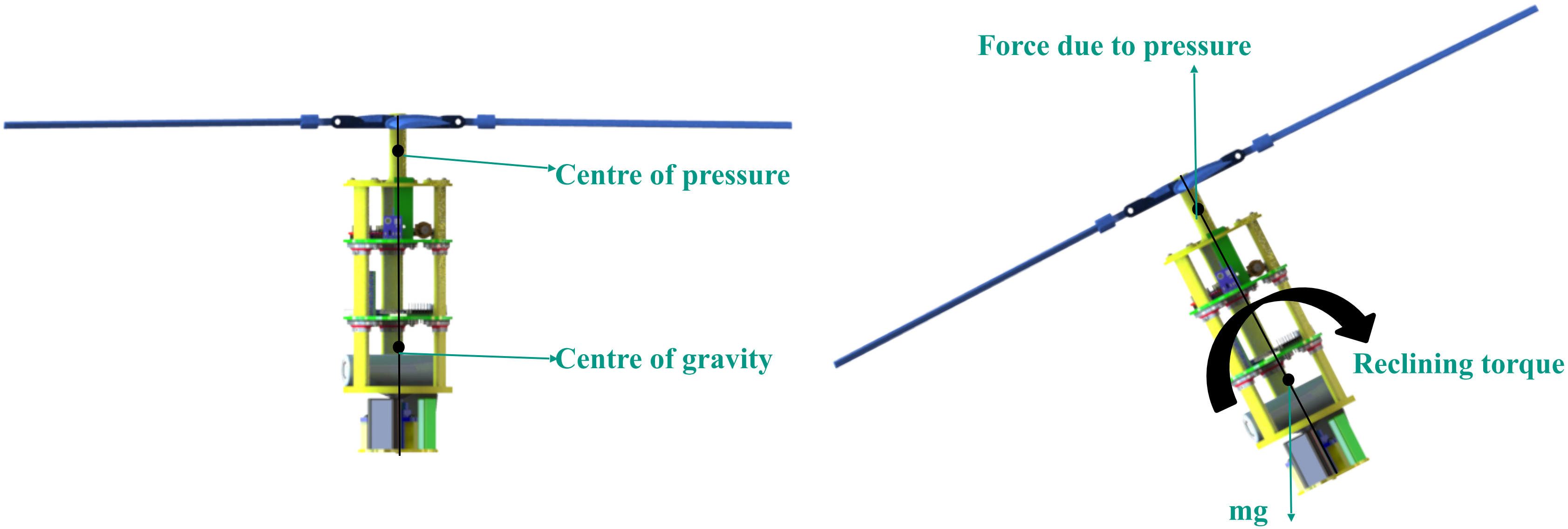
Design Strategy	Stalling Point	Drag	Pitching Moment C_m	Ease of fabrication	Structural Strength	Total (50)
A	9	8	8	8	7	40
B	8	7	7	7	9	38

Reasons for selection of **Design Strategy A**, Clark Z Airfoil :

❖ Ease of fabrication
❖ Provides sufficient drag

(0 to 10)
0-Least, 10-Most

Design Strategy A: Passive Payload Stability Control using COP above COG concept

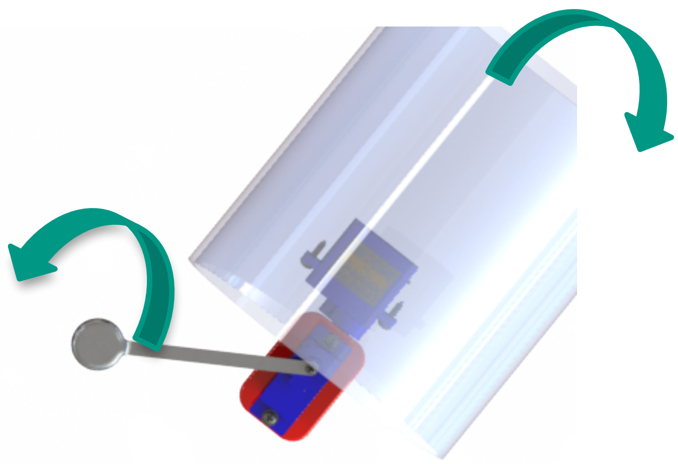


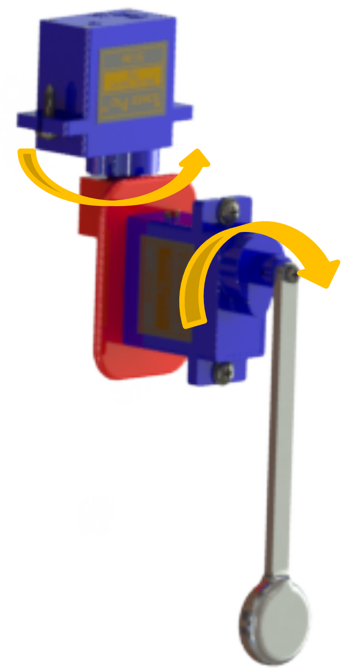
- Components in the payload are arranged such that the Centre of gravity (COG) is very low
- Centre of Pressure (COP) is present almost in the plane of the blades
- Due to this condition, a reclining torque is applied on the container when there is a tilt from the nadir direction leading to stable equilibrium.
- This torque realigns the payload.
- Thus, nadir direction is always maintained.

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

Design Strategy B: Active Payload Stability Control with a Heavy Mass

- Two axis servo stabilization is provided for the payload with the help of two servo motors
- Heavy mass is connected to one of the servo so as to provide a negative torque to counter the effect of tumbling torque
- An ECU will be used to measure the roll, pitch and yaw of the system which will then be processed and sent to the servo to counter the effect of these moments.





Payload Descent Stability Control Strategy Selection and Trade (3/4)

	Design Strategy A: Passive stability control using COP above COG concept	Design Strategy B: Active stability control using a heavy mass
Pros	• More aerodynamically stable due to lower COG point (battery section and camera section are placed at the bottom) • Lesser Weight • Realigning torque due to high COP position	• Very stable • System remains stable irrespective of wind conditions
Cons	• Stability depends upon the wind condition • Reclining torque will produce damped harmonic motion	• More weight added • Since an ECU, 2 servo motors are required, more current is required. • Since it is electronically controlled taking values, sufficient lag will be produced.

Design Strategy	Effective Control	Ease of manufacturability	Reliability	Weight	Cost	Total (50)
A	9	9	7	9	9	43
B	8	6	9	5	5	33

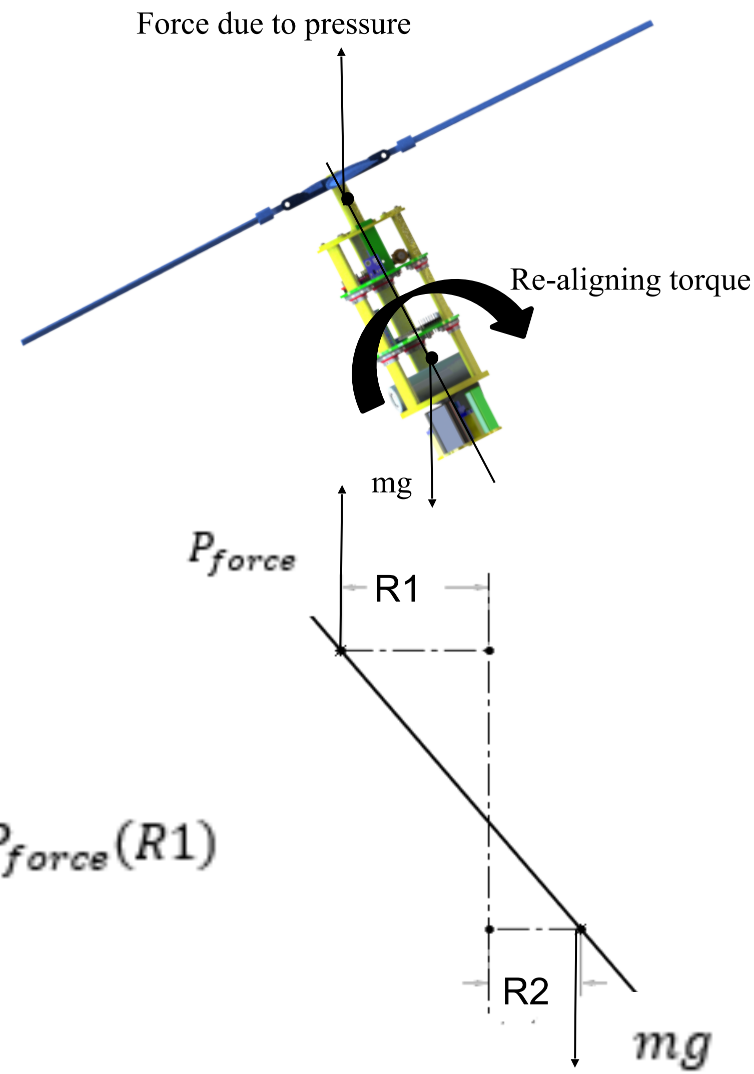
Reasons for selection of **Design Strategy A**, Passive Stability Control:
- ❖ Less weight, cheap
- ❖ No extra parts required to achieve stable equilibrium and hence, nadir direction
- ❖ More effective control

(0 to 10) 0-Least, 10-Most

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

Maintaining the NADIR direction

- COP is the point where the net aerodynamic force can be applied so as to inculcate the effect of a distributed force. It is the main point where all upward force is assumed to be applied(air resistance due to descend and rotation will provide a net upward force)
- CG is the point where the gravitational force can be applied to. This is the point where 'mg' force(downward force due to weight) is assumed to be applied
- CG was found to be below center of pressure which provides the re-aligning torque to the payload
- Also the simulation results for various tilt angles showed only a slight variation in the COP so irrespective of the tilt angle t will realign itself



$$Realligning\ torque = mg(R2) + P_{force}(R1)$$

Descent Rate Estimates (1/14)

Common Formulae

Where, = Drag force , = Coefficient of drag , = Air density (1.0959 kg/)
= Reference area (taken as Projected Area) , = Descent velocity
Solving the differential equations obtained from yields the results:

Where, v(t) = Descent velocity as a function of time
x(t) = Altitude as a function of time

Descent Rate Estimates (2/14)

Where, m = Mass of the body

g = Acceleration due to gravity (9.81m/)

T = Time of flight

= Altitude travelled

l = side length of the hemispherical parachute

Assumptions

- Vertical velocity component tends to zero post rocket-separation approximately at the altitude 700 m
- Air density at 30 and 350m in Stephenville is taken as the constant value throughout

Descent Rate Estimates (Container + Payload) (3/14)

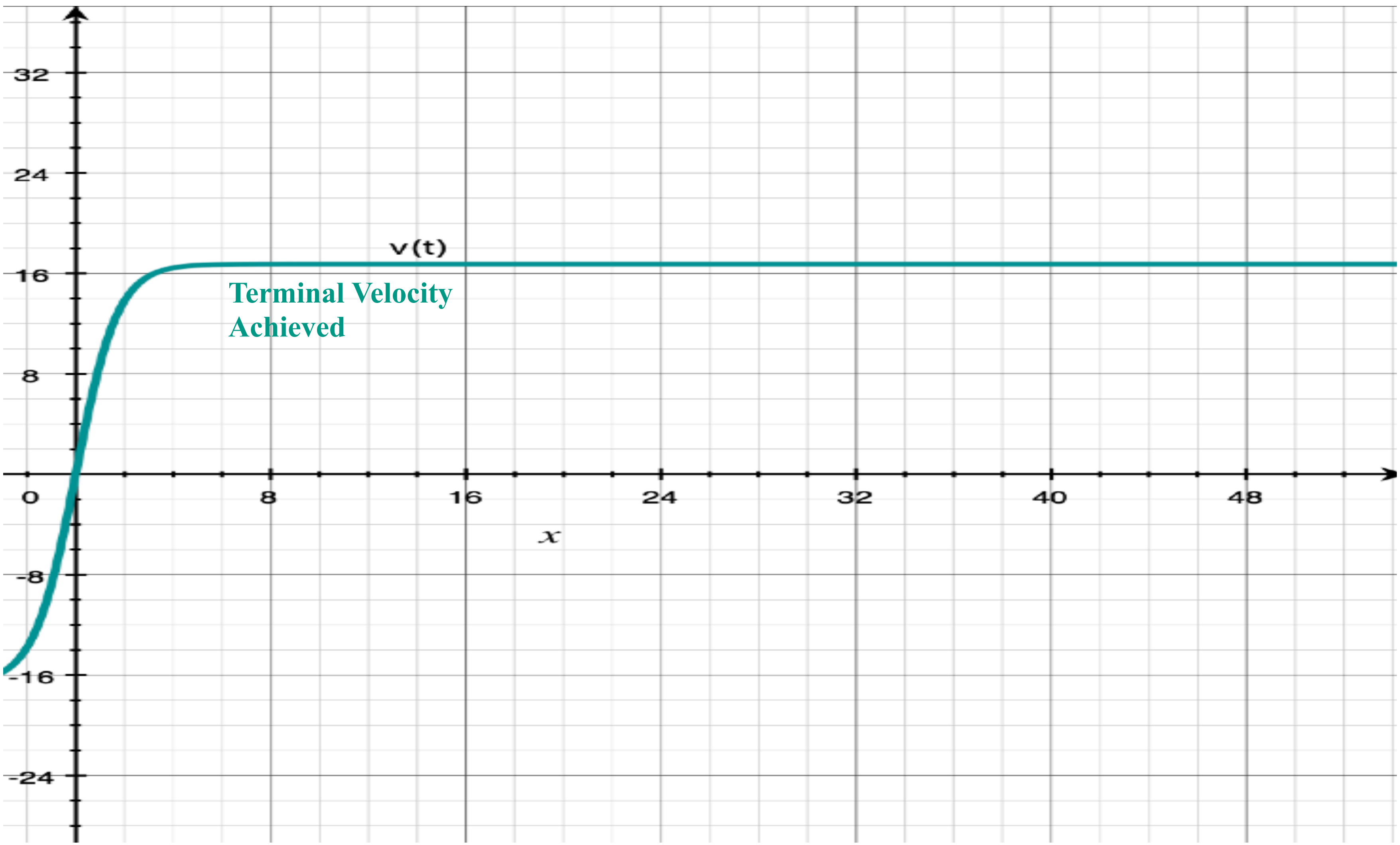
Descent Rate Estimation for the Container and Payload

- The time of flight from 700m to 450 m for the entire CanSat is obtained from the equation
- The velocity of the CanSat at 450 m after 22.08 s is obtained using v(t). Since rho is assumed constant, this value roughly coincides with the final velocity obtained from the drag force equation, i.e .

= 16.75 m/s

Here, m = 0.5 kg , A = 0.0399 , = 0.8 , = 350 m

Descent Rate Estimates (Container + Payload) (4/14)



Descent Rate Estimates (Container) (5/14)

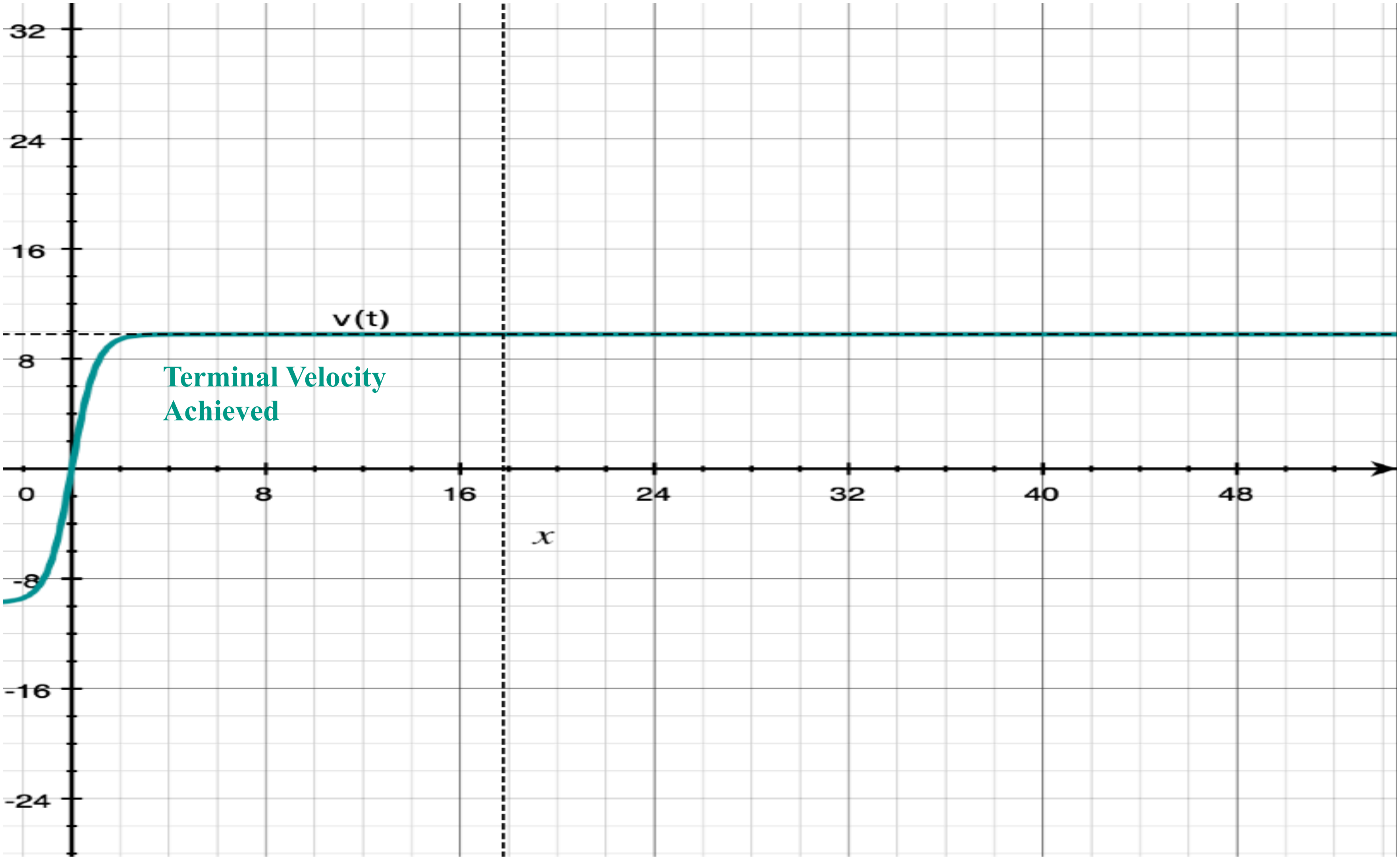
Descent Rate Estimation for the Container

- The time of flight from 450 m to ground for the Container is obtained from the equation
- The velocity of the body at 300m after 31.13 s is obtained using v(t). Since rho is assumed constant, this value roughly coincides with the final velocity obtained from the drag force equation. i.e.

= 9.76 m/s

Here, m = 0.17 kg , A = 0.0399 450 = ,0.8 = , m

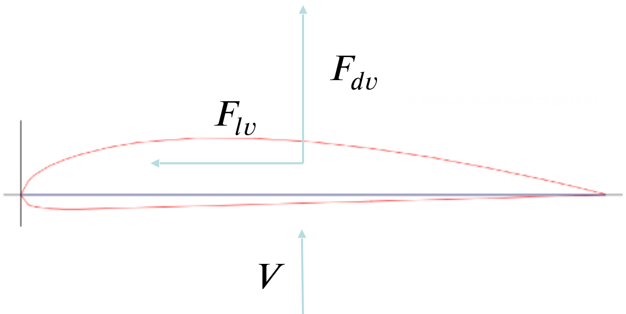
Descent Rate Estimates (Container) (6/14)



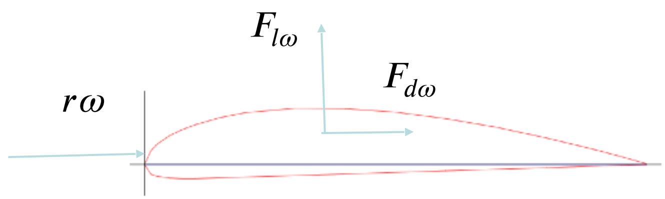
Descent Rate Estimates (Payload) (7/14)

Net Drag and Lift forces are divided into three components
- ❖ Lift and drag due to descent on the auto gyro
- ❖ Lift and drag due to auto rotation on the auto gyro
- ❖ Drag force on body due to descent

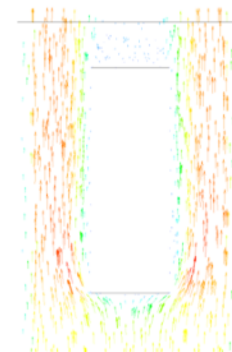
Net effect due to both is then superimposed to obtain the results.



- ❖ Drag force due to descent
- ❖ Lift force due to descent



- ❖ Drag force due to rotation (considering on a small cross section with area A')
- ❖ Lift force due to rotation



- ❖ Drag force due to descent (on container body)

Descent Rate Estimates (Payload) (8/14)

- Adding forces in vertical direction

$$m\frac{dV}{dt} = \frac{1}{2}\rho A V^2 C_{dv} + \frac{1}{2}\rho A (r\omega)^2 C_{lv} + \frac{1}{2}\rho A^* V^2 C_{dv}$$

- Adding moments in tangential direction

I

I

- The above equations are solved using fourth-order Runge-Kutta Method on XPPAUT Software. The optimal (terminal) velocity achieved for the auto-gyro is 13.29 m/s.

Descent Rate Estimates (Payload) (9/14)

Assumptions for calculations

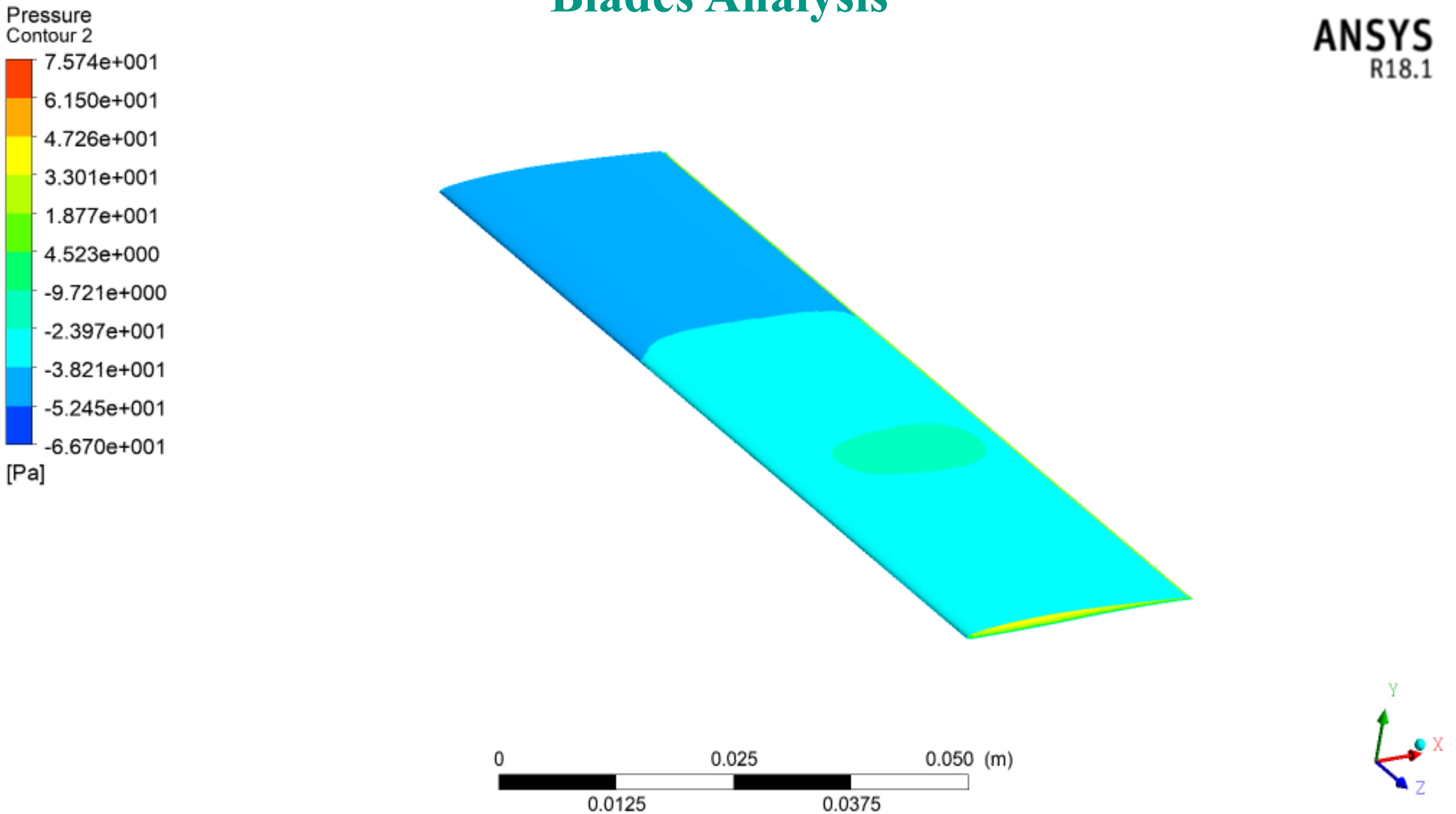
- Effect of natural wind velocity is neglected
- Frontal area for the parachute is approximated to be the area of hexagon
- Tip losses around the blades are neglected
- Frictional losses at the mounting points is neglected
- Bearing losses are neglected
- Coefficients are considered to be constant throughout the journey
- Variables, V and ω are considered to be constant for a time step

Where,

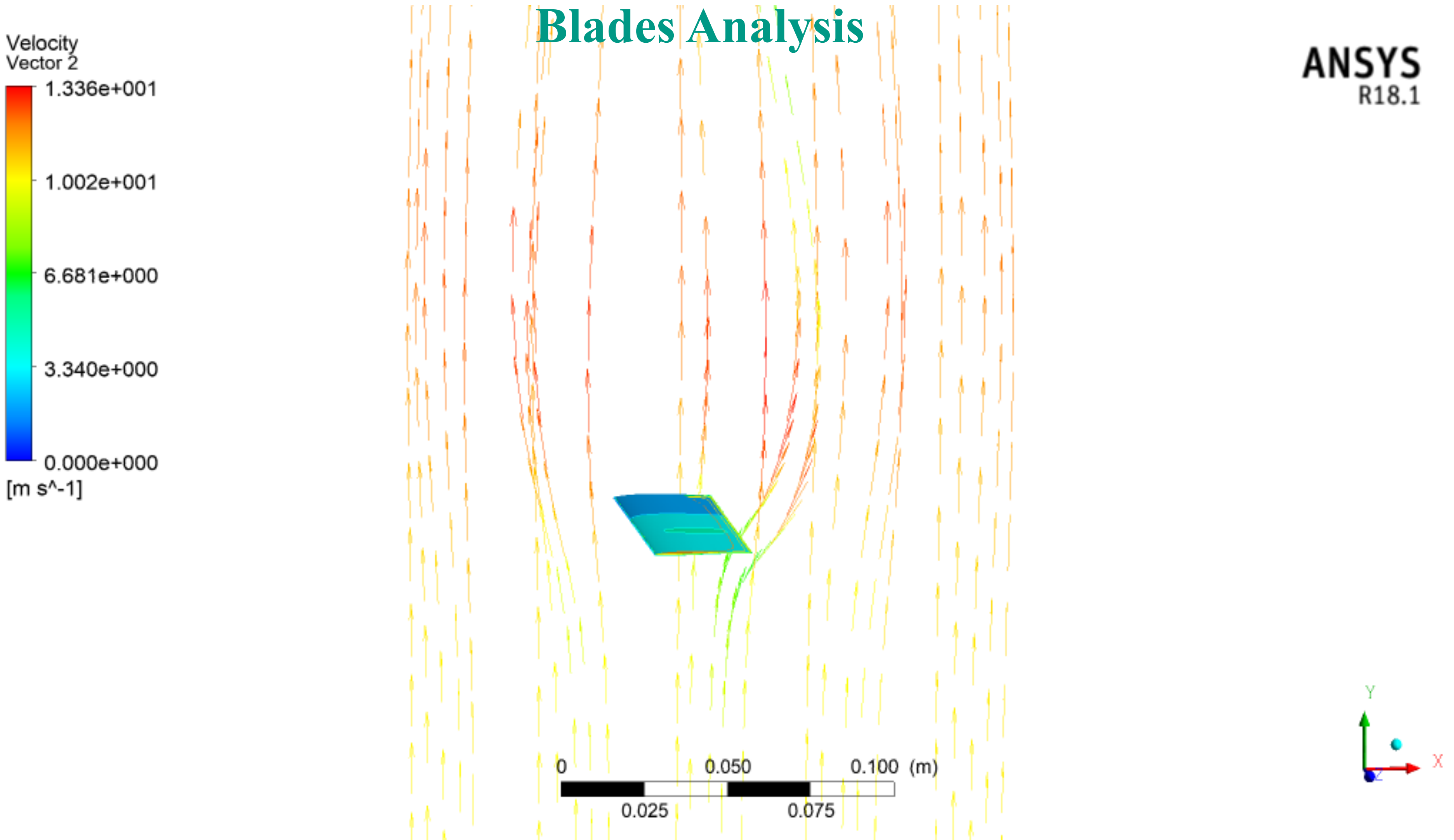
= Drag component of force due to descent on blades
= Lift component of force due to descent on blades
= Lift component of force due to rotation on blades
= Drag component of force due to rotation on blades
= Drag component of force on container body
=Drag component of force due to descent on blades
= Lift component of force due to descent on blades
= Lift component of force due to rotation on blades
= Drag component of force due to rotation on blades
= Drag component of force on container body
= Density of air
, = Area of cross-section for blades and container respectively
= distance of arbitrary section from the center of container

Descent Rate Estimates (10/14)

Blades Analysis

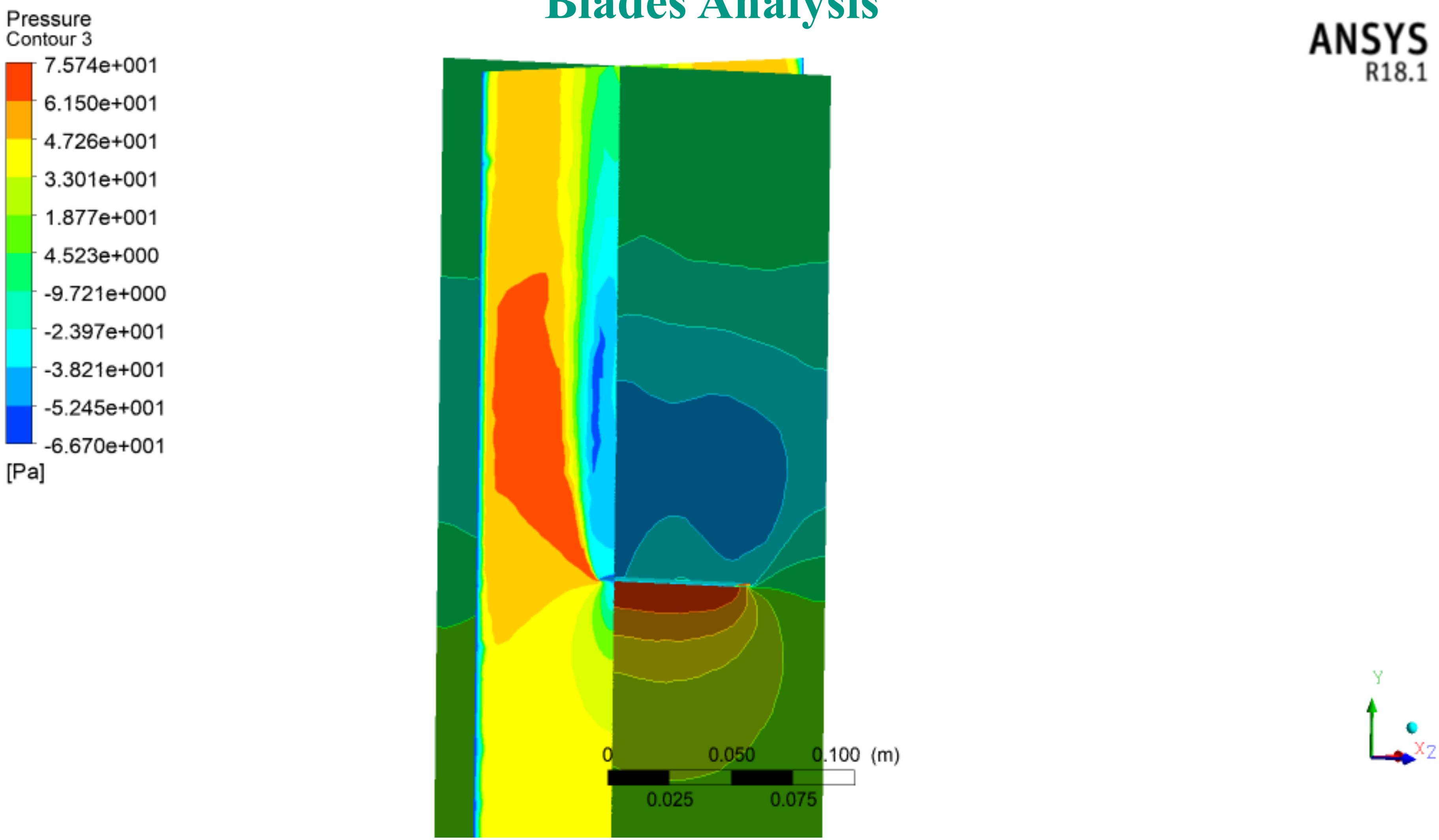


Descent Rate Estimates (11/14)

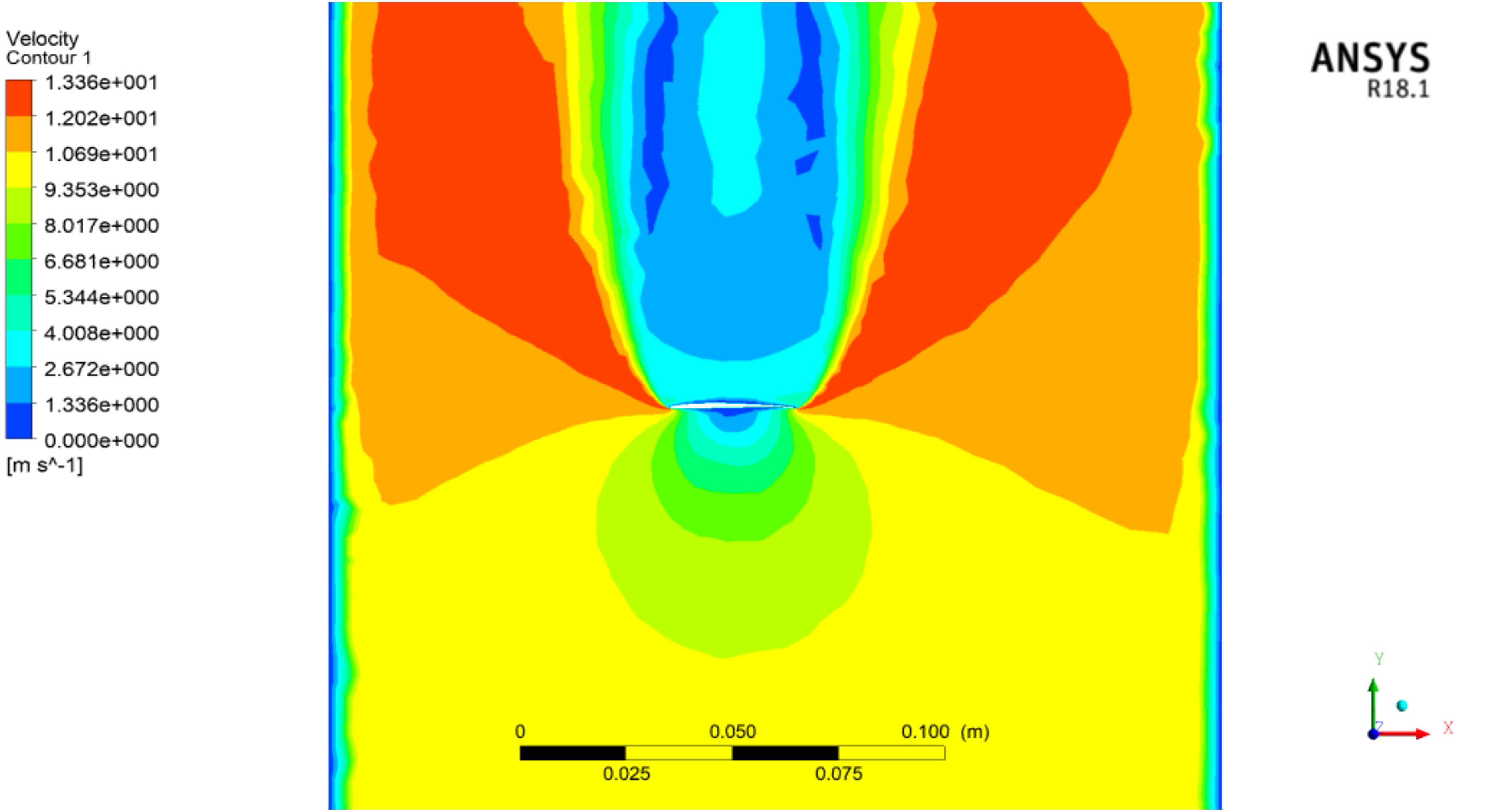


Descent Rate Estimates (12/14)

Blades Analysis



Blades Analysis



Descent Rate Estimates (14/14)

Descent System	Mass (g)	Terminal Velocity (m/s)	Time of Flight (s)
Container + Payload	500	16.75	22.08
Payload	330	13.29	32.12
Container	170	9.76	46.77

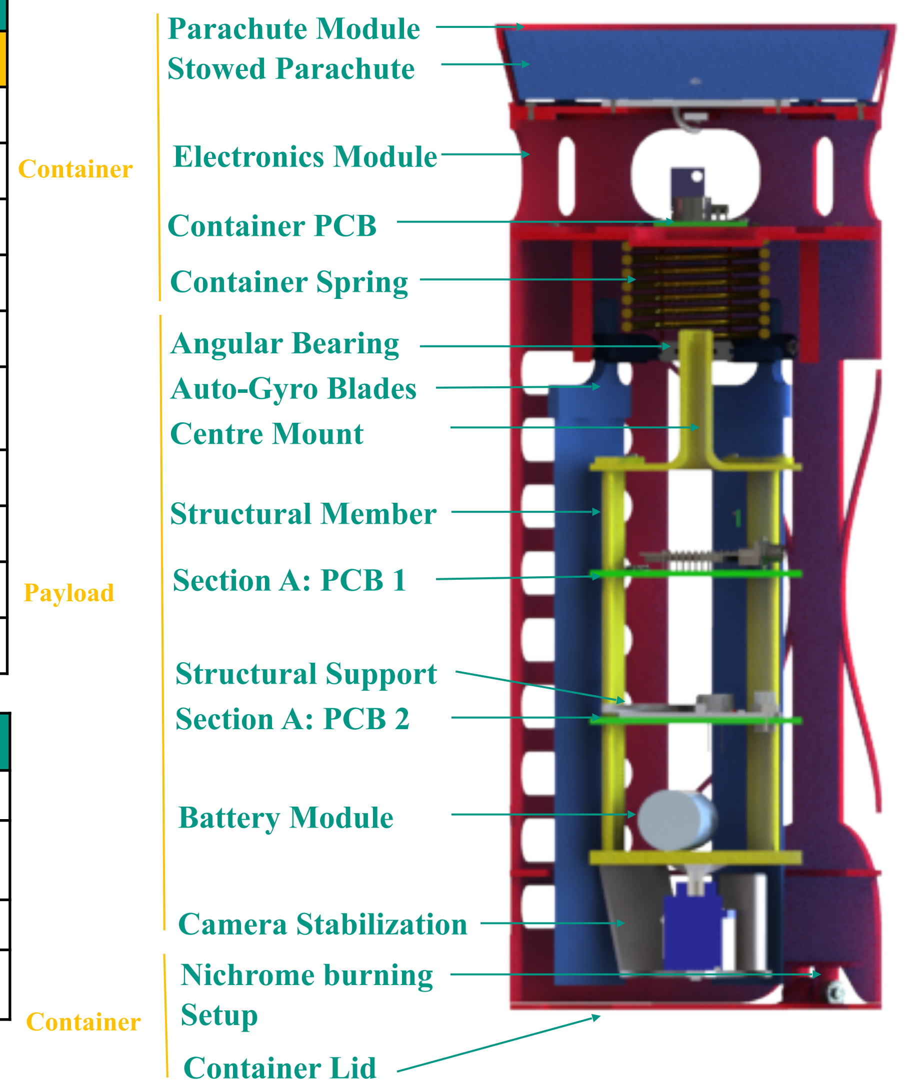
Mechanical Subsystem Design

Bhavya Arya

Mechanical Subsystem Overview

	Material Selection	
	Major Structural Members	**Materials**
Payload	Payload Top	SLS 3-D printed HIPS
	Rotor	Blow-Molded Polycarbonate
	Rotor Hub	Blow-Molded Polycarbonate
	Structural Members	FDM 3-D printed Polypropylene
	Structural Support	FDM 3-D printed Polypropylene
	Camera Stabilization Setup Mount	SLS 3-D printed PLA
Container	Parachute Module	SLS 3-D printed HIPS
	Parachute Mount	SLS 3-D printed HIPS
	Electronics Module	SLS 3-D printed HIPS
	Main Body	FDM 3-D printed HIPS

	Interface Definitions
Payload	Modular design based on vertical modules alignment
	Stowed Configuration: Bottom Lid is closed with a nylon thread which will burn due to a nichrome resistor at 450 m
Container	BMP 280 and an accessible power switch is mounted on container body
	Parachute is mounted using an O-ring to the parachute mount..

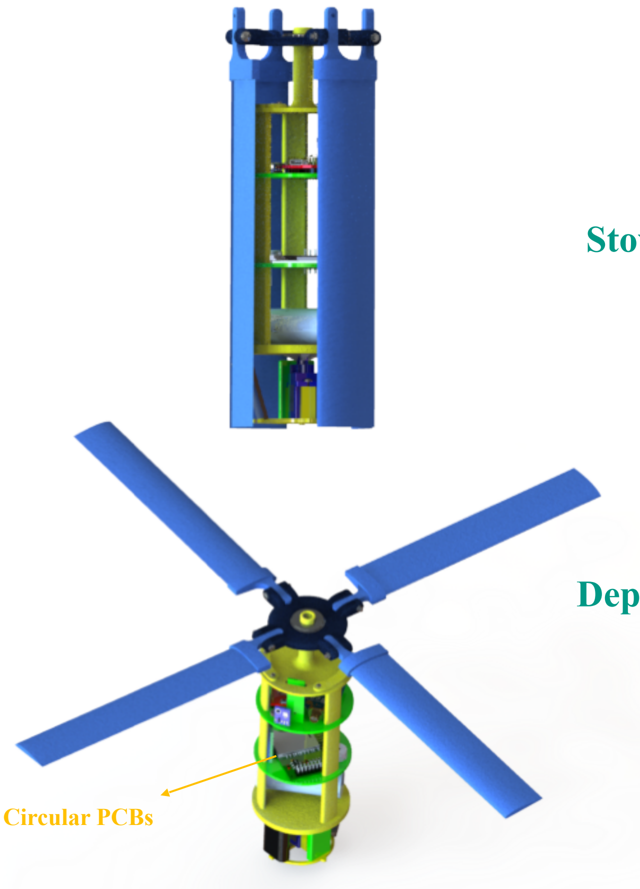


Payload Mechanical Layout of Components Trade & Selection (1/9)

S.No	Module	Key Trade Issues in Component selection
1	Payload Blades	Lightweight, ease of manufacturing Rigid structure to avoid flapping High shear strength
2	Auto-Gyro Hub	Good shear strength, close tolerances in the product for interference-fitted bearing
3	Payload Body	Lightweight to fulfill the 500 +/-10 g requirement The material should not block radio waves from FXP830 Freedom patch antenna.

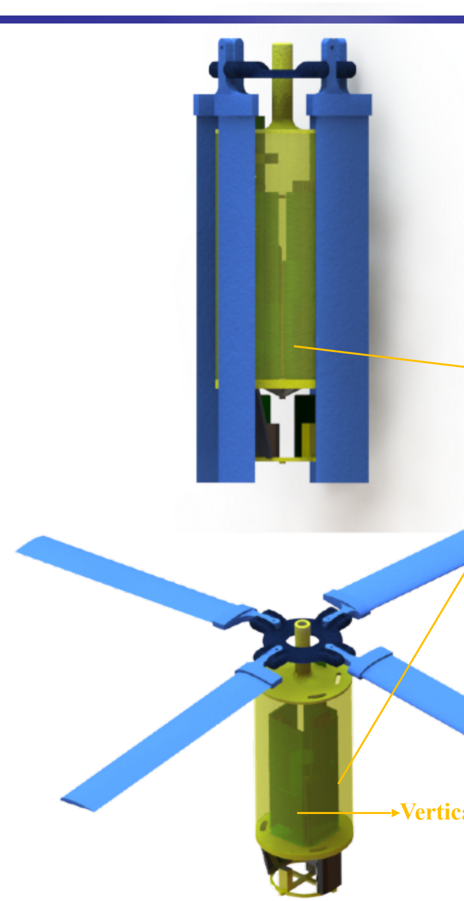
S.No	Module	Key Trade Issues in Mechanical Layout
1	Payload Blades	Requirement of immediate passive(without motor) realignment of blades
2	Auto-Gyro Hub	Need of a stopper to restrict blades' movement above some threshold value
3	Payload Body	Proper screwing of PCB and usage of epoxy to make strong connections to bear 30 Gs of shock. Placing various sub-modules like electronics' PCBs, battery section and camera sections ergonomically with a well-defined vertical modular alignment.

Payload Mechanical Layout of Components Trade & Selection (2/9)



Stowed configuration

Deployed configuration



Design Strategy A: Space frame structure with circular horizontal PCBs

Design Strategy B: Monocoque structure with rectangular vertical PCBs

Payload Mechanical Layout of Components Trade & Selection (3/9)

		Design Strategy A: Space Frame Structure with circular horizontal PCBs	Design Strategy B: Monocoque Structure with rectangular vertical PCBs
Pros	**Outer Mechanical Structure**	❖ Less Weight ❖ More modularity in design possible ❖ Restricts twisting better	❖ Easy manufacturing (single piece) ❖ This design is safer since it will better absorb the energy forces
	Electrical Components Location	❖ Easily accessible ❖ 2 stacked horizontal PCBs lead to more modularity and easy and quick repairs	❖ More space for easy placement of electrical components
Cons	**Outer Mechanical Structure**	❖ Concentrated loading at specific points ❖	❖ Expensive design ❖ No modularity possible (so last minute changes will be difficult during launch) ❖ Will also block radio waves
	Electrical Components	❖ Difficult to design a circular PCB	❖ Difficult repairs

Design Strategy	Shock Resistance	Strength: Weight Ratio	Stability	Ease of fabrication	Cost	Total (50)
A	9	8	7	6	8	38
B	7	6	5	9	7	34

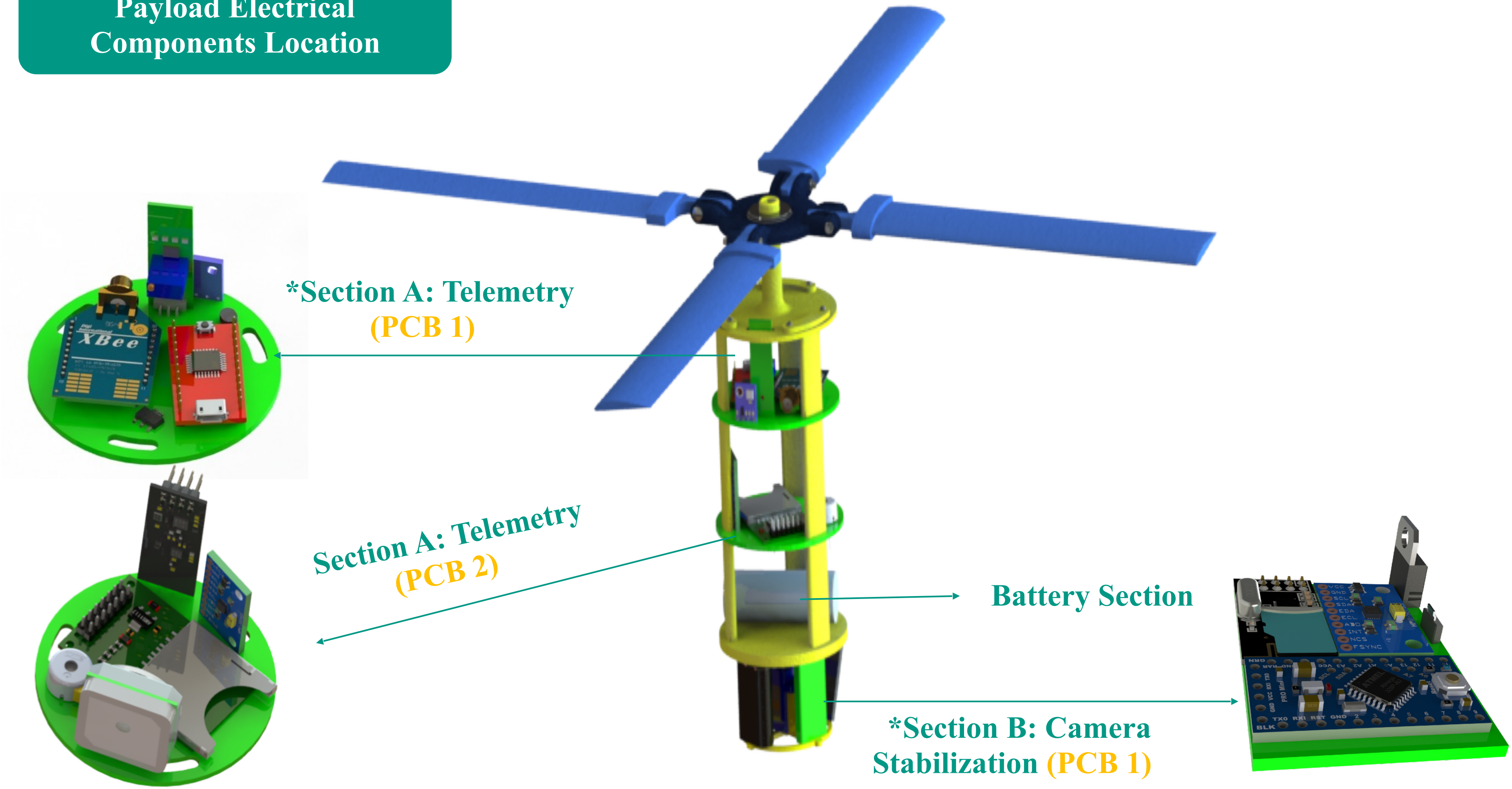
Reasons for selection of **Design Strategy A**, Space Frame Structure with circular horizontal stacked PCBs:

- ❖ 1. More modularity in design required for quick changes
- ❖ 2. Better shock durability and higher strength to weight ratio
- ❖ 3. Ease of fabrication due to modularity

(0 to 10)
0-Least, 10-Most

Payload Mechanical Layout of Components Trade & Selection (4/9)

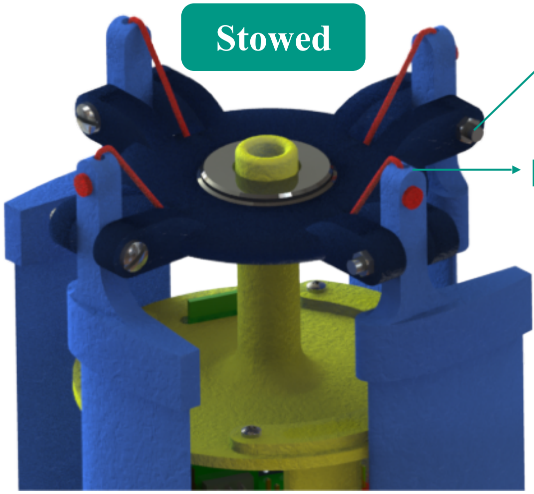
Payload Electrical Components Location



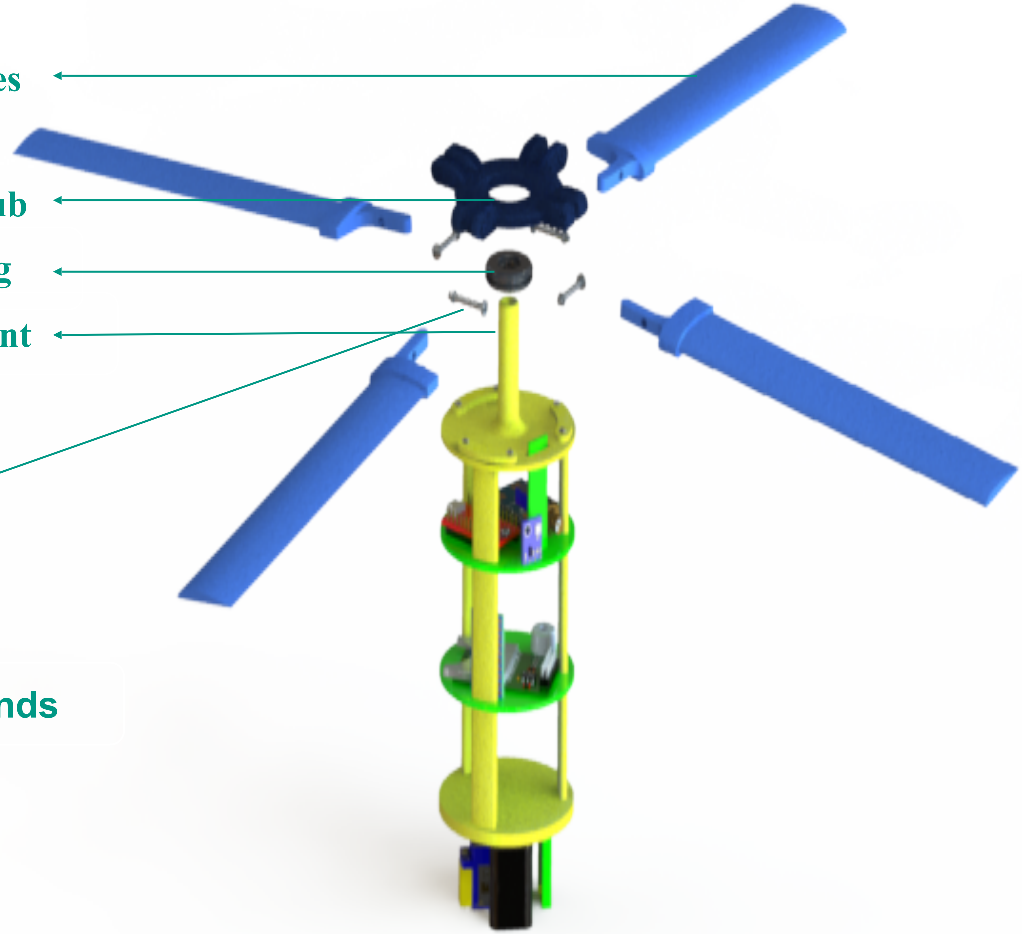
***Payload is divided into two parts: Section A- Telemetry Section and Section B: Camera Stabilization Section**

Payload Mechanical Layout of Components Trade & Selection (5/9)

Auto-Gyro Attachment Points



Stowed



Deployed

Payload Mechanical Layout of Components Trade & Selection (6/9)

Payload Top

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost ($/kg)	Pros	Cons	Notched Impact Strength (KJ/m^2)
A: HIPS	**1.03**	**100-300**	**30**	❖ **Better tensile strength** ❖ **Good surface finish**	❖ **Heavier** ❖ **Blocks Radio Waves**	**10.0 - 20.0**
B: PMP	0.83	10-25	35	❖ Rigid ❖ Lightweight	❖ Less tensile strength ❖ More elongation	4.0-14.0

Material	Shock Resistance	Tensile Strength	Elongation	Ease of fabrication	Weight	Cost	Total (60)
A	8	7	9	8	6	8	46
B	6	5	7	7	9	9	35

Reasons for selection of **Material A: High-Impact Polystyrene (HIPS)** , for Payload Top:

- ❖ More Tensile strength and less elongation
- ❖ Better Ease of Fabrication
- ❖ Better Shock Resistance

(0 to 10)
0-Least, 10-Most

Payload Mechanical Layout of Components Trade & Selection (7/9)

Structural Members and Structural Supports

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost ($/kg)	Pros	Cons	Notched Impact Strength (KJ/m^2)
A: Polypropylene	**0.946**	**40**	**30**	• **Stiff and strong** • **Good surface finish**	• **Impacted by UV** • **Heavy Warping**	**3.0-30.0**
B: PLA	1.25	37	25	• Low Warping • Recyclable	• Brittle in nature • Lesser shear strength	8.0-19.0

Material	Strength-Weight Ratio	Impact Strength	Warping	Ease of fabrication	Cost	Shear Strength	Total (60)
A	8	8	7	7	8	9	47
B	6	7	9	8	9	7	46

Reasons for selection of **Material A: Polypropylene for structural members and structural supports** :

❖ High impact strength
❖ High shear strength

(0 to 10)
0-Least, 10-Most

Payload Mechanical Layout of Components Trade & Selection (8/9)

Rotor and Rotor Hub

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost ($/kg)	Pros	Cons	Notched Impact Strength (KJ/m^2)
A: Polycarbonate	**1.2**	**70-80**	**30**	• **High stiffness-weight ratio** • **High tensile strength**	❖ **More weight** ❖ **Expensive manufacturing technology**	**60.0 - 80.0**
B: ABS	1.06-1.08	27-46	20	• Lightweight • Ease of fabrication	• Brittle in nature • Poor surface finish	10.0-20.0

Material	Stiffness-Weight Ratio	Impact Strength	Tensile Strength	Ease of fabrication	Cost	Heat Resistance	Total (60)
A	8	9	9	6	8	9	49
B	6	7	6	9	9	8	43

Reasons for selection of **Material A**, Blow-moulded polycarbonate for rotor and rotor hub:

❖ High tensile and impact strength

❖ High stiffness-weight ratio

(0 to 10)
0-Least, 10-Most

Payload Mechanical Layout of Components Trade & Selection (9/9)

Setup for camera stabilization mount

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost ($/kg)	Pros	Cons	Notched Impact Strength (KJ/m^2)
A: ABS	**1.06-1.08**	**27-46**	**20**	• **Lightweight** • **Ease of fabrication**	• **Brittle in nature** • **Poor surface finish**	**8.0-10.0**
B: PLA	1.25	37	25	• Low Warping • Recyclable	• Brittle in nature • Lesser shear strength	8.0-19.0

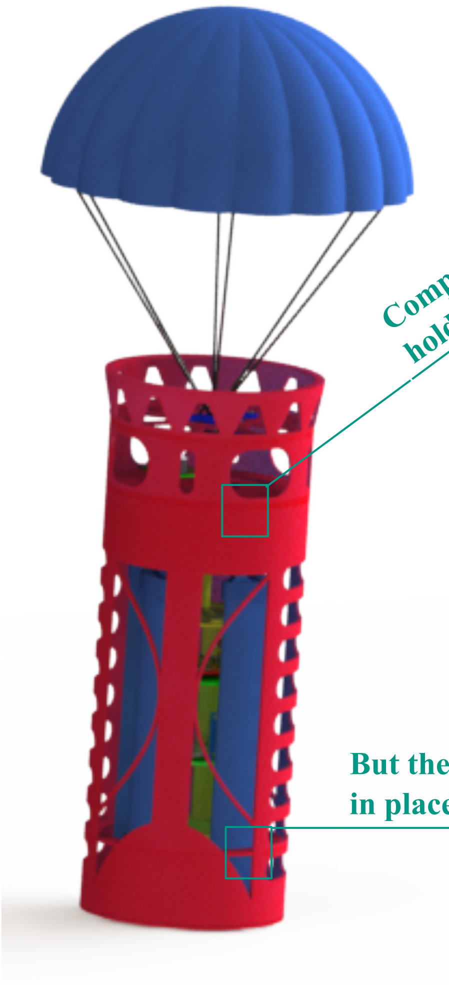
Material	Stiffness-Weight Ratio	Impact Strength	Tensile Strength	Resilience	Less Brittleness	Heat Resistance	Total (60)
A	9	8	8	8	7	9	49
B	6	9	7	9	9	7	46

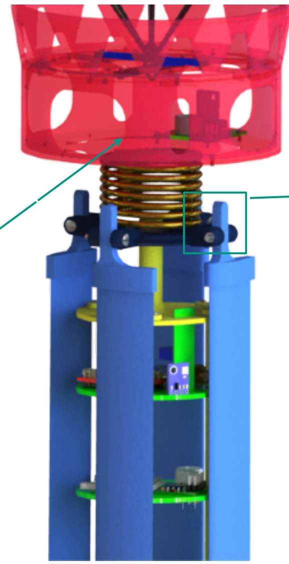
Reasons for selection of **Material A**, ABS for camera stabilization setup mount:
- ❖ Lightweight and cheap
- ❖ High stiffness-weight ratio and ease of fabrication

(0 to 10)
0-Least, 10-Most

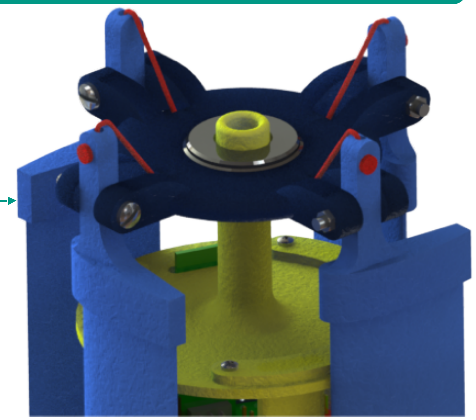
Payload Pre Deployment Configuration Trade & Selection (1/4)

Design Strategy A: Stowed Payload using bottom lid connected through nylon thread



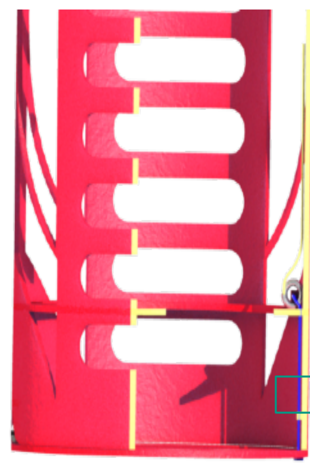


Compressed Spring holds it in place



Payload remains in place due to L-shaped protrusions, also the blade opening is prevented due to circular extension from the payload

This is how payload is stowed

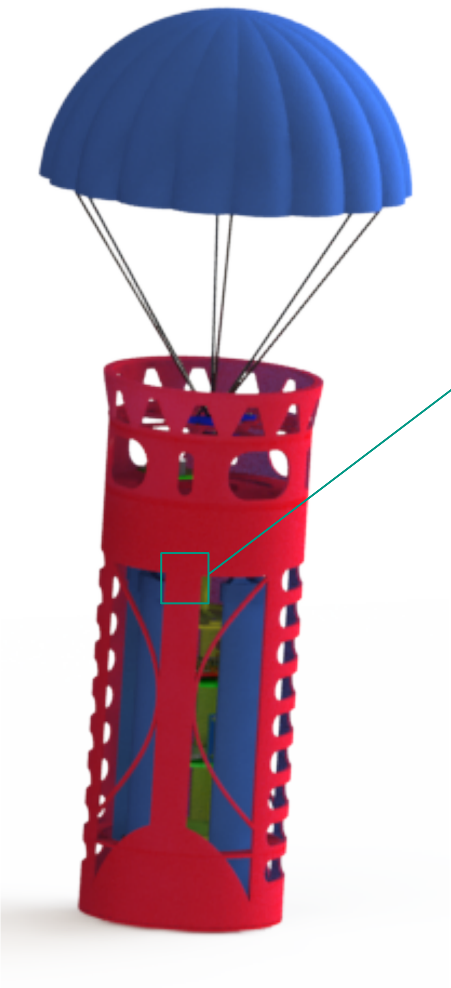


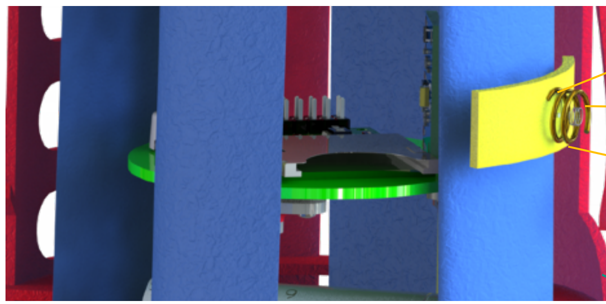
But the Compressed Spring holds payload in place due to closed bottom lid

The nylon thread is attached to a mount on the cylinder and passing through a hole in the hinged lid on the other end around which nichrome wire is wound.

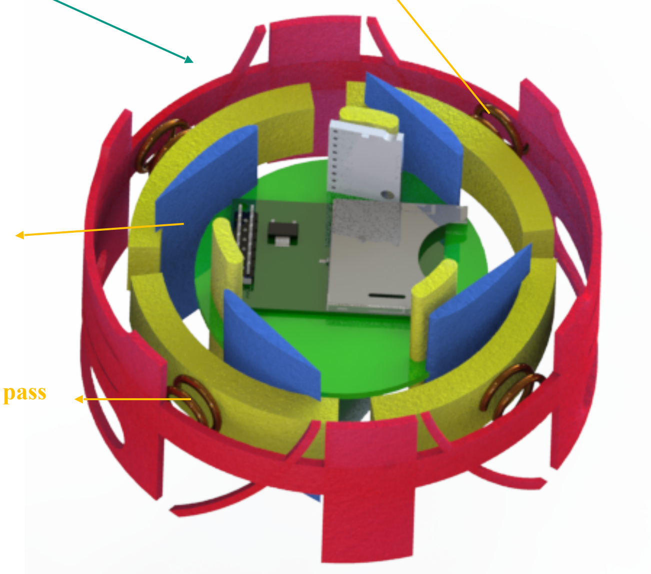
Payload Pre Deployment Configuration Trade & Selection (2/4)

Design Strategy B: Stowed Payload using peripheral spring constraint mechanism





4 Peripheral restrainers bound by 4 corresponding springs' restoring force and solenoid to hold payload in place.



At 450 m, the current will pass through the solenoid thus attracting the restrainers outward.

This is how payload is stowed

Payload Pre Deployment Configuration Trade & Selection (3/4)

	Design Strategy A: Stowed Payload using bottom lid connected through nylon thread to container	Design Strategy B: Stowed Payload using peripheral spring and solenoid constraint mechanism
Pros	❖ More robust ❖ Simpler in design with lesser overall parts to keep the payload in stowed configuration ❖ It limits rotation of the payload inside the container using L-shaped protrusions	❖ It will keep overall system more stable ❖ Springs will provide damping mechanism and absorb shocks including 30 Gs of shock more efficiently and reliably
Cons	❖ Mechanically fixed system, no response to external stimuli like shocks	❖ More weight ❖ Potential to break auto-gyro blades due to excessive restoring force of the coil springs

Design Strategy	Shock Resistance	Reliability	Weight	Ergonomics	Cost	Strength	Total (60)
A	7	8	8	8	9	9	49
B	9	7	6	9	7	8	46

Reasons for selection of **Design Strategy A**, Stowed Payload using bottom lid connected through nylon thread to container:

❖ Simpler Design
❖ More robust, prevents rotation and flapping of payload

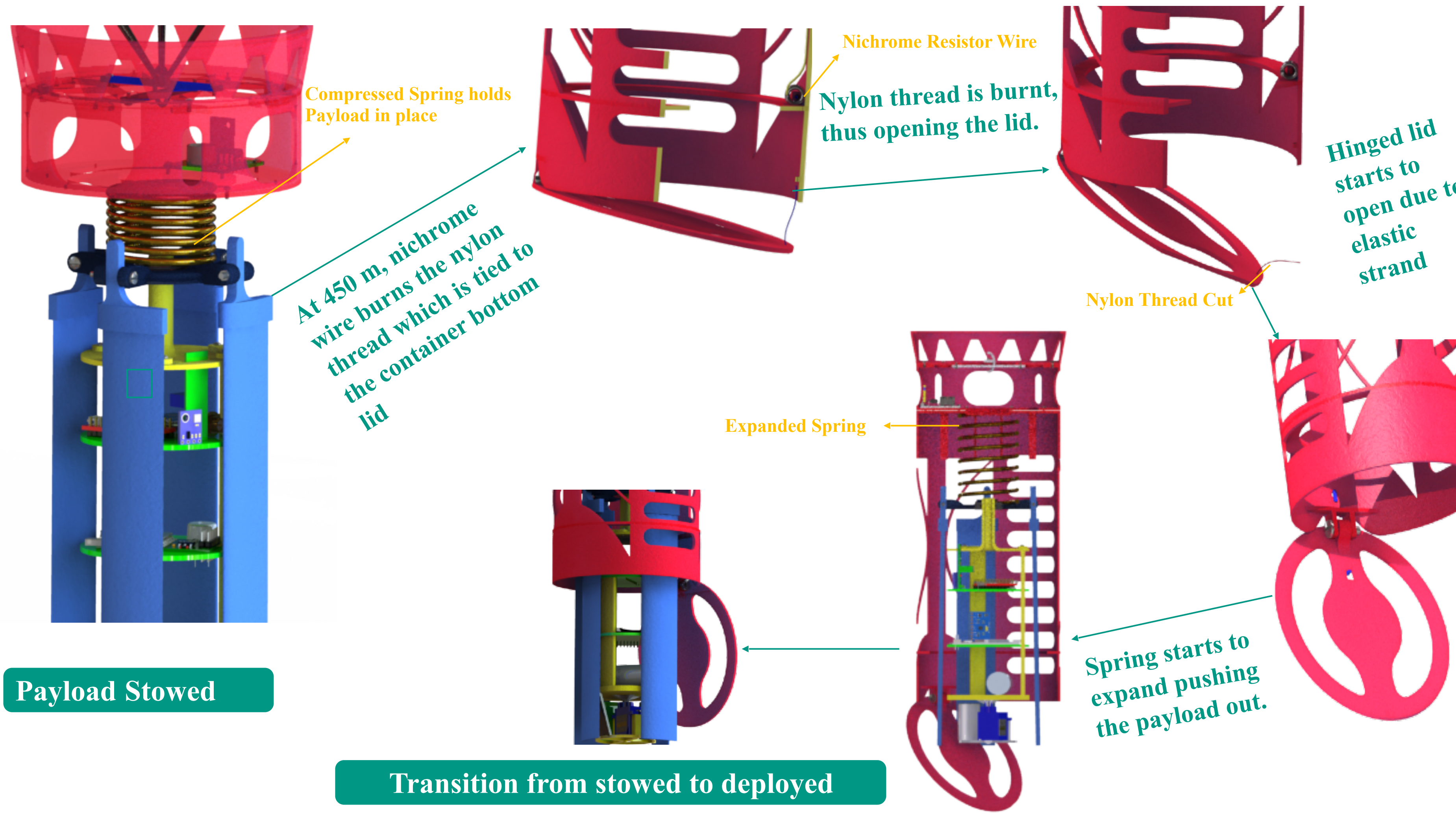
(0 to 10)
0-Least, 10-Most

Payload Pre Deployment Configuration Trade & Selection (4/4)

Sr. No.	Key Trade Issues in Stowed Configuration	Our Design-Strategies
1	Movement of payload inside container	L-shaped extensions in between the four rotors up to the rim of the top electronics module are made to hold the payload in place
2	Flapping of blades due to random vibrations	Ring-shaped mechanical restrainer is put around the rotors to prevent flapping
3	The spring mechanism can distort the hub thus loosening the interference fitted bearing	A flanged shoulder is provided to keep the bearing in place
4	30 Gs of shock can force open the bottom lid due to nylon thread breaking	Analysis on SolidWorks has demonstrated and verified the mechanism’s strength
5	Vertical vibrations can damage the camera mount module due to payload oscillations inside the container	Spring of appropriate stiffness constant has been selected to avoid this phenomenon

Payload Deployment Configuration Trade & Selection (1/6)

Mechanism A: Nichrome Burning Setup (Stage-1)

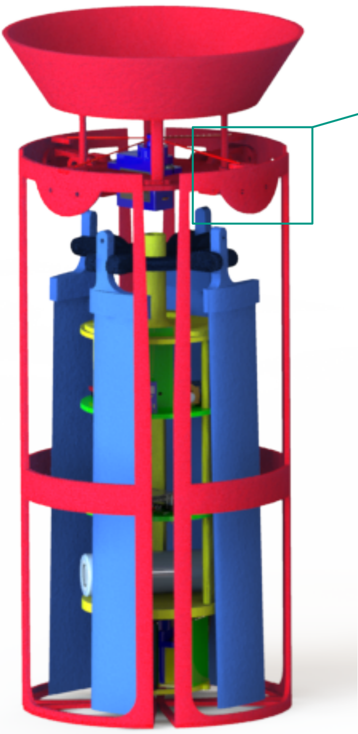


Payload Stowed

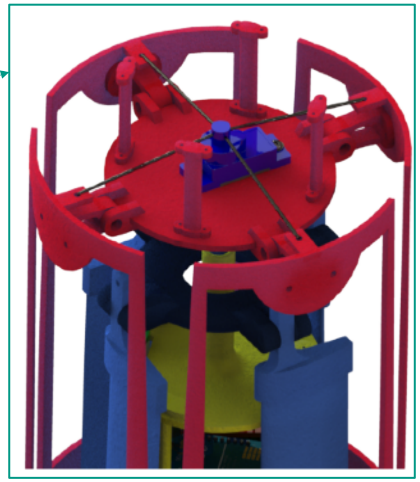
Transition from stowed to deployed

Payload Deployment Configuration Trade & Selection (2/6)

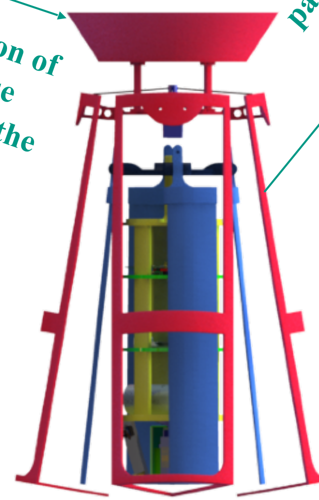
Mechanism B: Servo Actuation (Stage-1)



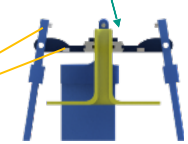
Payload Stowed



At 450 m, rotation of 9g servo will cause inward tension in the string in the four directions which in turn will push the 4 hinged flaps out thus opening the container.



As the flaps start opening out, payload starts coming out



Neodymium Magnets

Transition from stowed to deployed

Payload Deployment Configuration Trade & Selection (3/6)

	Mechanism A: Nichrome-Burning Setup	Mechanism B: Servo Actuation
Pros	❖ Simpler mechanism, lesser number of moving parts ❖ Less Weight	❖ More space for payload release during container opening
Cons	❖ Requirement of 1600-2000 mA current to burn the nylon thread, so a battery with better capacity is required. ❖ High dependence on nylon thread to hold the bottom lid	❖ More weight due to servo mechanism ❖ Difficult to maintain stowed configuration of payload ❖ Complex mechanism due to 4 moving parts of CanSat and lesser shock durability

Mechanism	Ease of Mechanism	Reliability	Shock Durability	Ease of fabrication	Cost	Weight	Total (60)
A	8	8	8	8	9	8	49
B	9	7	6	7	8	7	44

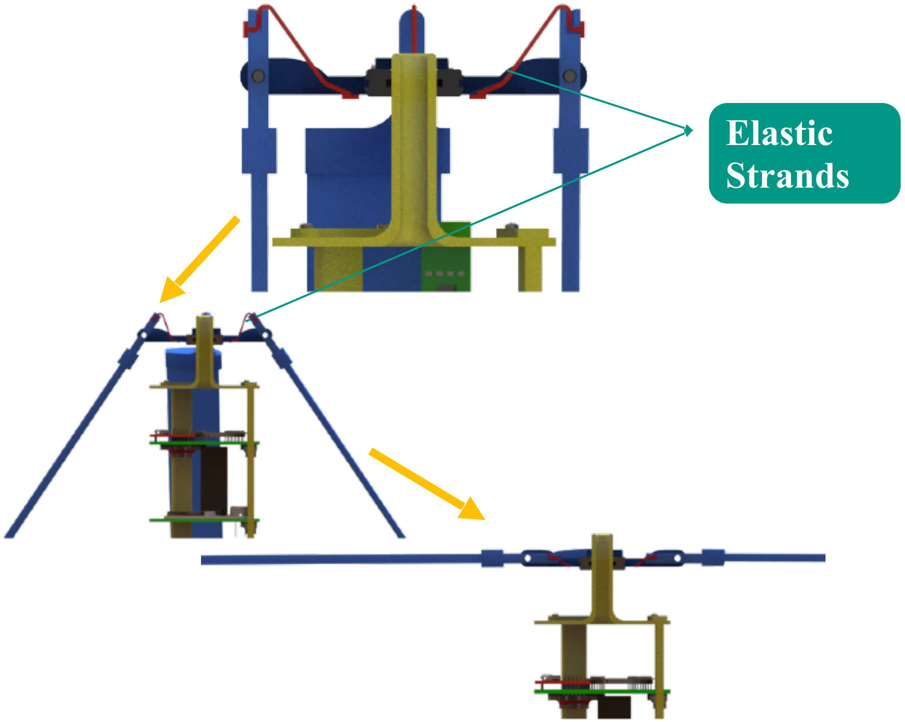
Reasons for selection of **Mechanism A**, Nichrome-Burning Setup:

- ❖ Simpler Design
- ❖ Lightweight (due to absence of any servo)
- ❖ This mechanism has been tested and verified through drones

(0 to 10)
0-Least, 10-Most

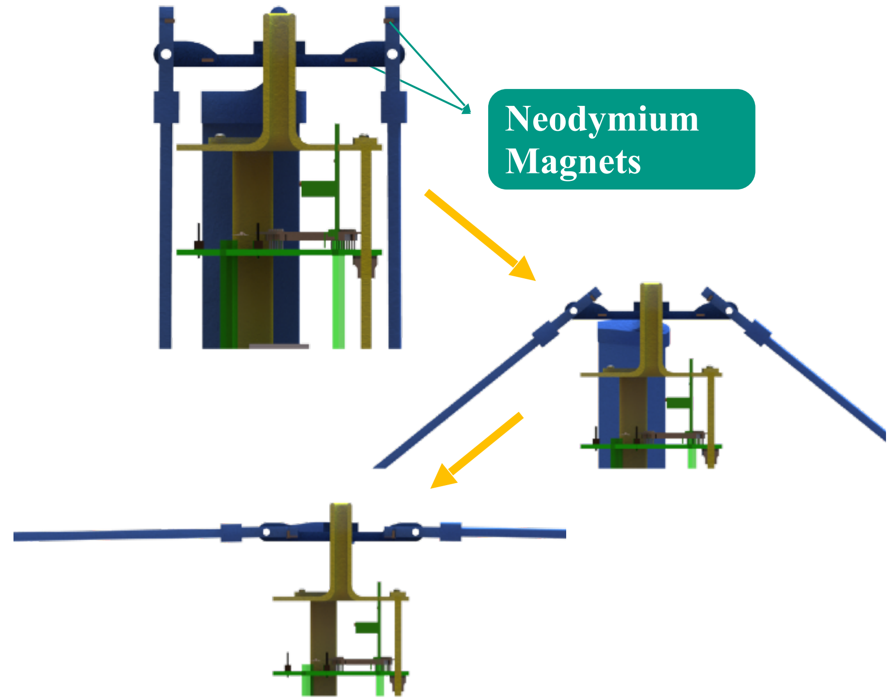
Payload Deployment Configuration Trade & Selection (4/6)

Payload Deployment (Stage-2)



Design Strategy A: Payload Deployment using Elastic Strands

Elastic strands and air pressure will force open the blades



Design Strategy B: Payload Deployment using Neodymium Magnets

During separation from payload, the neodymium magnets will lock each other due to strong magnetic attraction and force open the blades.

Payload Deployment Configuration Trade & Selection (5/6)

	Design Strategy A: Payload Deployment using elastic strands	Design Strategy B: Payload Deployment using neodymium magnet
Pros	• Self-sustainable action: Elastic strands will force open the blades whatever maybe the direction of release of payload • More reliable • Cost-effective	• Neodymium magnets will ensure good locking and no flapping.
Cons	• Excessive temperature on launch day can affect the elasticity of the strands.	• More weight • Hall sensor magnets can interfere with magnetic field lines of neodymium magnets.

Design Strategy	Quick Action	Self-sustainable action	Blades Flapping	Weight	Cost	Total (50)
A	8	9	6	8	9	40
B	7	7	9	6	7	36

Reasons for selection of **Design Strategy A**, Payload Deployment using elastic strands :

1. More reliability due to self-sustainable action
2. Light-weight and cost-effective

(0 to 10)
0-Least, 10-Most

Payload Deployment Configuration Trade & Selection (6/6)

Sr. No.	Key Trade Issues in transition to Deployed Configuration	Our Design-Strategies
1	If the orientation of the container is not in the nadir direction at the time of payload release, the release cannot be guaranteed solely by gravity	This is countered by the spring loaded design which will push the payload out
2	Hinderance to payload release during lid opening	Nylon burning setup along with the elastic strands will ensure opening of lid to greater than 90 degrees, thus providing complete and free space for payload release
3	Swaying of the lid at the moment of release	Topological optimization has been done to reduce the lid’s inertial movement
4	Payload will start tumbling during the release	SolidWorks simulations have demonstrated the center of pressure point above the center of gravity, thus reorienting itself leading to stable equilibrium
5	Nylon wire connections can get stuck with the payload	The setup is kept at the container bottom and the wire length is kept minimum to avoid it getting stuck.

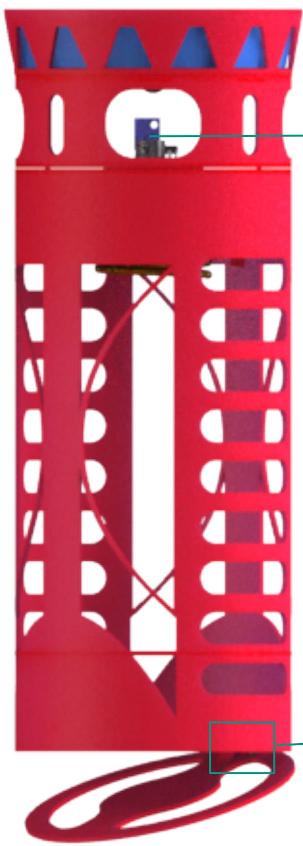
Container Mechanical Layout of Components Trade & Selection (1/7)

Sr. No	Module	Key Trade Issues in Mechanical Layout
1	Parachute Module	Immediate deployment of parachute from rocket. Need of air ducts to facilitate this stage.
2	Container Electronics Module	Proper screwing of PCB and usage of epoxy to make strong connections to bear 30 Gs of shock.
3	Container Body	Sufficient strength to hold the payload properly
4	Container Lid	Minimum weight in lid to prevent swaying

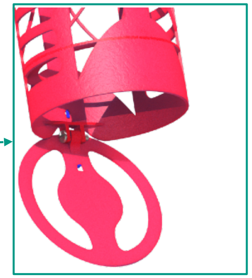
Sr. No	Module	Key Trade Issues in Component selection
1	Parachute Module	This module's base should have high impact resistance to bear 30 Gs of shock and 15 Gs of launch acceleration.
2	Container Electronics Module	Lightweight and impact resistance.
3	Container Body	High yield strength to counter axial forces from launch till deployment and to safely carry the payload inside till 450 m.
4	Container Lid	High ultimate strength in hinge points to counter shear stresses.

Container Mechanical Layout of Components Trade & Selection (2/7)

Design Strategy A: Container Electronics on top of Payload section with thin lid



Container Electronics on top
(shifting COG upwards)



Design Strategy B: Container Electronics placed on container lid

Container Electronics on lid
(Excessive Swaying)

Container Mechanical Layout of Components Trade & Selection (3/7)

	Design Strategy A: Container Electronics on top of Payload section with thin lid	Design Strategy B: Container Electronics placed on container lid
Pros	• No swaying as compared to the design strategy B • Heavy electronics module of container is fixed with respect to CanSat.	• COG of the CanSat is lowered down. • Shorter length of nichrome wire is required for burning the nylon thread connecting lid and container.
Cons	• Longer length of nichrome wire is required. • COG is shifted upwards	• Excessive swaying when the lid will open. • Changing COG due to swaying will culminate in unstable equilibrium.

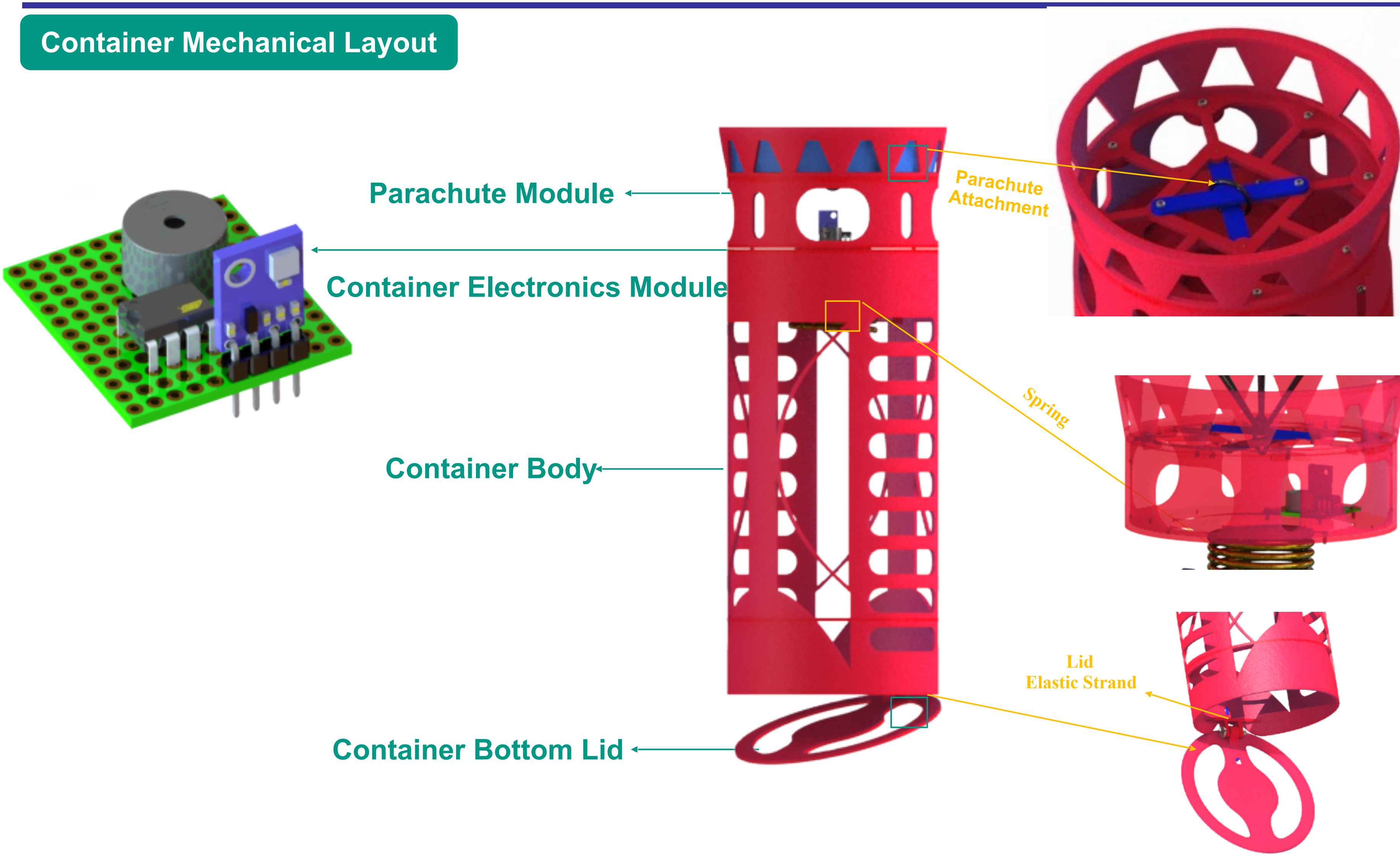
Design Strategy	Shock Resistance	Load Distribution	Stability	Ease of fabrication	Cost	Total
A	8	7	9	7	8	39
B	6	5	6 (swaying)	7	8	32

Reasons for selection of **Design Strategy A**, Container Electronics on top of Payload section:
1. Uniform load distribution
2. More stable
3. Better shock durability

(0 to 10)
0-Least, 10-Most

Container Mechanical Layout of Components Trade & Selection (4/7)

Container Mechanical Layout



Container Mechanical Layout of Components Trade & Selection (5/7)

Parachute Module

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost ($/kg)	Pros	Cons	Notched Impact Strength (KJ/m^2)
A: HIPS	**1.03**	**100-300**	**30**	❖ **Better tensile strength** ❖ **Good surface finish**	❖ **Less stress crack resistance** ❖ **Blocks Radio Waves**	**10.0 - 20.0**
B: Polyethylene terephthalate	1.37	190-260	35	❖ High environmental stress crack resistance	❖ Less impact strength ❖ Increasing Cost and not easily available	1.5 - 3.5

Material	Shock Resistance	Tensile Strength	Weight	Ease of fabrication	Cost	Stress Crack Resistance	Total (60)
A	9	8	9	8	8	6	48
B	6	7	7	7	7	9	36

Reasons for selection of **Material A: High Impact Polystyrene**, for Payload module:

- ❖ High Impact strength to bear 30 Gs of shock during deployment from rocket
- ❖ Less weight, easily available, ease of fabrication, higher tensile strength

(0 to 10)
0-Least, 10-Most

Container Mechanical Layout of Components Trade & Selection (6/7)

Parachute Mount

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost ($/kg)	Pros	Cons	Notched Impact Strength (KJ/m^2)
A: HIPS	**1.03**	**100-300**	**30**	❖ **Better tensile strength** ❖ **Good surface finish**	❖ **Less stress crack resistance** ❖ **Blocks Radio Waves**	**10.0 - 20.0**
B: ABS	1.06-1.08	27-46	20	❖ Lightweight ❖ Ease of fabrication	❖ Brittle in nature ❖ Poor surface finish	8.0-10.0

Material	Shock Resistance	Tensile Strength	Weight	Ease of fabrication	Cost	Less Brittleness	Total (60)
A	9	8	9	7	8	9	50
B	7	7	8	9	9	7	48

Reasons for selection of **Material A: High Impact Polystyrene**, for parachute mount:

- ❖ High Impact strength to bear 30 Gs of shock during deployment from rocket
- ❖ Less weight, easily available, higher tensile strength

(0 to 10)
0-Least, 10-Most

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

Electronics Module and Container Main Body

Material	Density (g/cm^3)	Tensile Strength (MPa)	Cost ($/kg)	Pros	Cons	Notched Impact Strength (KJ/m^2)
A: HIPS	**1.03**	**100-300 MPa**	**30**	• **Better tensile strength** • **Good surface finish**	• **Less stress crack resistance** • **Blocks Radio Waves**	**10.0 - 20.0** •
B: PLA	1.25	37	25	• Low Warping • Recyclable	• Brittle in nature • Lesser shear strength	8.0-19.0

Material	Shock Resistance	Tensile Strength	Weight	Ease of fabrication	Warping	Less Brittleness	Total (60)
A	9	9	9	7	9	9	52
B	7	7	8	9	8	8	47

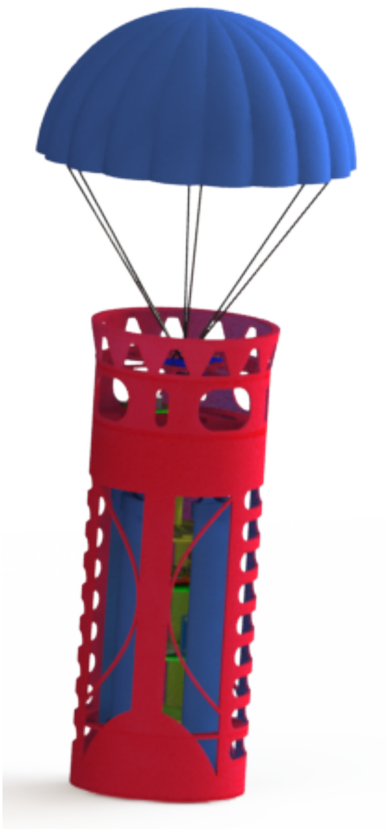
Reasons for selection of **Material A: High Impact Polystyrene**, for Electronics Module:

❖ High Impact strength to bear 30 Gs of shock during deployment from rocket

❖ Less weight, easily available, higher tensile strength and low warping

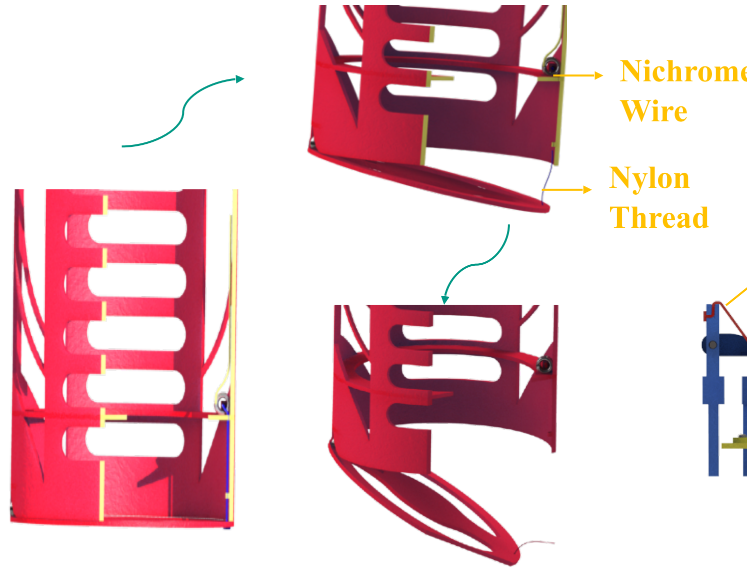
(0 to 10)
0-Least, 10-Most

Payload Release Mechanism



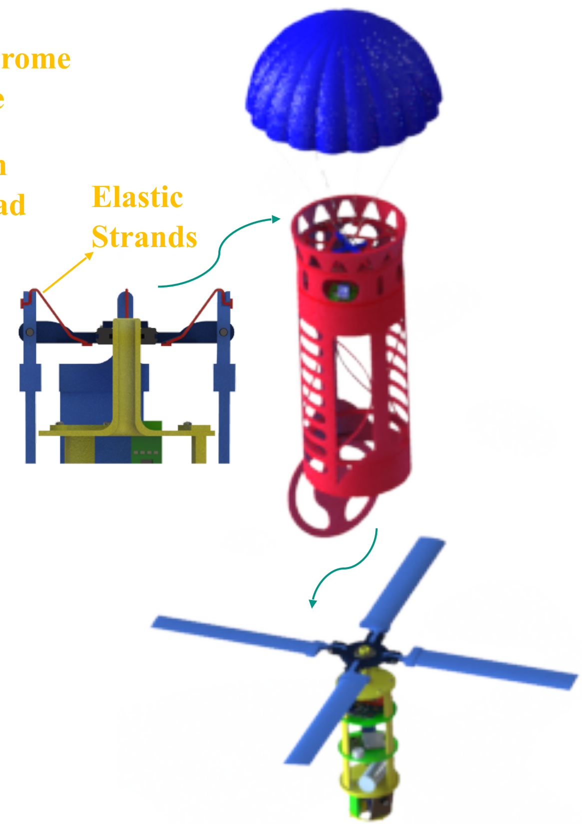
Phase 1: Pre-Deployment

Payload is kept in the container
In the stowed configuration.



Phase 2: Transition

At 450m, the MCU will command the Nichrome burning setup to pass large current (around 700 mA) through the nichrome wire to burn the nylon thread around which it is wound. The nylon thread is attached to a mount on the cylinder and passing through a hole in the hinged lid on the other end. After burning of the nylon thread, the hinged lid will open, thus payload will start coming out.

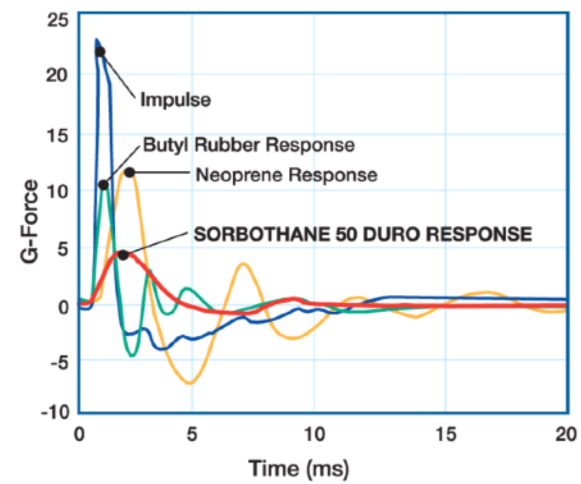


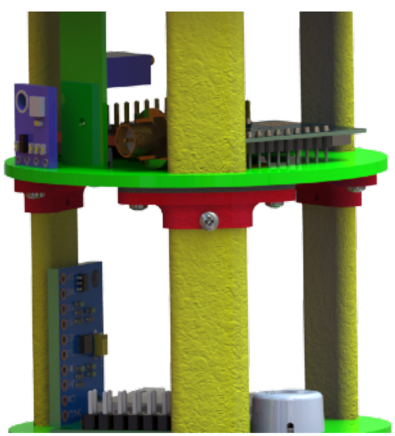
Phase 3: Separation

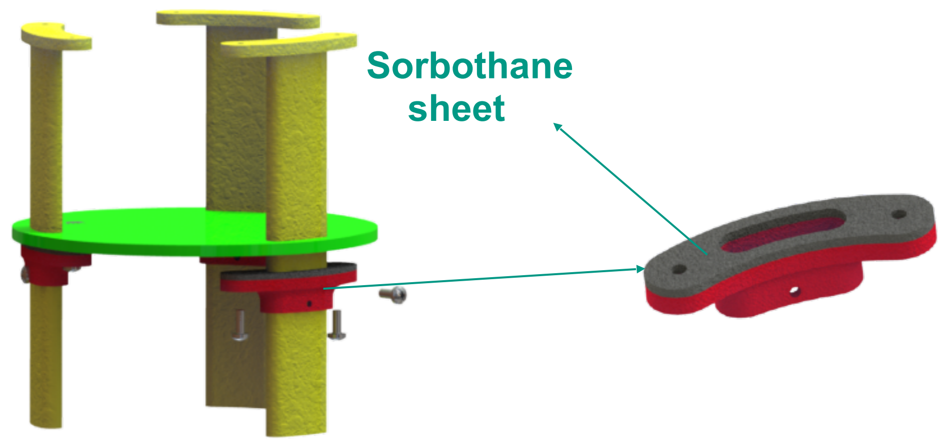
Elastic strands and air pressure will force the rotors to open. The rotors will start rotating due to lift forces generated by the downward velocity of the container.

Electronics Structural Integrity (1/2)

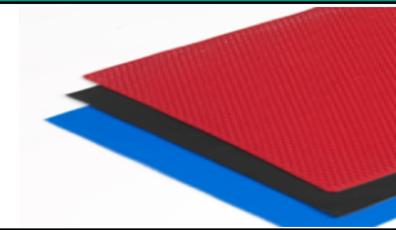
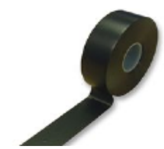
- All PCBs are rigidly mounted to the structural members of the payload via supporting members, all connections are joint through screws.
- A layer of **Sorbothane** is provided between the PCB and the support members for shock absorption so that no shock is transferred to the PCBs
- Sorbothane has excellent shock dampening properties, so it will absorb the major part of the 30G's of shock which will be generated on the system







Electronics Structural Integrity (2/2)

	Description	Photos
Electronic component mounting methods	Components are properly soldered on the PCB and it is prevented from shock due to damping action of Sorbothane layer	
Electronic component enclosures	Payload is covered with a *taffeta nylon fabric which is wrapped around the structural members of the payload	
Securing electrical connections	Connections are secured via epoxy, resin, glue and electrical PVC tape	 
Descent control attachments	All descent control attachments are securely screwed to respective mounting points also a layer of glue is put on the edges to secure the joints(M2-0.4, Philips screws are used)	

*** Taffeta nylon covering is not shown in any CAD model for better understanding of the model**

Mass Budget (1/10)

Payload Electronics Components

CanSat System	Component	Model Name	Quantity	Mass (g)	Uncertainty	Determination
Payload (Section-A: Telemetry Section)	Temperature sensor	BMP-280	1	1.3540	±0.0001	Measured
	Air pressure sensor					
	GPS sensor	UBLOX Neo-6M	1	12.0142	±0.0001	Measured
	Voltage sensor	SAMD21 ADC	1	-	-	-
	Pitch and roll sensor	MPU 9250	1	1.5186	±0.0001	Measured
	Autogyro spin rate sensor	AH49E Hall Sensor	1	0.5242	±0.0001	Measured
	SD Card Shield	Street27 MicroSD	1	4.5221	±0.0001	Measured
	SD Card	SanDisk 8 GB Class 4	1	0.5231	±0.0001	Measured
	Communication Module	NRF24L01	1	2.0659	±0.0001	Measured
	Processor	SAMD21 MCU Dev Breakout	1	5.0852	±0.0001	Measured
	Payload RTC	SAMD Internal RTC	1	-	-	-
	Payload Antenna	FXP380 Freedom Patch Antenna	1	1.0741	±0.0001	Measured
	Payload radio	XBEE Pro S2C	1	3.8123	±0.0001	Measured
	Audio Buzzer	Multicomp MCKPI-G2437-3671 Piezo Buzzer	1	3.0156	±0.0001	Measured
	Battery	Samsung 18650 25R	1	45.0241	±0.0001	Measured

Mass Budget (2/10)

CanSat System	Component	Model Name	Quantity	Mass (g)	Uncertainty	Determination
	Voltage Regulator	LM1117 LDO	1	0.1121	±0.0001	Measured
	PCB (10% error)	-	2	8.0	±0.8	Estimated (Vendor)
	Boost Converter	LTC3121	1	0.1865	±0.0001	Measured
	Ambient Light Sensor	-	1	0.1795	±0.0001	Measured
Payload (Section-B: Camera Stabilisation Section)	Battery	Envie Battery	1	31.8451	±0.0001	Measured
	Processor	Arduino Pro Mini	1	6.0125	±0.0001	Measured
	Servo	SG90	1	9.0321	±0.0001	Measured
	Pitch and roll sensor	MPU 9250	1	1.5126	±0.0001	Measured
	Bonus camera	Piquancy Ultra HD	1	20.0451	±0.0001	Measured
	SD Card	Sandisk SD Card Class 4	1	0.5642	±0.0001	Measured
	Communication Module	NRF24L01	1	2.0789	±0.0001	Measured
	Voltage Regulators	LM1117 LDO, LM7805 LDO	2	1.6957	±0.0001	Measured
	PCB (10% error)	-	1	3.0	±0.3	Estimated (Vendor)
	Miscellaneous (LEDs and other passive components)	-	-	15	-	Estimated
			Total	**179.7977**		

Mass Budget (3/10)

Container Electronics Components

CanSat System	Component	Model Name	Quantity	Mass	Uncertainty	Determination
Container	Processor	AT Tiny 85	1	1.0159	±0.0001	Measured
	Battery	Samsung 18650 25R	1	45.0147	±0.0001	Measured
	Air Pressure Sensor	BMP280	1	1.3735	±0.0001	Measured
	Transistor	TIP120 BJT	1	0.1465	±0.0001	Measured
	Audio Buzzer	Multicomp MCKPI-G2437-3671 Piezo Buzzer	1	3.0987	±0.0001	Measured
	Nichrome Wire (10% error)	-	1	3.0	±0.3	Estimated
	PCB (10% error)	-	1	2.0	±0.2	Estimated (Vendor)
	Voltage Regulator	LM1117 LDO	1	0.1124	±0.0001	Measured
	Miscellaneous (LEDs and other passive components)	-	-	12		Estimated
			Total	**67.7617**	**±0.5006**	

we cannot use HIPS for any part, max working temperature is between 60-70

get (4/10)

Mechanical Structural Elements

		Material	Quantity	Mass(g)	Uncertainty	Determination
Payload	Payload top	SLS 3D-printed HIPS	1	12.5421		Measured
	Structural member	FDM 3-D printed Polypropylene	3	10.51		SolidWorks estimates
	Structural support	FDM 3-D printed Polypropylene	6	14.23		SolidWorks estimates
	Rotor hub	Blow-Molded Polycarbonate	1	19.3214		Measured
	Rotors	Blow-Molded Polycarbonate	4	22.10		SolidWorks estimates
	Setup for camera stabilization	SLS 3-D printed PLA	1	18.37		SolidWorks estimates
			Total	**97.0735**		
Container	Parachute module	SLS 3-D printed HIPS	1	14.37		SolidWorks estimates
	Electronics module	SLS 3-D printed HIPS	1	11.51		SolidWorks estimates
	Main body	FDM 3-D printed HIPS	1	42.46		SolidWorks estimates
	Parachute Mount	SLS 3-D printed HIPS	2	1.8230		Measured
			Total	**70.1630**	**10.2201**	

we cannot use HIPS for any part, max working temperature is between 60-70

Shikhar M

get (5/10)

Mechanical Non-Structural Components

		Dimensions	Quantity	Mass(g)	Uncertainty	Determination
Payload	Angular Bearing	FAG 7200B	1	15		Data sheet
	Nut	M4 Pan head	3	5.1369		Measured
	Bolt	M4 Pan head	3	12.3999		Measured
	Screws	ST4-20 cros head screws	21	10.7625		Measured
	Sorbothane sheet(10% error)	1 Sheet	1	5.0		Estimated
	Elastic strands	0.25 metres	-	4.2200		Measured
			Total	**52.5193**	**1.5005**	
Container	Parachute	Hexagonal with side 230mm	1	16		Data sheet
	Nut	M4 Pan head	1	1.7123		Measured
	Bolts	M4 Pan head	1	4.1333		Measured
	Screws	ST4-20 cros head screws	16	8.2100		Measured
	Elastic strands	1 metre	-	1.8100		Measured
			Total	**31.8656**		

we cannot use HIPS for any part, max working temperature is between 60-70

dget (6/10)

		Payload	Uncertainty	Container	Uncertainty
	Structural Elements)	52.5193		31.8656	
	Structural Elements	97.0735		70.1630	
Electronics	Components	179.7977		67.7617	

	Payload	Uncertainty	Container	Uncertainty
Components (Non-Structural Elements)	232.3170		99.6273	
Structural Elements	97.0735		70.1630	

	Total Mass	Uncertainty
Components (Non-Structural Elements)	331.9443	
Structural Elements	167.2365	

	Total Mass	Uncertainty
Container	167.7903	
Payload	329.3905	

Mass Budget (7/10)

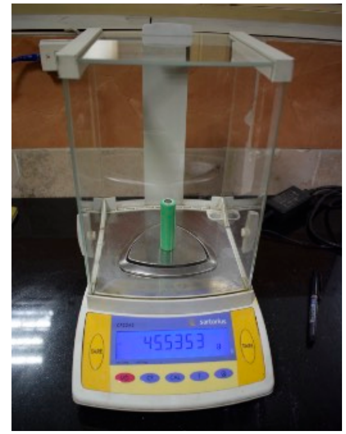
Total Mass: 499.1808 17.9442

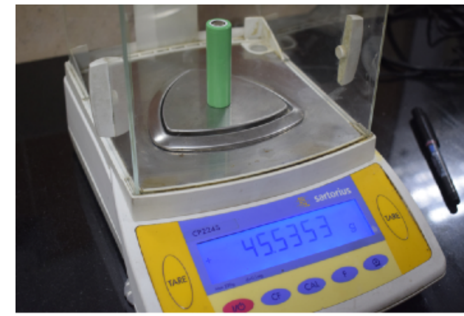
Limit	Total Mass	Margin	Method of Correction
Upper	517.1250	+17.2150	Decrease weight*
Lower	481.2366	-18.7634	Increase weight*

***Through topological optimization on SolidWorks**

Mass Budget (8/10)

Sources of Uncertainties





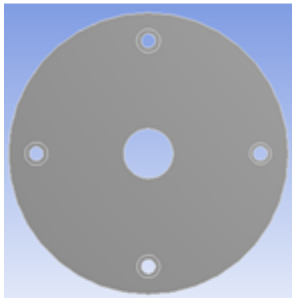
- ❖ Least count of the weighing scale used is 0.1 g, an error of 0.1 g is introduced in all the components whose weight is measured
- ❖ SolidWorks provides an estimated mass of the design based on ideal manufacturing and ideal material properties, which is not achievable so an error of 10% of the estimated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

Methods of Correction for weight

- ❖ Mass of electronic components and mechanical non structural elements is fixed and the uncertainties arising can only be confirmed after complete assembly of the model
- ❖ But a variation in mass can be obtained through optimization of the design, so as to achieve the complete mass in a range of 500g +/-10g
- ❖ Topology optimizations are used to reduce the weight of the structure keeping the factors of strength intact which results in weight reduction
- ❖ At present 30% weight is reduced and this value can be increased up to 50% if complete assembly weighs over 510g or it can be reduced to 20%if the complete assembly weighs less than 490g

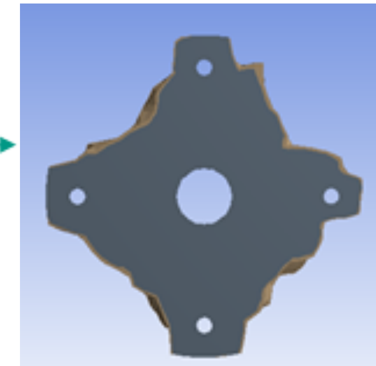
Mass Budget (9/10)

Methods of correcton for weight



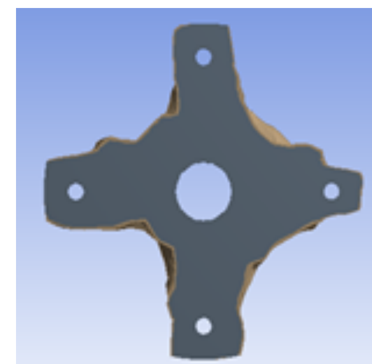
Initial design

If mass 490 g more percentage of mass will be retained after optimization



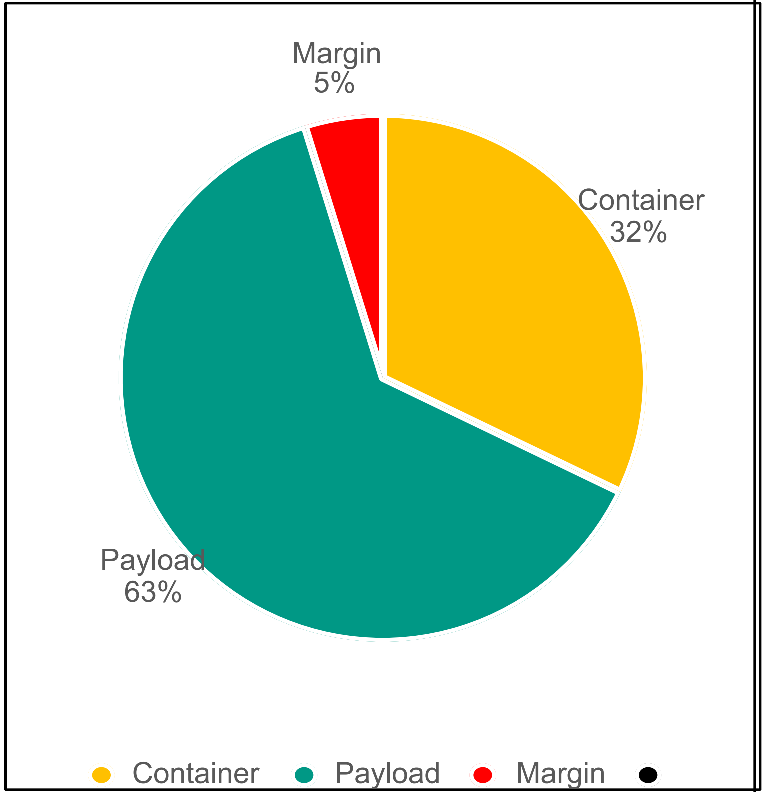
Design to be used if mass is between 490-500 g

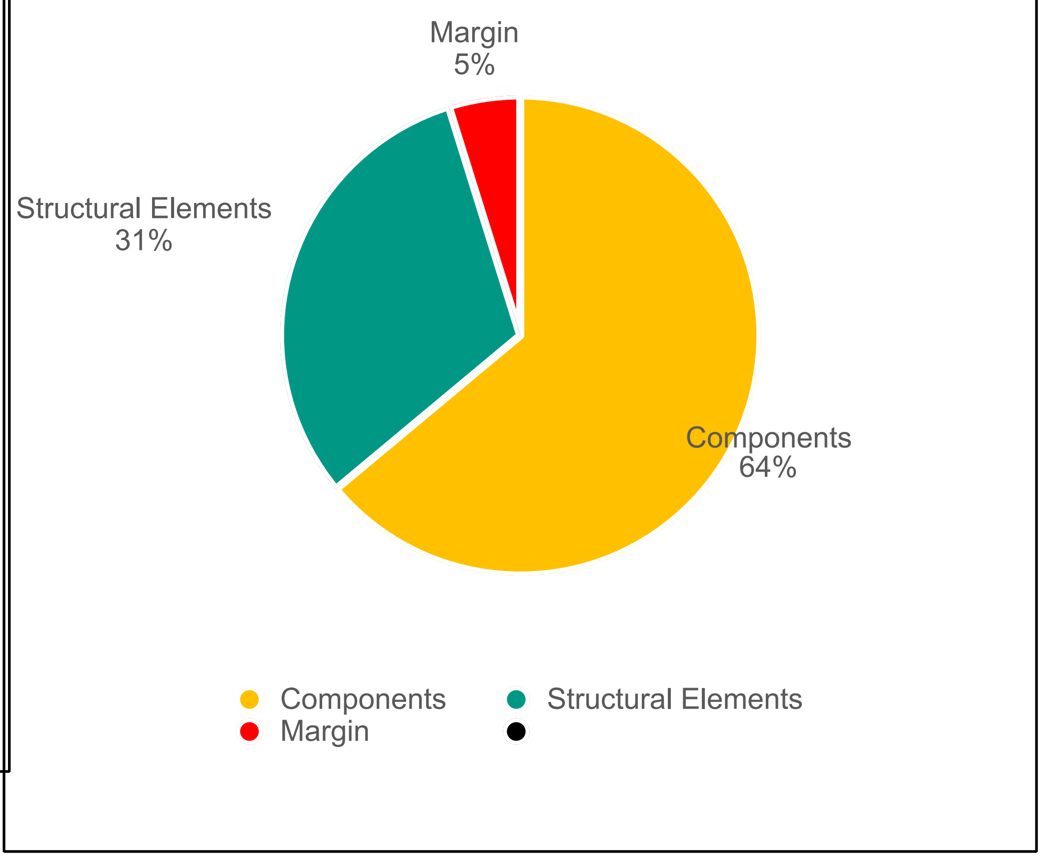
If mass 510 g less percentage of mass will be retained after optimization



An exemplary optimization of parachute lid is depicted where the mass of the lid can be kept between the two extremes depending upon the weight constraint. Similar analysis can be done on all structural elements to keep the mass in desired range.

Mass Budget (10/10)

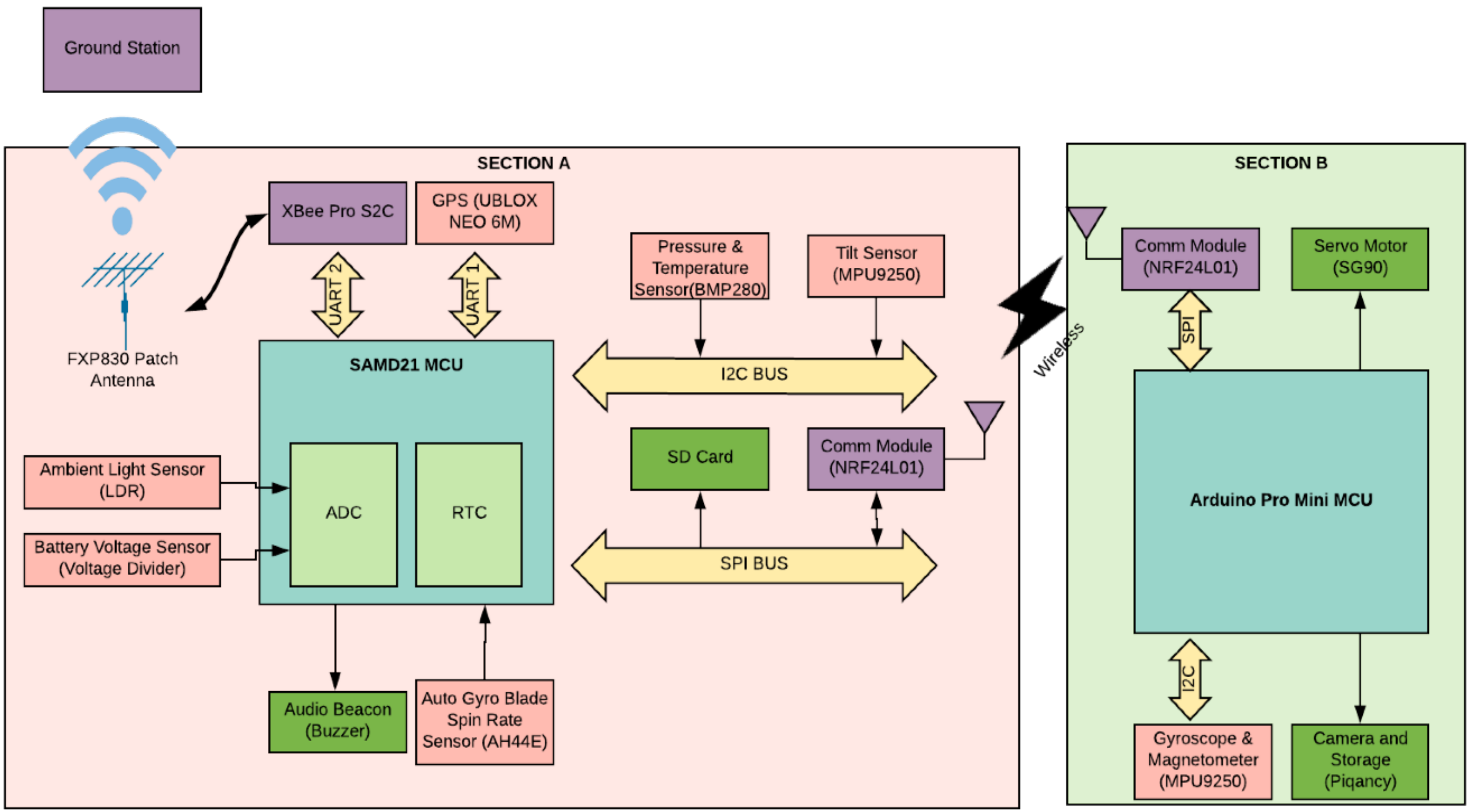




Communication and Data Handling (CDH) Subsystem Design

Sourav Bhattacharjee

Payload CDH Overview



Payload Processor and Memory Trade & Selection (1/7)

SECTION-A: Telemetry Section

Microcontroller Board	Input Voltage(V)	CPU Speed(MHz)	Boot time(s)	Processor	Flash Memory (kB)	SRAM (kB)	EEPROM (kB)	Data Interfaces
SparkFun SAMD21 Mini Breakout	**3.3 - 9**	**48**	**~1.7**	**ARM Cortex-M0+ CPU (32 bit)**	**256**	**32**	**32**	**1. 6 Serial Communication Interfaces, configurable to operate as either: • USART • I2C(3.4MHz) • SPI • LIN Slave 2. 21 GPIO's 3. 11 ADC Pins at 12 bit resolution 4. 1 DAC Pin at 10 bit Resolution**
Arduino Nano	4.5 – 9	16	~2-3	AVR enhanced RISC architecture (8 bit)	32	2	1	1. 1 Programmable USART 2. 1 Master/Slave SPI Serial Interface 3. 1 Byte-Oriented 2 wire Serial Interface 4. 21 GPIO's 5. 7 ADC pins at 10 but resolution

SECTION-A: Telemetry Section

Feature	Quantity
Processor	ARM Cortex-M0+ CPU running at up to 48MHz Single-cycle hardware multiplier Micro Trace Buffer (MTB)
Memory	256KB Flash Memory 32KB SRAM 32KB of EEPROM (emulated in Flash)
Serial Interfaces available	Up to six Serial Communication Interfaces (SERCOM), each configurable to operate as either: • USART with full-duplex and single-wire half-duplex configuration • I2C up to 3.4MHz • SPI • LIN slave
Serial Interfaces used	UART: 2 + 1 (for debug only) I2C: 1 SPI: 1
GPIOs available	Total: 21 Analog Input: 11 Analog Output: 1 Digital: 21 PWM: 10 HW Interrupts: 21
GPIOs used	Total: 13 Analog Input:1 Digital: 12 HW Interrupts: 2

Reasons for selection of **Spark Fun SAM D21 Mini Breakout** :

- Multiple UART interfaces: Allows faster communication with multiple UART peripherals·
- Faster CPU and greater memory: Allows faster code execution and more space for code·
- Inbuilt RTC: Allows us to eliminate external RTC·
- 3.3V operation: Allows us to build a more power efficient system

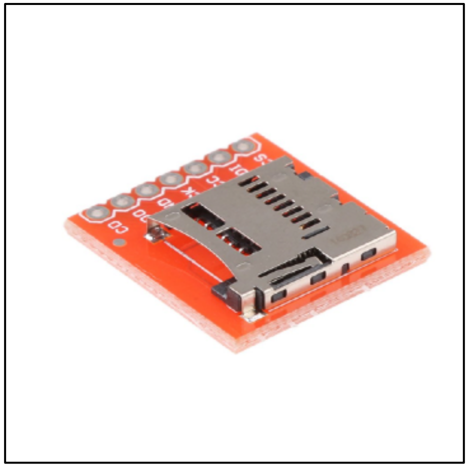
SD Card Shield Selection

SECTION-A: Telemetry Section

Model Number	Connection Type	Size(cm2)	Weight (gram)	Supply Voltage (V)	Price($)
Street27 MicroSD TF Memory Card Board Adapter Shield	**SPI**	**2.5 x 2.4**	**4.54**	**3.0 to 5.0**	**3.48**
CENTIoT Micro SD mini Storage Board TF Card Reader Memory Shield Module	SPI	4.1 x 2.4	10.0	4.5 to 5.5	7.06

Reasons for selection of **Street27 MicroSD TF Memory Card Board Adapter Shield**:

1. Less weight
2. Smaller footprint
3. No redundant LDO and level shifter: More power efficient



please enter dimensions

rocessor & Memory Trade & (4/7)

SECTION-A: Telemetry Section

Model Number	Speed	Dimensions (mm)	Capacity	Operating Temperature	Price($)
Sandisk 8GB Class 4	**40 Mb/s**	**15 x 11**	**8 GB**	**-25C to 85C**	**5.77**
Strontium 8GB MicroSDHC Class 6	10 Mb/s	15 x 11	8 GB	-13C to 80C	1.48

Reasons for selection of **Sandisk 8GB Class 4** :

1. High Speed
2. More durable.
3. Small size and low weight.
4. Supports all data formats.

Payload Processor and Memory Trade & Selection (5/7)

SECTION – B: Stand-Alone Camera Stabilization Section

Microcontroller Board	Input Voltage(V)	CPU Speed(MHz)	Boot time(s)	Processor	Flash Memory (kB)	SRAM (kB)	EEPROM (kB)	Data Interfaces
SparkFun SAM D21 Mini Breakout	3.3-12	48	~1.7	ARM Cortex-M 0 + CPU (32 bit)	256	32	32	1. 6 Serial Communication Interfaces, configurable to operate as either: • USART • I2C(3.4MHz) • SPI • LIN Slave 2. 21 GPIO's 3. 11 ADC Pins at 12 bit resolution 4. 1 DAC Pin at 10 bit Resolution
Arduino Pro Mini	**4.5 - 9**	**16**	**~2-3s**	**AVR enhanced RISC architecture (8 bit)**	**32**	**2**	**1**	**1. 1 Programmable USART 2. 1 Master/Slave SPI Serial Interface 3. 1 Byte-Oriented 2 wire Serial Interface 4. 21 GPIO's 5. 7 ADC pins at 10 but resolution**

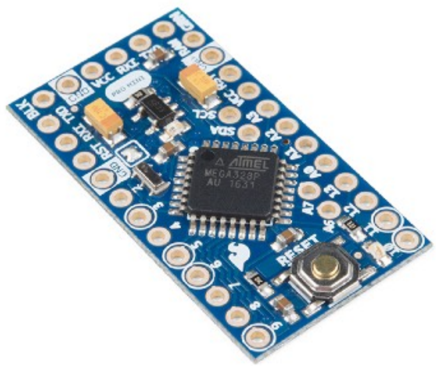
Payload Processor and Memory Trade & Selection (6/7)

SECTION – B: Stand-Alone Camera Stabilization Section

Feature	Quantity
Processor	AVR enhanced RISC architecture (8 bit) running at 16 MHz
Memory	32KB Flash Memory 2KB SRAM 1KB of EEPROM
Serial Interfaces available	1 Programmable Serial USART 1 Master/Slave SPI Serial Interface 1 Byte-oriented 2-wire Serial Interface (Philips I2C compatible)
Serial Interfaces used	UART: 1 (for debug only) I2C: 1 SPI: 1
GPIOs available	Total: 21 Analog Input: 8 Digital: 21 PWM: 6
GPIOs used	Total: 8 Digital: 8 PWM: 1

Reasons for selection of **Arduino Pro Mini (5v/16MHz)** :

- · Cheaper
- · Lesser number of redundant MCU peripherals
- · 5V operation: Allows us to directly communicate to all the PCB I/O devices



Payload Processor & Memory Trade & Selection (7/7)

SECTION – B: Stand-Alone Camera Stabilization Section

Model Number	Speed	Size (mm²)	Capacity	Operating Temperature	Price($)
Sandisk 8GB Class 4	**40 Mb/s**	**15 x 11**	**8 GB**	**-25C to 85C**	**5.77**
Strontium 8GB MicroSDHC Class 6	10 Mb/s	15 x 11	8 GB	-13C to 80C	1.48

Reasons for selection of **Sandisk 8GB Class 4** :

1. High Speed
2. More durable.
3. Small size and low weight.
4. Supports all data formats.

Calculate range based on input power, tx gain, rx gain, cable loss,

Shikhar M
Range table addition

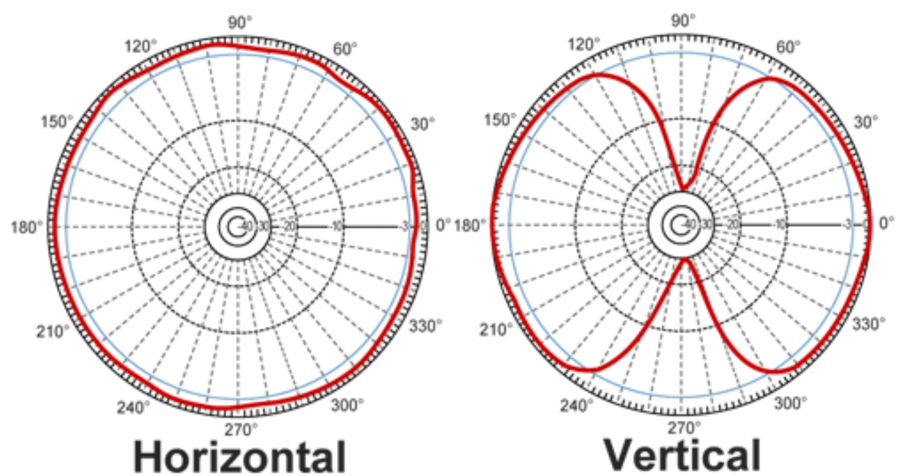
ntenna Trade and Selection

				VSWR	Weight	Dimensions	Connector	Polarization	Temperature	Input Power	Range* (m)	Cost
Freedom	GHz		Ohms	< 2.0	1g	42 x 7	Ipex MHF	Linear	-40C to 85C	2W Max	1710	$7.88
Duck Antenna	2.4 - 2.5 GHz	5.5 dBi	50 Ohms	< 2.0	25g	210 x 19	Type N-Male	Linear Vertical	-40 to 85C	50W	3329	$2.09

*Range is calculated under conditions shown below

Antenna Radiation Patterns

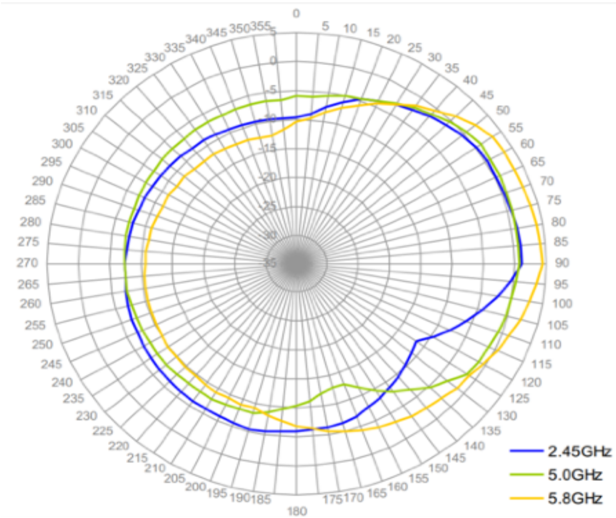
Rubber Duck Antenna



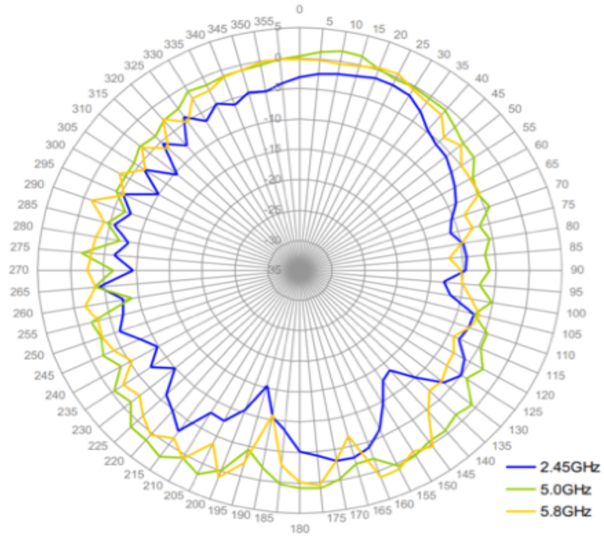
Parameter	Value
Antenna gain(dB)	2.6
Transmission Power(dBm)	33.103
Operating Frequency(MHz)	2400
Cable Loss(dB)	4
Receiver Sensitivity(dBm)	-73
Free space path loss(dB)	111.703

Calculated Range = 1710m

Payload Antenna Trade & Selection (2/2)



Horizontal Plane



Vertical Plane

FXP830 Freedom

Reasons for selection of **FXP830**:
1. Omnidirectional in nature this antenna allows data transmission in all directions.
2. It's light weight and negligible size helps in the accommodation of other components.
3. Low connector impedance causes low signal loss.

Payload Radio Configuration (1/2)

Device	Operating frequency	Tx supply current	Rx supply current	Sensitivity	Cost
XBee Pro S2B	2.4 GHz	205mA @ 3.3V	47mA @ 3.3 V	-102 dBm	28.36
XBee Pro S2C	2.4 GHz	120mA @ 3.3V	31mA @ 3.3V	-101 dBm	27.65
XBee-PRO ZNet 2.5	900 MHz	265 mA	65 mA	-92 dBm	74

Reasons for selection of **XBEE Pro S2C**:
1. Data/Clock rates of up to 5Mb/s are possible.
2. High operating frequency.
3. Low Tx and Rx currents.

- **Team ID: 1516**
- **Transmission is ceased once landing ... eter, blade spin rate sensor)**
- **Upon powering up, the CanSat pay ... Hz sample rate.**

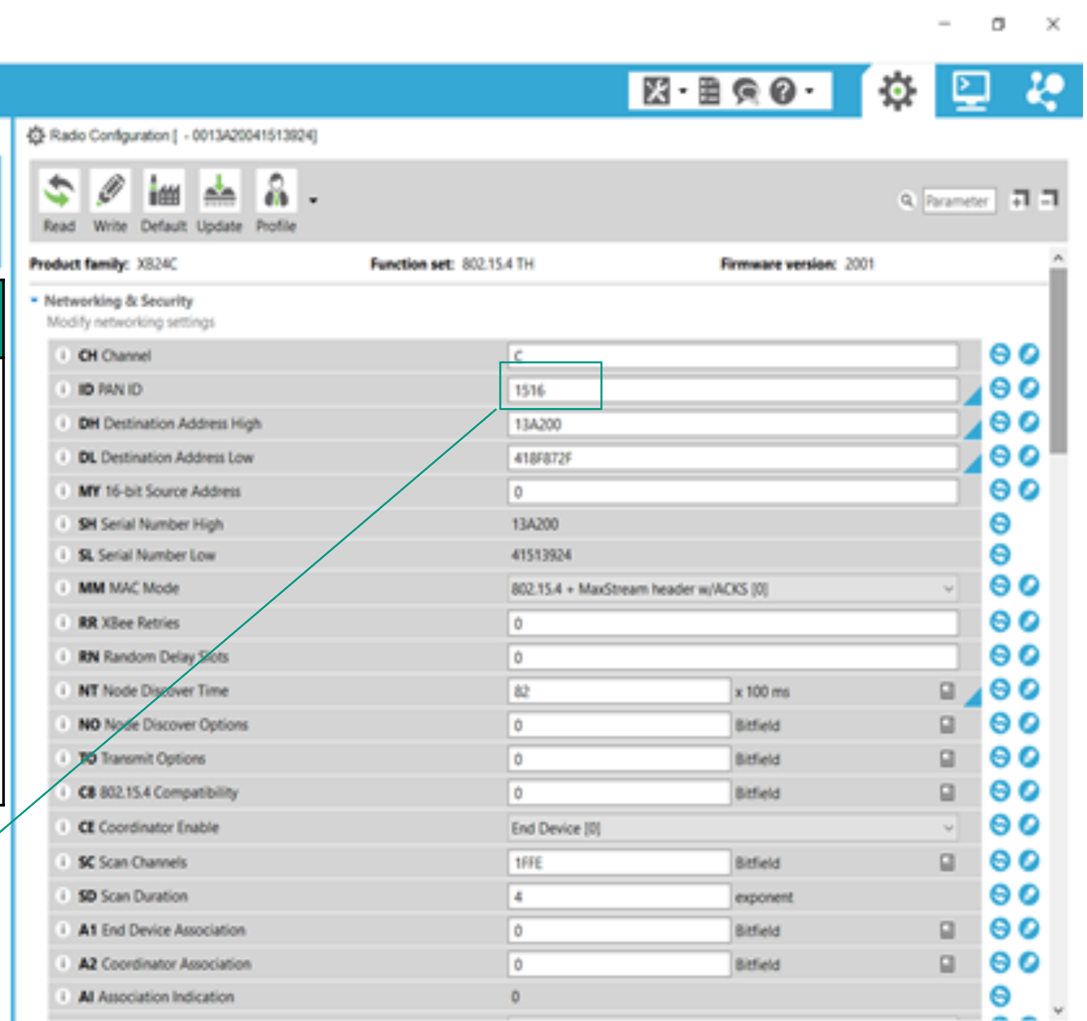
Include transmission control
How is this managed during each mission phase?

Radio Configuration (2/2)

Transmission Control

Transmission is ceased once landing state is detected by various sensor data:

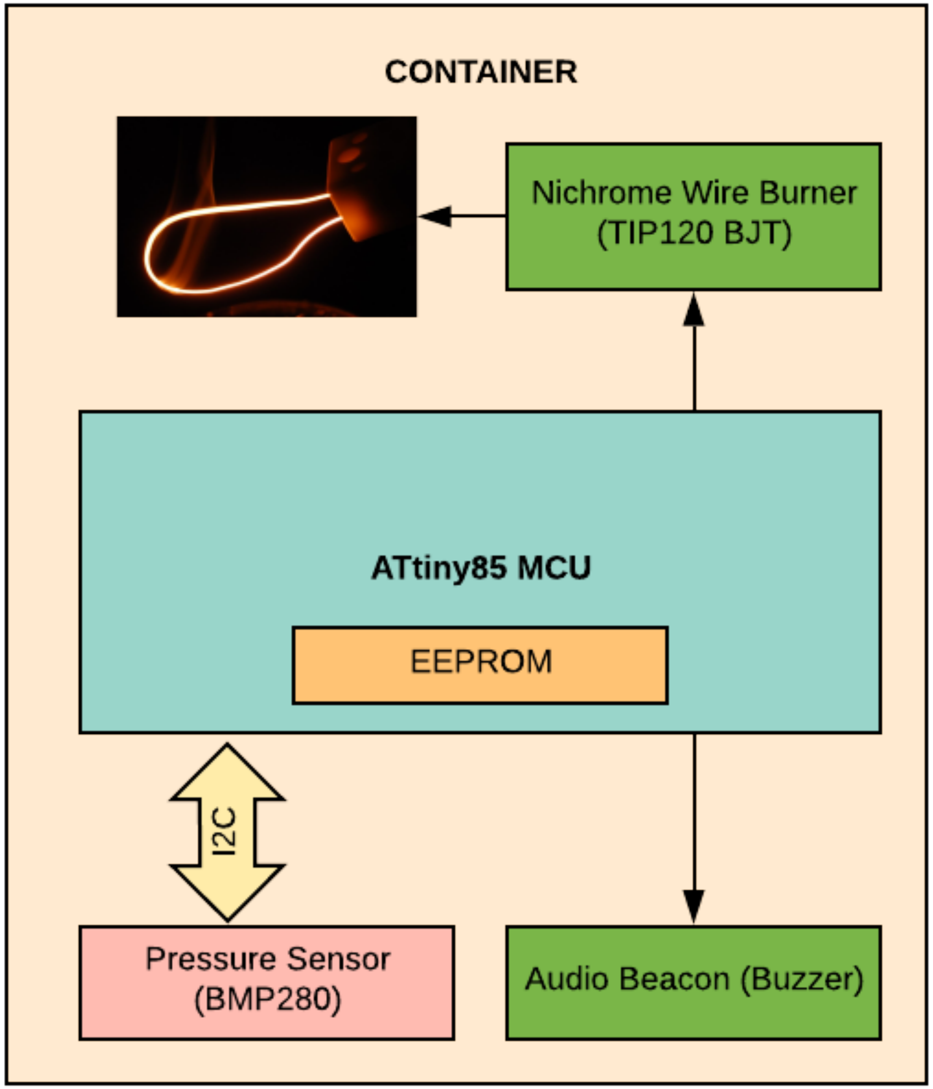
- Accelerometer reads a sharp negative pulse.
- Air pressure reaches maxima and becomes constant.
- Blade Spin Rate becomes zero.
- Pitch and roll become constant at some non-zero value.



PANID set to team number

XCTU Screenshot

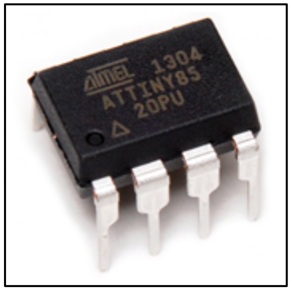
Container CDH Overview



Container Processor & Memory Trade & Selection (1/3)

Microcontroller Board	Input Voltage(V)	CPU Speed (MHz)	Boot time	Processor	Memory			Data Interfaces
					Flash	SRAM	EEPROM	
ATtiny85/V	**1.8 - 5**	**8**	**64 ms**	**Advanced RISC Architecture (8 bit)**	**8k**	**512 B**	**512 B**	**1. 1 USI – Universal Serial Interface with start condition detector. 2. 6 GPIOs 3. 4 ADC pins at 10 bit ADC**
Arduino Pro Mini	4.5 - 9	16	~2-3s	AVR enhanced RISC architecture (8 bit)	32k	2k	1k	1. 1 Programmable USART 2. 1 Master/Slave SPI Serial Interface 3. 1 Byte-Oriented 2 wire Serial Interface 4. 21 GPIO's 5. 7 ADC pins at 10 but resolution

Reasons for selection of **ATtiny 85**:
- Small form factor saves weight and space.
- More power efficient.
- Easy to programme and test.



Container Processor & Memory Trade & Selection (2/3)

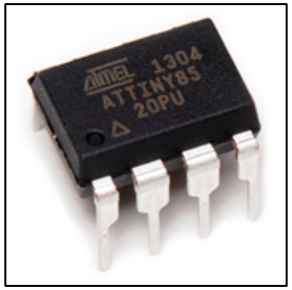
Feature	Quantity
Processor	AVR enhanced RISC architecture (8 bit) running at 10 MHz
Memory	8KB Flash Memory 512 Bytes SRAM 512 Bytes of EEPROM
Serial Interfaces available	1 USI – Universal Serial Interface with start condition detector.
Serial Interfaces used	I2C: 1
GPIOs available	Total: 6 Analog Input: 4 Digital: 6 PWM: 2
GPIOs used	Total: 3 Digital: 3 PWM: 1

Container Processor & Memory Trade & Selection (3/3)

Memory Selection

Model Number	Weight	Dimensions (mm2)	Capacity	Interface	Price($)
Internal EEPROM	**-**	**-**	**512 Bytes**	**-**	**-**
EEPROM AT24C256C	1g	4.8 x 5.8	256 kB	I2C	1.40

Reasons for selection of **internal EEPROM** :
1. No extra component required.
2. Saves weight and space.
3. Faster.
4. Avoids using I2C.

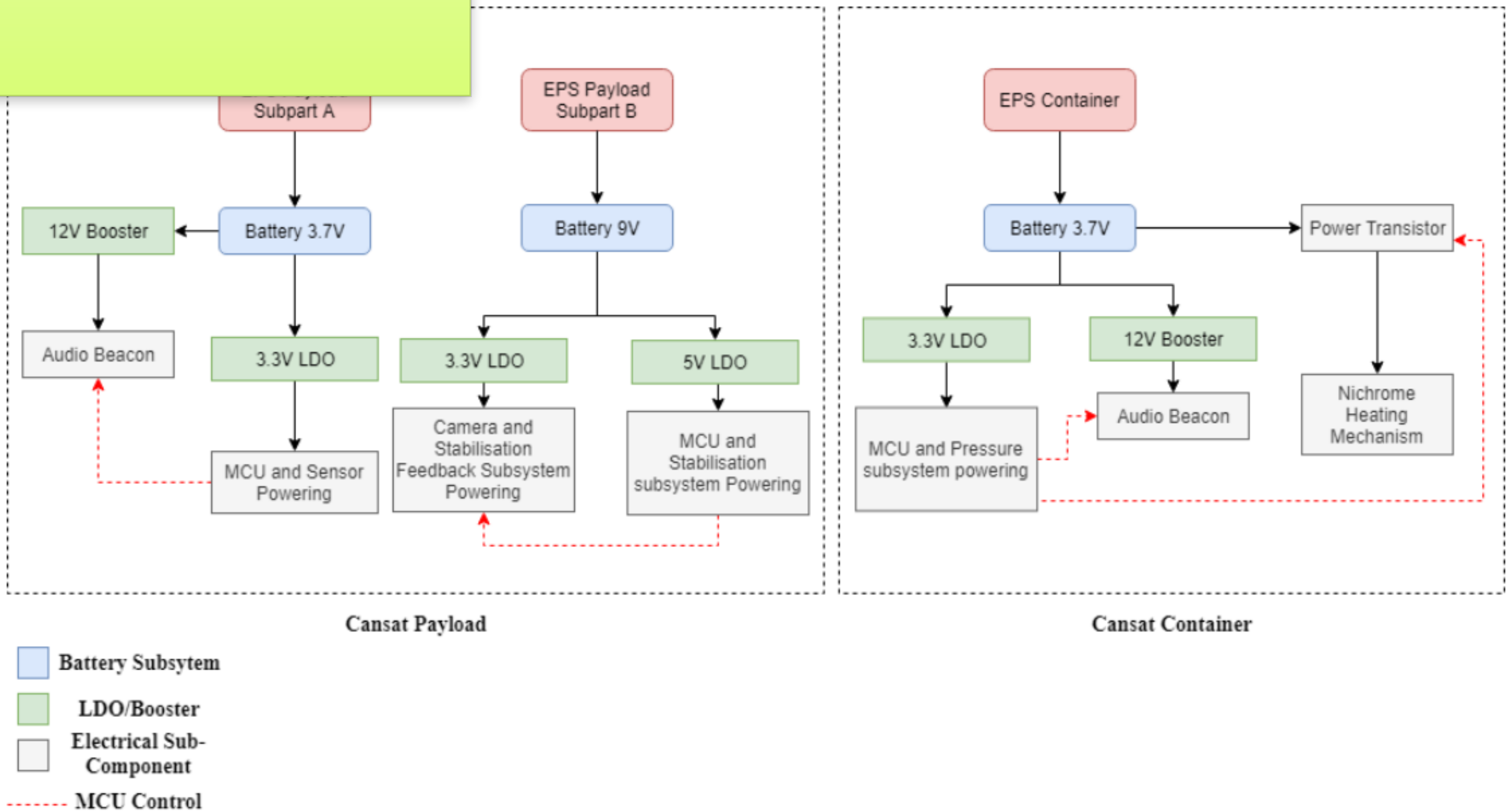


Electrical Power Subsystem (EPS) Design

Shikhar Makhija

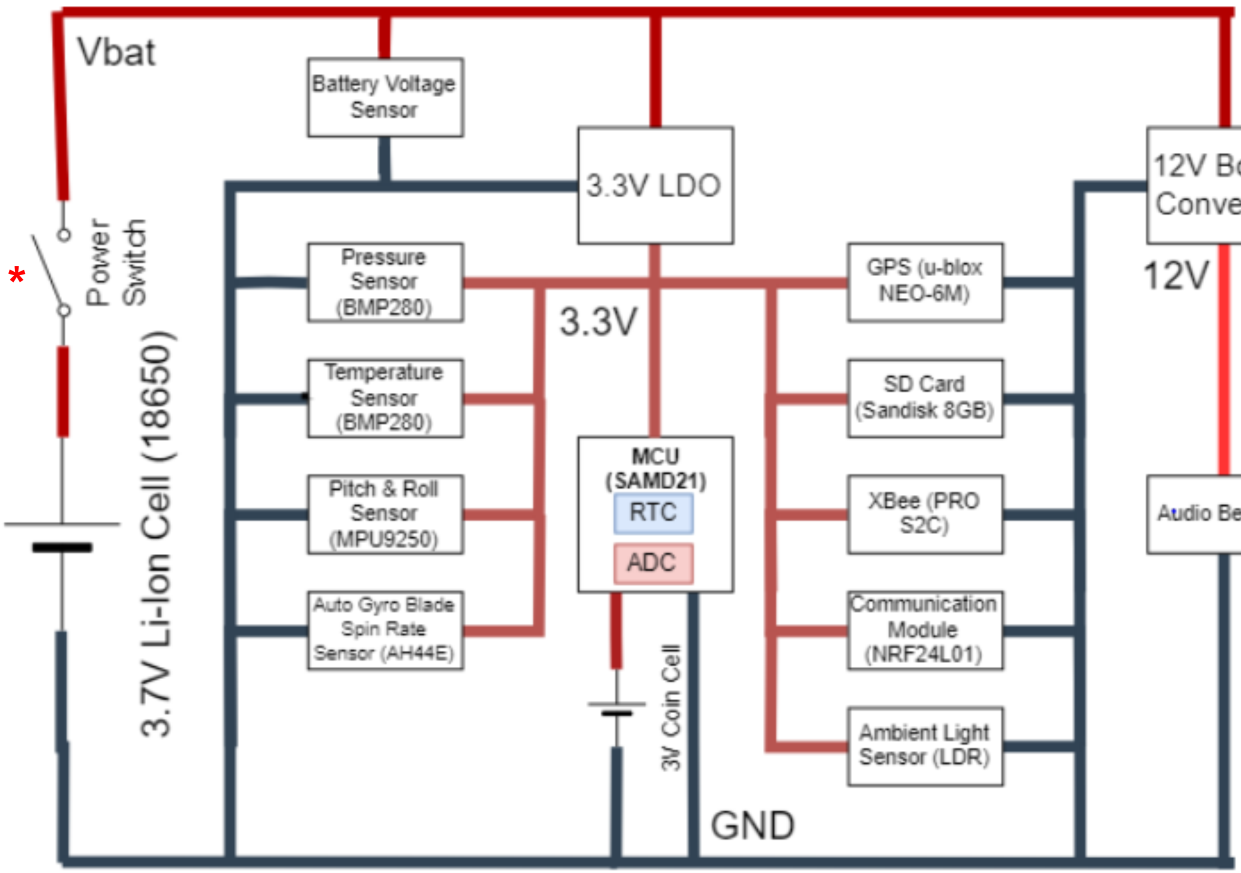
Remove the switch because one
swith doesnot control all the systems

view

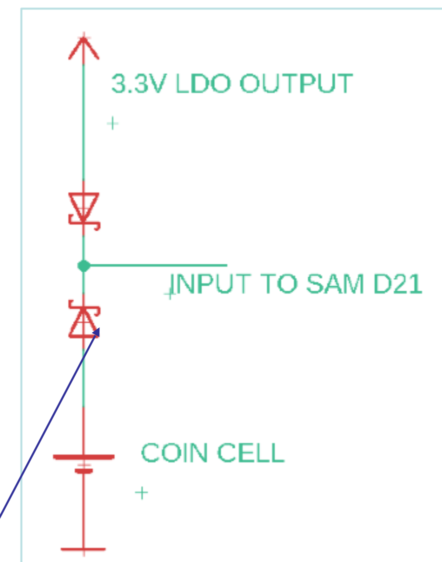


Payload Electrical Block Diagram (1/2)

The Payload EPS, is divided into two sub-parts A and B.



Sub-part: A



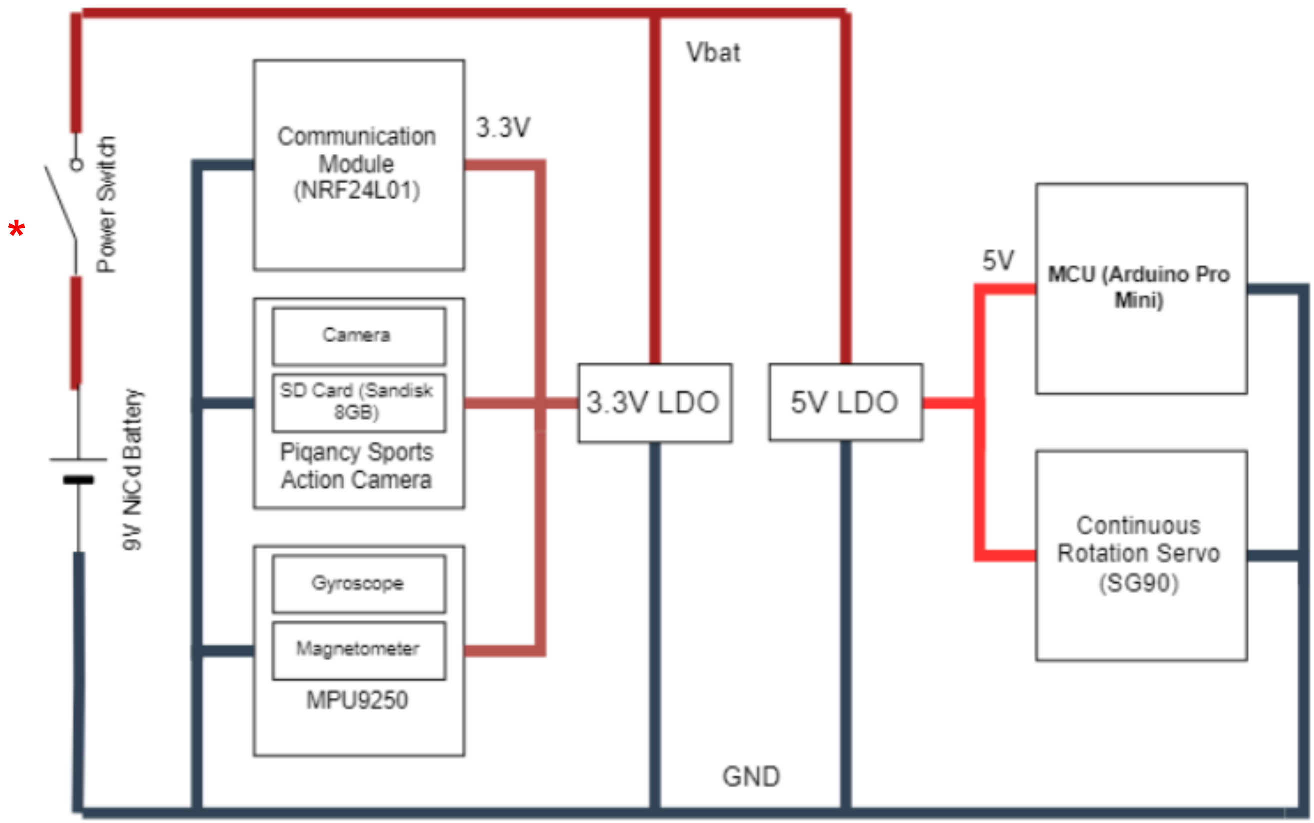
Schottky diode for faster switching and low drop

Battery to Coin-cell Switching Circuit (Internal RTC Management)

Payload Electrical Block Diagram (2/2)

The Payload EPS, is divided into two sub-parts A and B.

***Payload is divided into two parts: Section A- Telemetry Section and Section B: StandAlone Camera Stabilization Section**



Sub-part: B

Umbilical power source to CanSat: DC Jack with voltage 9V.

in flight time 2 min

ower Budget (1/4)

he Payload Power Budget – Subpart A

Pre – Flight Time = 2 hrs.

In – Flight Time = 2 min = 0.033 hrs.

Post – Flight Time = 1 hrs.

Component	Current (mA)			Voltage (V)	Duty Cycle (%)			Average Power Consumed (mW)			Average Energy Consumed (Wh)	Source
	Min	Typical	Max		Pre-Flight	In-Flight	Post-Flight	Pre-Flight	In-Flight	Post-Flight		
Sparkfun SAMD21 Mini	0.025	30	92	3.3	100	100	100	99	99	99	**0.305247**	Datasheet/ Estimate
Xbee-Pro S2C	36	120	120	3.3	2	2	2	124.34	124.34	118.8	**0.377838**	Datasheet
GPS UBLOX-NEO6m	39	47	67	3.3	0	100	100	128.7	155.1	128.7	**0.39902**	Datasheet
NRF24L01	0.4	11.95	13.5	3.3	0	1.6	0	1.32	36	1.32	**0.006959**	Datasheet
Buzzer	0	20	20	12	0	0	100	0	0	240	**0.24**	Datasheet
BMP280	0.003	0.72	1.12	3.3	0	100	0	0.009	2.37	0.009	**0.000225**	Datasheet
MPU9250	0.008	3.7	3.7	3.3	0	100	0	0.027	12.21	0.027	**0.0011**	Datasheet
SD Card	0.25	3.61	75	3.3	0	4.5	0	0.825	11.92	0.825	**0.003468**	Datasheet

Payload Power Budget (2/4)

The Payload Power Trade and Selection – Subpart A

Component	Current (mA)			Volta (V)	Duty Cycle (%)			Average Power Consumed (mW)			Average Energy Consumed (Wh)	Source
	Min	Typical	Max		Pre-Flight	In-Flight	Post-Flight	Pre-Flight	In-Flight	Post-Flight		
Auto-Gyro Blade Spin Rate Sensor	6	6	9	3.3	100	100	100	19.8	19.8	19.8	**0.061049**	Datasheet
Battery Voltage Sensor	0.185	0.185	0.185	3.7	100	100	100	0.684	0.684	0.684	**0.002109**	Calculation
Ambient Light Sensor	0.165	0.247	0.33	3.3	100	100	100	0.815	0.815	0.815	**0.002513**	Calculation
Miscellaneous (LEDs and other passive components)	50	50	50		100	100	100	165	165	165	**0.508745**	Estimate
LM1117 LDO	132.04	273.41	431.83	3.7	100	100	100	52.8	109.36	52.8	**0.16751**	Estimate
LTC3121 Boost Converter	0.5	20	20	3.7	0	0	100	1.65	1.65	12.6	**0.016037**	Estimate
Total			**665.577**					**594.97096**	**738.249**	**840.381**	**2.091819**	

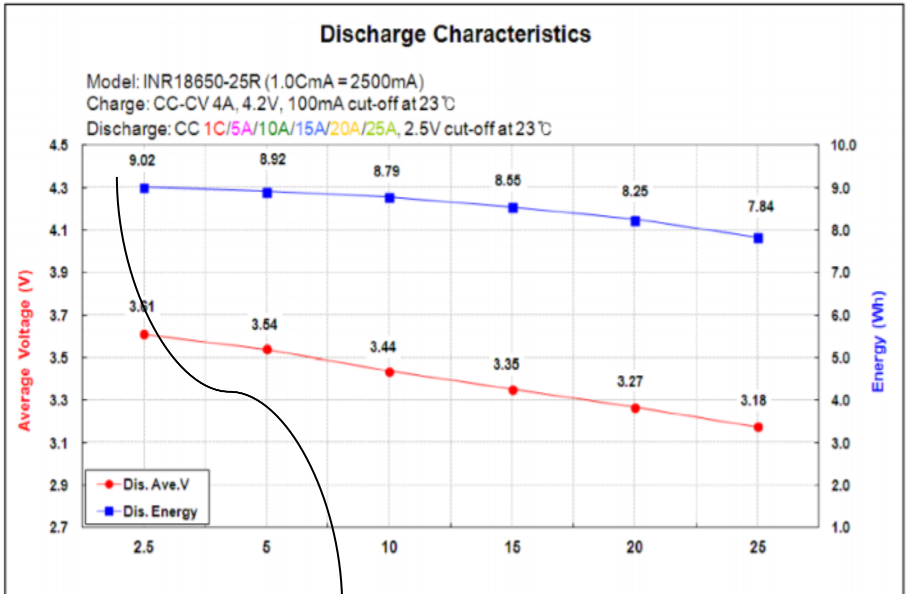
Payload Power Budget (3/4)

The Payload Power Trade and Selection – Subpart B

Component	Current (mA)			Voltage (V)	Duty Cycle(%)			Average Power (mW)			Average Energy Consumed	Source
	Min.	Typical	Max.		Pre-flight	In-flight	Post-flight	Pre-flight	In-flight	Post-flight	Net(Wh)	
Arduino Pro Mini	0.025	50	92	5	100	100	100	250	250	250	**0.770825**	Datasheet/ Estimate
Servo (SG90)	20	50	125	5	0	80	0	100	550	100	**0.345815**	Datasheet/ Estimate
MPU9250	0.0084	3.7	3.7	3.3	0	100	0	0.028	12.21	0.0277	**0.0011**	Datasheet
NRF24L01	0.4	11.95	13.5	3.3	0	1.6	0	1.32	36	1.32	**0.006959**	Datasheet
SD Card	0.25	3.61	75	3.3	0	33	0	0.825	24.92	0.825	**0.00455**	Datasheet
Piqancy Sports Action Camera	0.003	10	20	3.3	0	50	0	0.009	33	0.009	**0.002776**	Estimate
Miscellaneous (LEDs and other passive components)	50	50	50		100	100	100	165	165	165	**0.508745**	Estimate
LM1117 LDO	5	19.26	117.2	9	100	100	100	28.5	109.36	114	**0.18011**	Estimate
LM7805 LDO	4.3	160	221.3	9	100	100	100	480	640	480	**1.493312**	Estimate
Total			**338.5**					**1026**	**1821**	**1111**	**3.314192**	

Payload Power Budget (4/4)

Subpart – A: Samsung 18650 25R

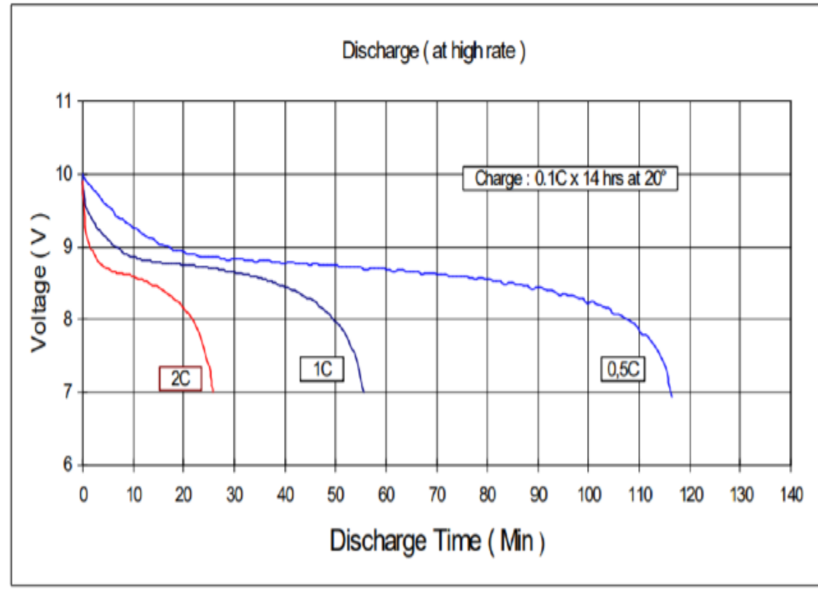


From the graph, the battery capacity is approximately, 9.250Wh at **average** current drawn rate 0. 5A (80% of peak, approx.)

Energy required by Payload Sub-Part A = 2.0918Wh

Margin Offered = 9.250 – 2.0918 = 7.1582Wh

Subpart – B: Envie 9V NiMh

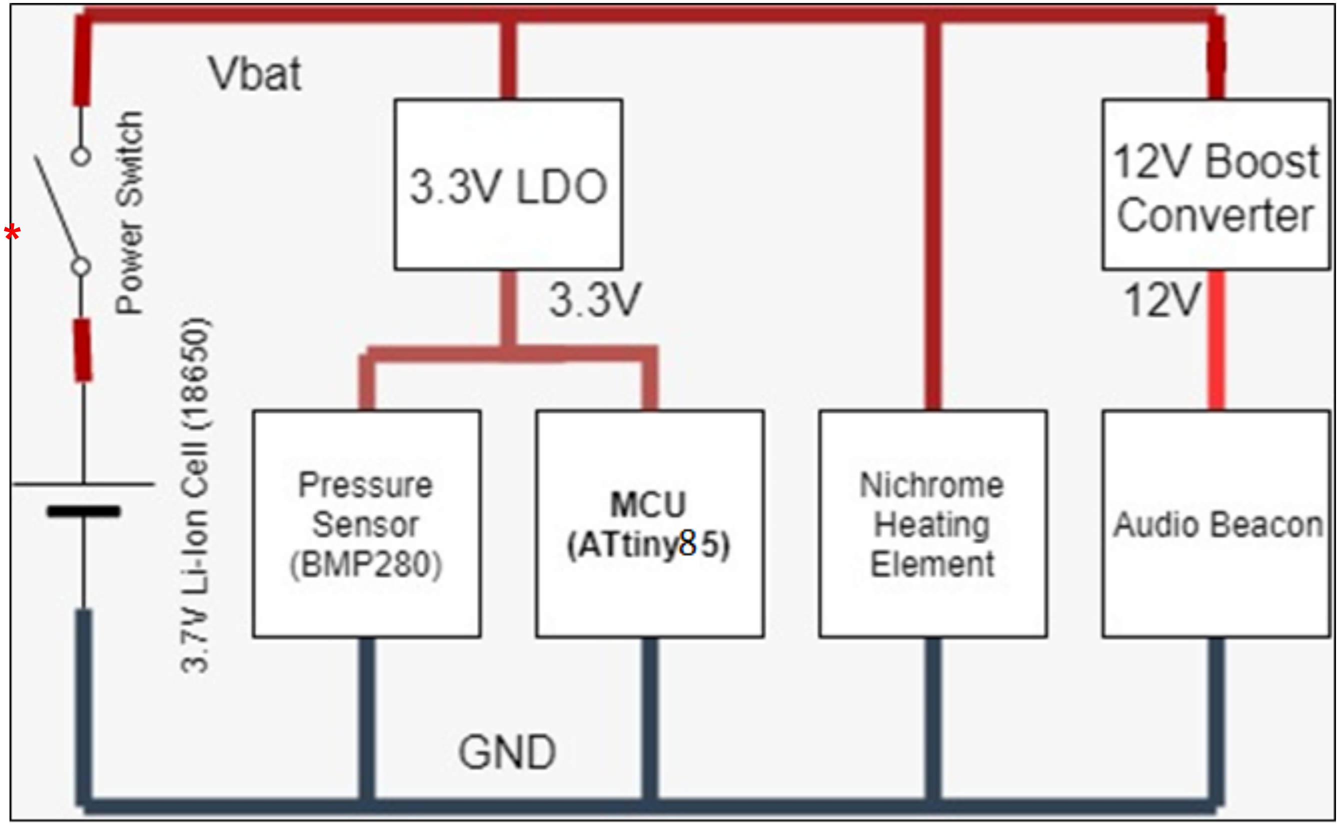


The battery capacity averaged: 8V x 700 mA = 5.6Wh

Energy required by Payload Sub-Part B = 3.314Wh

Margin Offered = 5.6 – 3.314 = 2.286Wh

Container Electrical Block Diagram



Container Block Diagram

Umbilical power source to CanSat: Five V DC Jack

Saurav current bhi likhna hai container ka

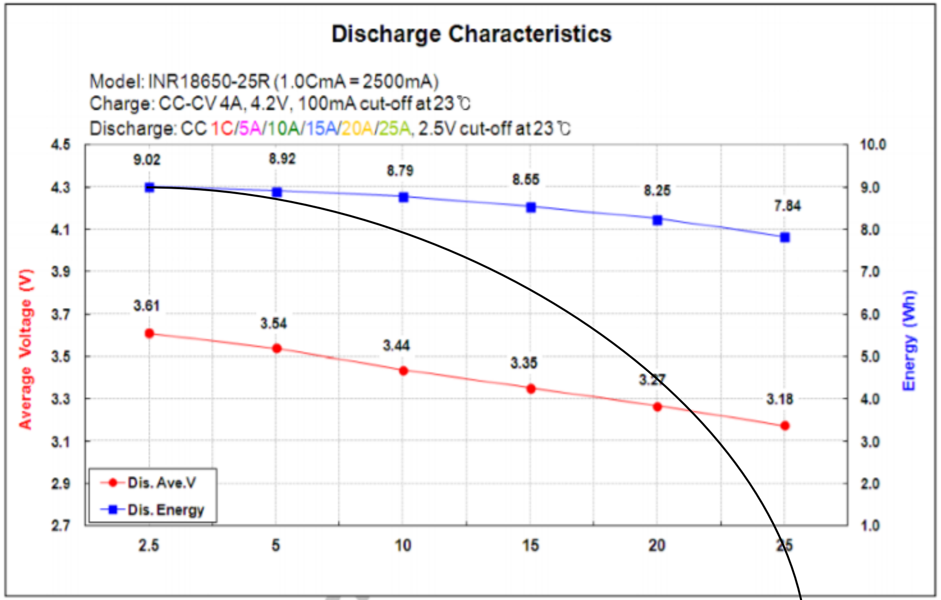
Sourav Bhattacharjee
It's fine I think. I showed battery

Power Budget (1/2)

	(mA)			Voltage (V)	Duty Cycle(%)			Average Power			Average Energy (Wh)	Source
	Min.	Typical	Max		Pre-Flight	In-Flight	Post-Flight	Pre-Flight	In-Flight	Post-Flight		
ATtiny85	0.35	2.5	10	3.3	100	100	100	8.25	8.25	8.25	**0.0254**	Datasheet/ Estimate
BMP280	0.0028	0.72	1.12	3.3	0	100	0	0.009	2.37	0.00924	**0.00022**	Datasheet
Buzzer	0	20	20	12	0	0	100	0	0	240	**0.24**	Datasheet
Nichrome Wire Burner	0	2000	2000	3.7	0	1.667	0	0	3.334	0	**0.0003**	Calculated
Miscellaneous (LEDs and other passive components)	50	50	50		100	100	100	165	165	165	**0.509**	Estimate
LM1117 LDO	5	3.22	11.12	3.7	100	100	100	2	11.288	2	**0.007**	Estimate
LTC3121 Boost Converter	0.5	20	20	3.7	0	0	100	1.65	1.65	12.6	**0.0160**	Estimate
Total			**2084.8**					**176.91**	**191.89**	**427.859**	**0.797**	

Container Power Budget (2/2)

Container: Samsung 18650 25R



From the graph, the battery capacity is approximately, 9.250Wh at **average** current drawn rate 0.5A (80% of peak, approx.)

Energy required by Container = 0.797Wh

Margin Offered = 9.25 – 0.797Wh = 8.453Wh

Flight Software (FSW) Design

Raunit Singh

FSW Overview(1/2)

Programming Language

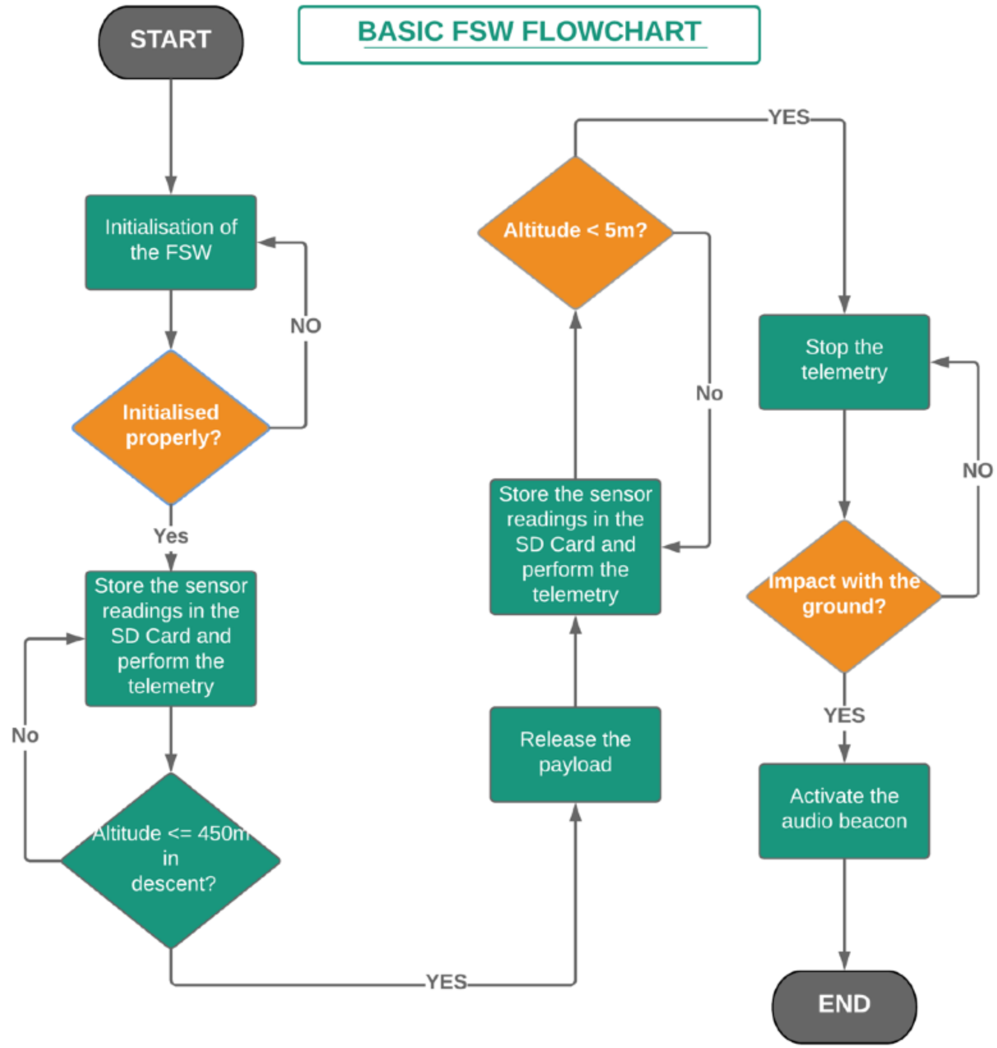
- C
- C++
- Python

Development Environment

- Arduino IDE

Rationale

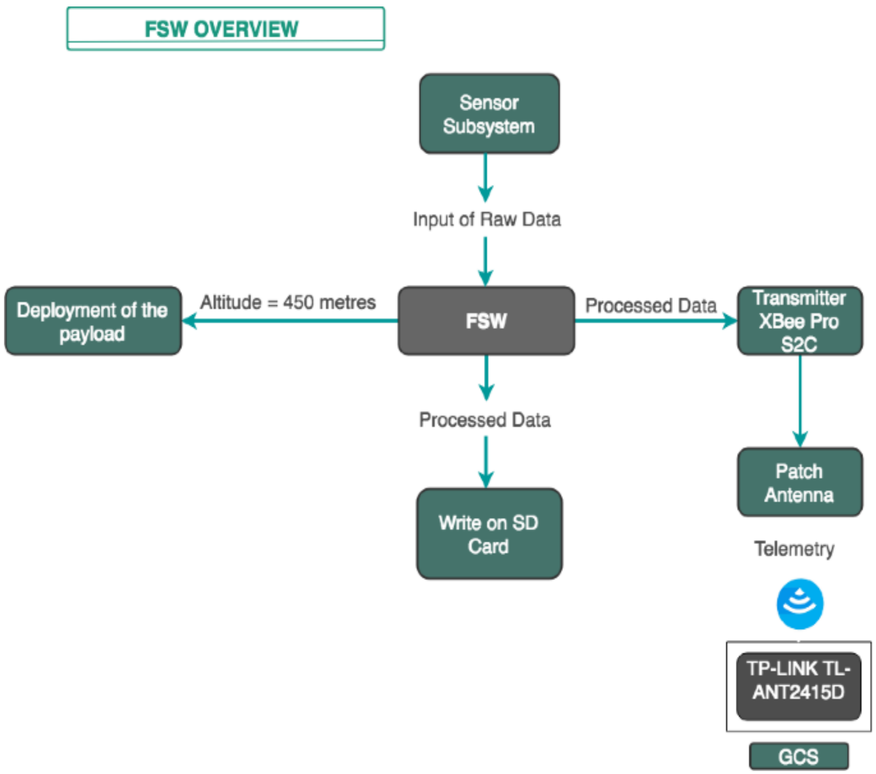
- Vast set of predefined libraries.
- Reduces hassle of interfacing with a PC.
- Memory management of C/C++ extends the support for lower end microcontrollers.
- Great community support.
- Versatile and robust.
- Extremely fast execution as compared to other languages like python.



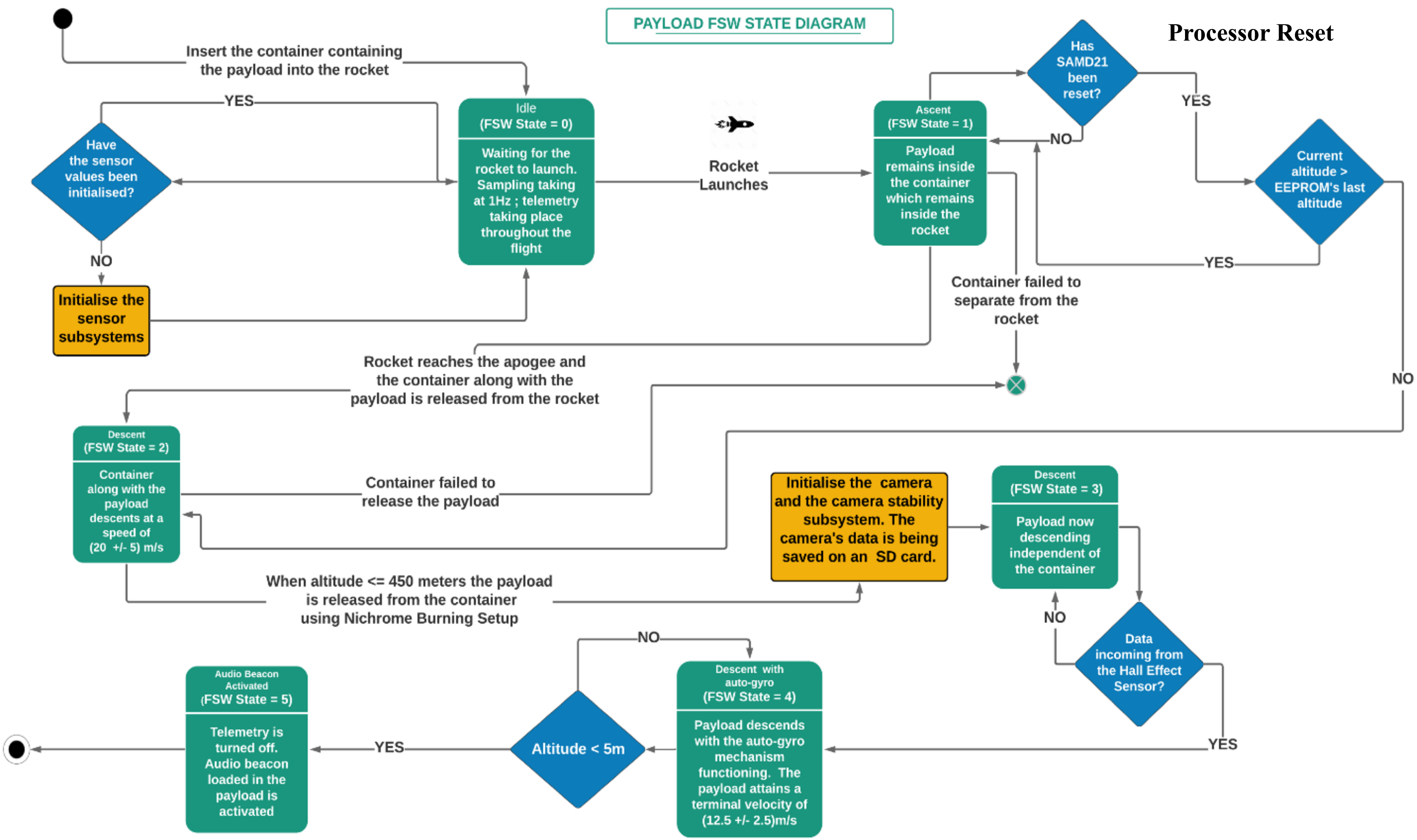
FSW Overview(2/2)

Brief Summary of FSW Tasks

- Calibrating the sensors and resetting the mission time to 0.
- Read the data from sensors (in raw format) and process the data.
- Telemetry of the processed data and storing the data in the SD card.
- Deployment of the payload when altitude = 450 meters.



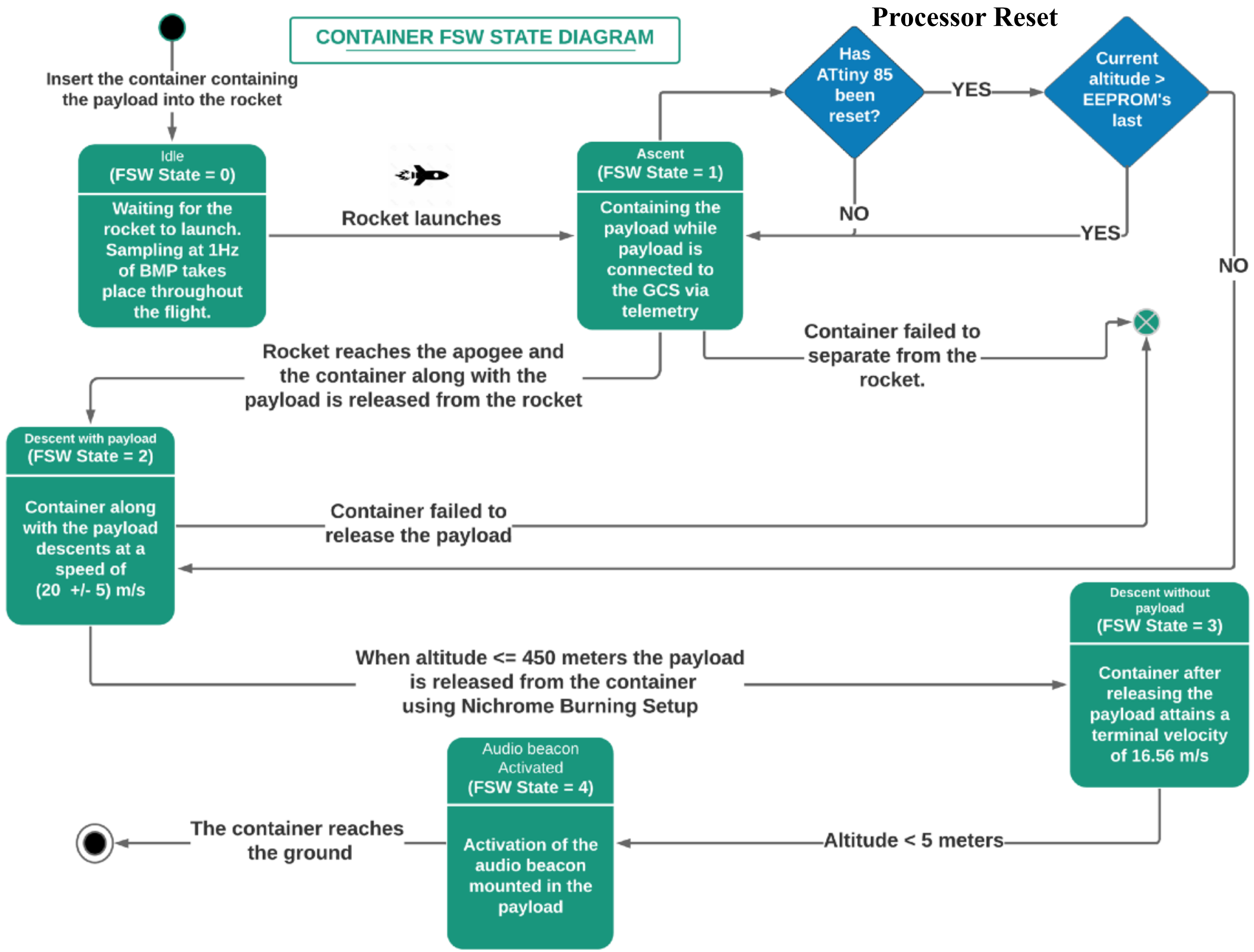
Payload FSW State Diagram (1/2)



Payload FSW State Diagram (2/2)

Sr. No.	Process	Description
1	**Sampling of sensors**	The sampling of sensors takes place throughout the flight at 1Hz frequency.
2	**Communication**	The communication between the payload and the GCS takes place via RF waves. The half duplex communication (calibration command) between the payload and the GCS takes from patch antenna (FXP830) installed in the payload and the GCS Antenna(TLANT-2415D).
3	**Data Storage**	The storage of the camera's data after the initialisation of the camera subsystem takes place on the Camera module's SD card. The sensor's raw data is stored in the pre-installed SD card present in the Spark Fun SAMD21.
4	**Mechanism activations**	At 450m, the payload is released from the container which results in the kicking in of the auto-gyro mechanism(which is not controlled by software system). After turning off the telemetry, the audio beacon is activated.
5	**Major Decision Points in Logic**	Backup of the FSW State throughout the flight(refer to the state chart diagram for the details of the same). Activation of the auto-gyro mechanism(incoming of the data from the Hall Effect Sensor).
6	**Power Management**	The SAMD21 is kept on standby mode and is woken up when the power switch is pushed. It switches unused modules to standby mode when they are not being used to conserve power.

Container FSW State Diagram (1/2)



Container FSW State Diagram (2/2)

Sr. No.	Process	Description
1	**Sampling of sensors**	The sampling of sensor(BMP) takes place throughout the flight at 1Hz frequency.
2	**Communication**	No direct communication takes place between the container and the GCS, the communication takes place via the payload. The communication between the payload and the GCS takes place via RF waves. The half duplex communication between the payload and the GCS takes from patch antenna (FXP830) installed in the payload and the GCS Antenna(TLANT-2415D).
3	**Data Storage**	The sensor's raw data is stored in the ATtiny85 EEPROM.
4	**Mechanism activations**	Activation of the audio beacon when the container makes contact with the ground.
5	**Major Decision Points in Logic**	Backup of the FSW State throughout the flight(refer to the state chart diagram for the details of the same).
6	**Power Management**	The ATtiny85 is kept on normal mode throughout the flight. It switches pressure sensor to low power mode when it is not being used.

Raunit please fill Test methodology take reference from Cansat integration and testing

Development Plan

elopment

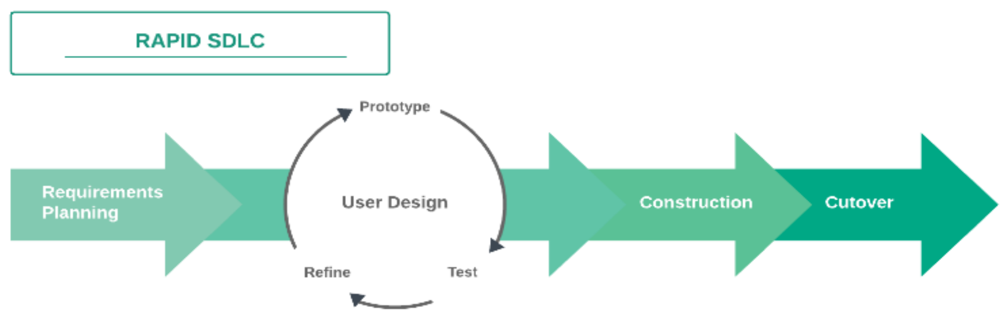
- We have been holding regular meets.
- By following the RAD SDLC, the testing has been done regularly.

Prototyping and Prototyping Environments

- The software is being tested on breadboard regularly.
- Once the PCB is ready, the testing would take place on that.

Software Subsystem Development Sequence

- SDLC model followed for the development of the software is RAPID or RAD.



Test Methodology

- The test methodology followed is **Functional Testing.**
- The sequence of the various types of testing:
  1. *Unit Testing*: Each module is tested independently.
  2. *Integration Testing*: The unit tested modules are integrated and tested.
  3. *System Testing*: The entire system is tested for bugs and errors.
  4. *Functional Testing*: The whole system is tested to check if the all the requirements are met seamlessly.

Development Team

- Sourav Bhattacharjee
- Raunit Singh
- Shikhar Makhija

Ground Control System (GCS) Design

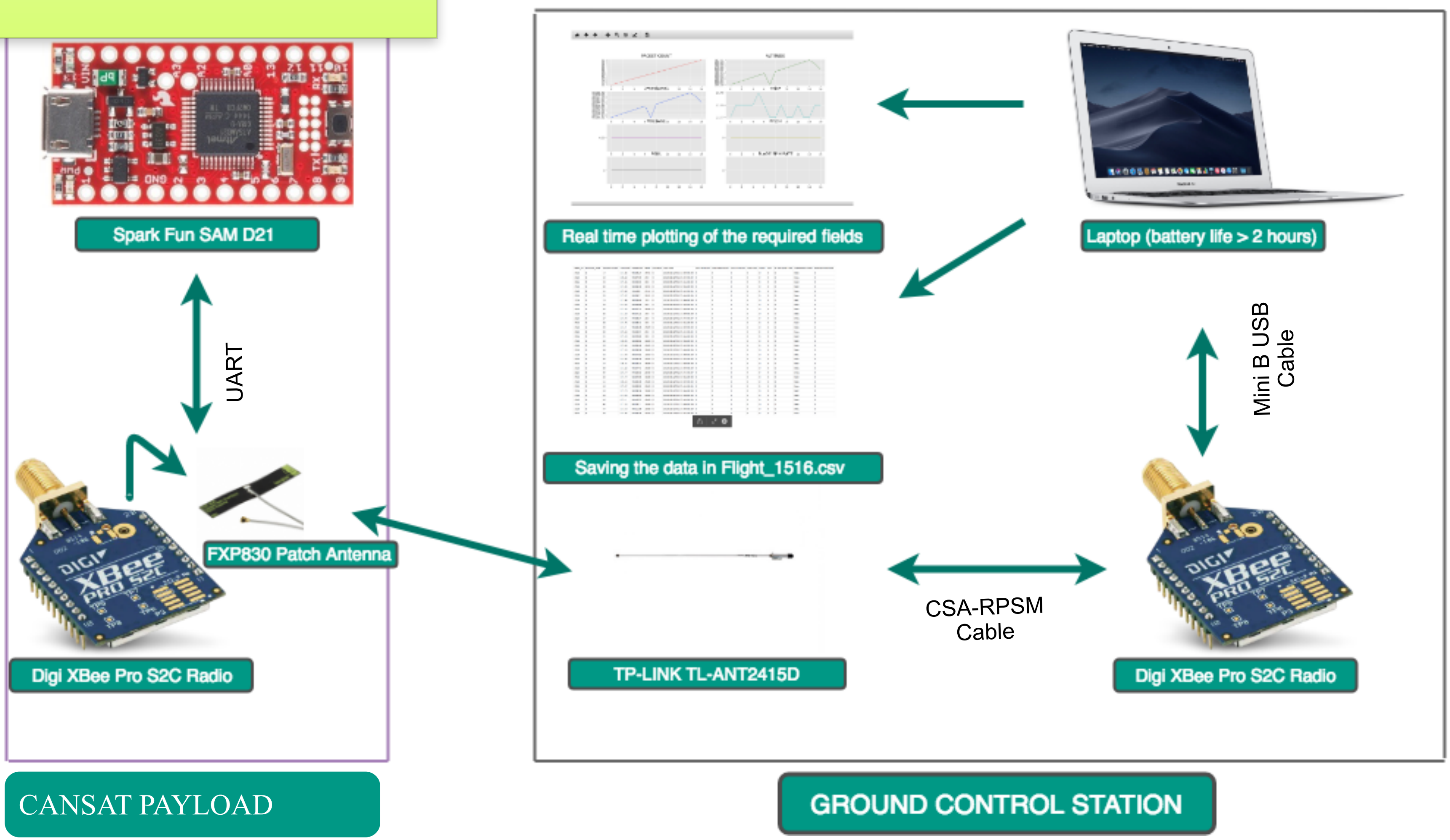
Advait Paithankar

insert probe antenna as well

Guest User

view

GCS OVERVIEW



Add range for antenna

Shikhar M

[illegible]nna Trade & Selection (1/4)

[illegible]	[illegible]	[illegible]	Directivity	Range (m)	VSWR	Weight (kg)	Mounting Type	Connector	Cost
[illegible] ANT2415D	**[illegible]**	**[illegible]**	**Omni-Directional**	**2500**	**2.0:1**	**1.81**	**Hand held**	**N-Female**	**$140.39**
TY-860 Yagi Antenna	12dbi	900MHz	Directional	10560	1.5:1	1.4	Hand held	N-Female	$110
Airpath Wirelessnet Solutton Air Grid Antenna	23dbi	2.4GHz	Directional	14057	1.5:1	3.3	Table top	N-Female	$170

* Range of TPLink TL-ANT-2415D is calculated on these parameters

Calculated range = 2500m

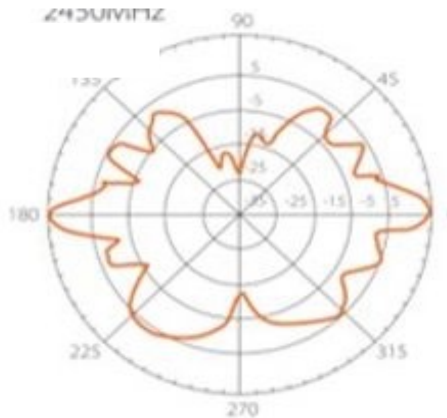
Parameter	Value
Antenna Gain(dB)	15
Transmission Power(dBm)	43.01
Operating frequency(MHz)	2400
Cable loss(dB)	15
Receiver Sensitivity(dBm)	-65
Free space path loss(dB)	108.01

Antenna Mounting	
TPLink- TL-ANT2415D	**Hand-Held**
TY-860 Yagi Antenna	Hand-Held
Airpath Wirelessnet Solutton Air Grid Antenna	Table-Top

GCS Antenna Trade & Selection (2/4)

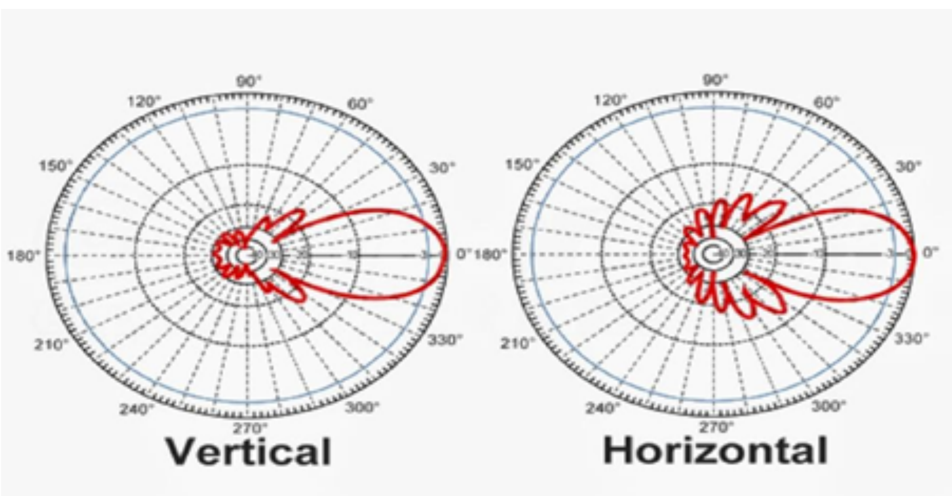
Antenna Radiation Patterns

Horizontal Plane



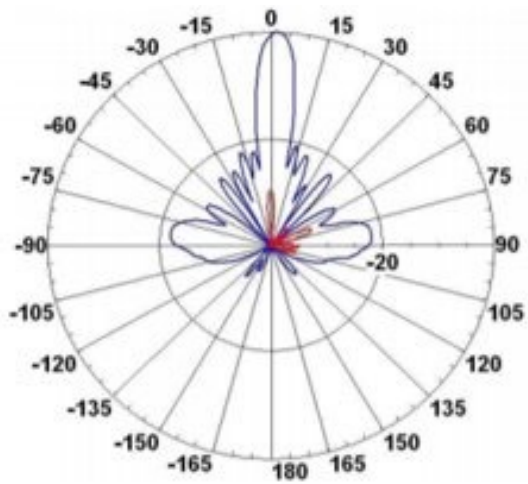
Vertical Plane

Radiation Pattern
TP Link TL-ANT-2415D

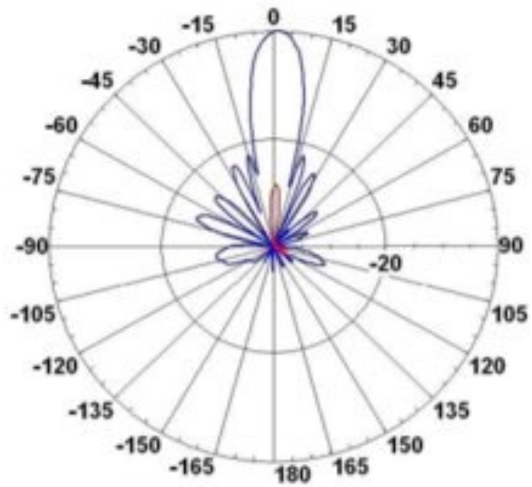


Radiation Pattern
TY- 860 Yagi Antenna

GCS Antenna Trade & Selection (3/4)



Horizontal Plane



Vertical Plane

Radiation Pattern
Wireless Grid Antenna

SELECTED: TP Link TL-ANT-2415D-ANTENNA

Reasons:

- ❖ 15dBi Omni-directional operation highly enlarges the wireless coverage.
- ❖ Lower impedance causes low signal loss.
- ❖ N-Female connector, compatible with all our electrical equipment.
- ❖ Excellent Transmission Range.
- ❖ Easier estimation of antenna efficiency, as the antenna pattern similar to **FXP830.**

TP Link TL-ANT-2415D ANTENNA

GCS Antenna Trade & Selection (4/4)

CANSAT

Patch antenna installed in the payload transmits the data

Calibration Command

RF Signal

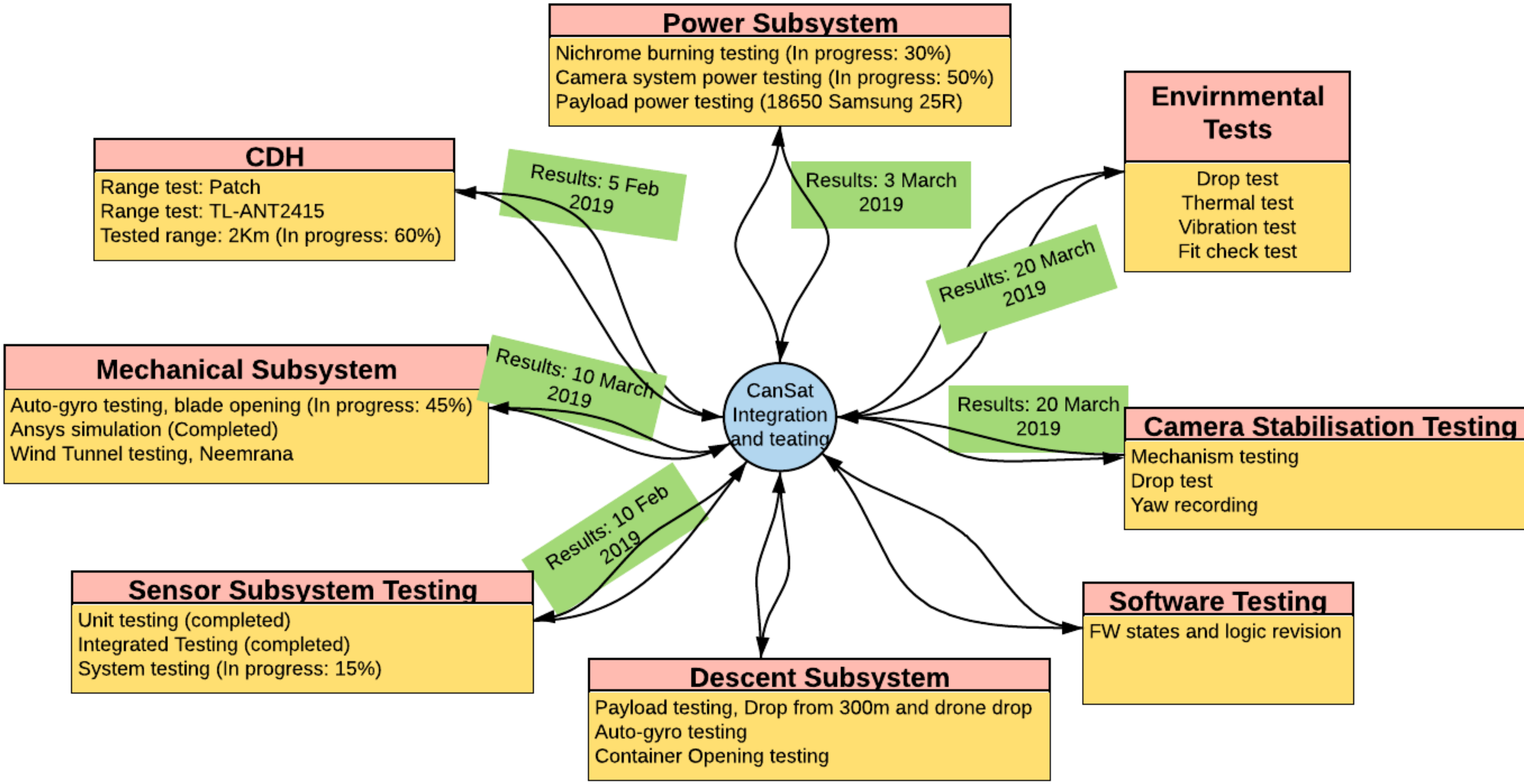
Antenna would be hand held by one of the GCS Crew member

TP Link TL-ANT-2415D ANTENNA

Ground Control Station

CanSat Integration and Test

Shaonak Dayal


Power Subsystem
Nichrome burning testing (In progress: 30%)
Camera system power testing (In progress: 50%)
Payload power testing (18650 Samsung 25R)
Envirnmental Tests
Drop test
Thermal test
Vibration test
Fit check test
CDH
Range test: Patch
Range test: TL-ANT2415
Tested range: 2Km (In progress: 60%)
Results: 5 Feb 2019
Results: 3 March 2019
Results: 20 March 2019
Mechanical Subsystem
Auto-gyro testing, blade opening (In progress: 45%)
Ansys simulation (Completed)
Wind Tunnel testing, Neemrana
Results: 10 March 2019
CanSat Integration and teating
Results: 20 March 2019
Camera Stabilisation Testing
Mechanism testing
Drop test
Yaw recording
Results: 10 Feb 2019
Sensor Subsystem Testing
Unit testing (completed)
Integrated Testing (completed)
System testing (In progress: 15%)
Software Testing
FW states and logic revision
Descent Subsystem
Payload testing, Drop from 300m and drone drop
Auto-gyro testing
Container Opening testing

Advait Please complete the two slides, rest everything has been updated I guess.

tegration and Test (2/2)

Environmental Test Plans

❖ Electronics System: Individual testing of Sensors, telemetry as well as range test for antenna are to be performed.

❖ Mechanical System: Stress strain simulations along with shock simulation, Drop test for Auto-gyro and parachute.

❖ Software System: Complete software system testing and debugging.

Environmental Test Plans

❖ Fit check will be done using aluminium cylinder

❖ Drop test performed while Integrated Level testing.

❖ Vibration testing done using orbit sander.

❖ Thermal test performed in a steady temperature of 60 degrees Celsius.

Integrated Level Functional Test Plans

❖ Payload and Container combined drop test from drone.

❖ Drop test with auto-gyro activated.

❖ Wind tunnel testing at Neem Rana.

❖ Packet generation and transmission by collecting data from sensor subsystem.

❖ Complete sensor subsystem and camera subsystem testing with battery.

❖ Camera subsystem testing on rotating surface for stabilization testing.

Subsystem Level Testing Plans

❖ All the subsystems to be tested individually.

❖ All sensors to be tested on breadboard.

❖ Telemetry to be tested on by transmitting sensor data.

❖ Defining flight software states for different phases during CanSat flight.

❖ Testing range of XBEEs using inbuilt tool from XCTU.

❖ Testing the power consumed by all electronic components.

❖ Structural integrity will be tested on subsystem level by creating near actual environment

Requirements Compliance

Kshitij Shekhar

Requirements Compliance Overview

- All the requirements mentioned in the guidelines were taken with the highest priority. All the departments worked within the guidelines stated.
- The majority of the requirements are currently complied.
- We have worked even on the bonus point and hope to fulfill it..
- Various tests will be conducted to check the impact severity and hopefully our CanSat will withstand it.
- Overall CanSat show great results but if there will be any possibility for loopholes, then improvements and optimizations will be made and will be updated in CDR.
- The following slides trace and demonstrate compliance with all Requirements. Comments have been added where necessary.
- The table filled according to requirement based compliance helps us to see which subsystem is needed to be developed.
- The legend gives color coding to indicate if a requirement is met.

No Comply	Partial	Comply

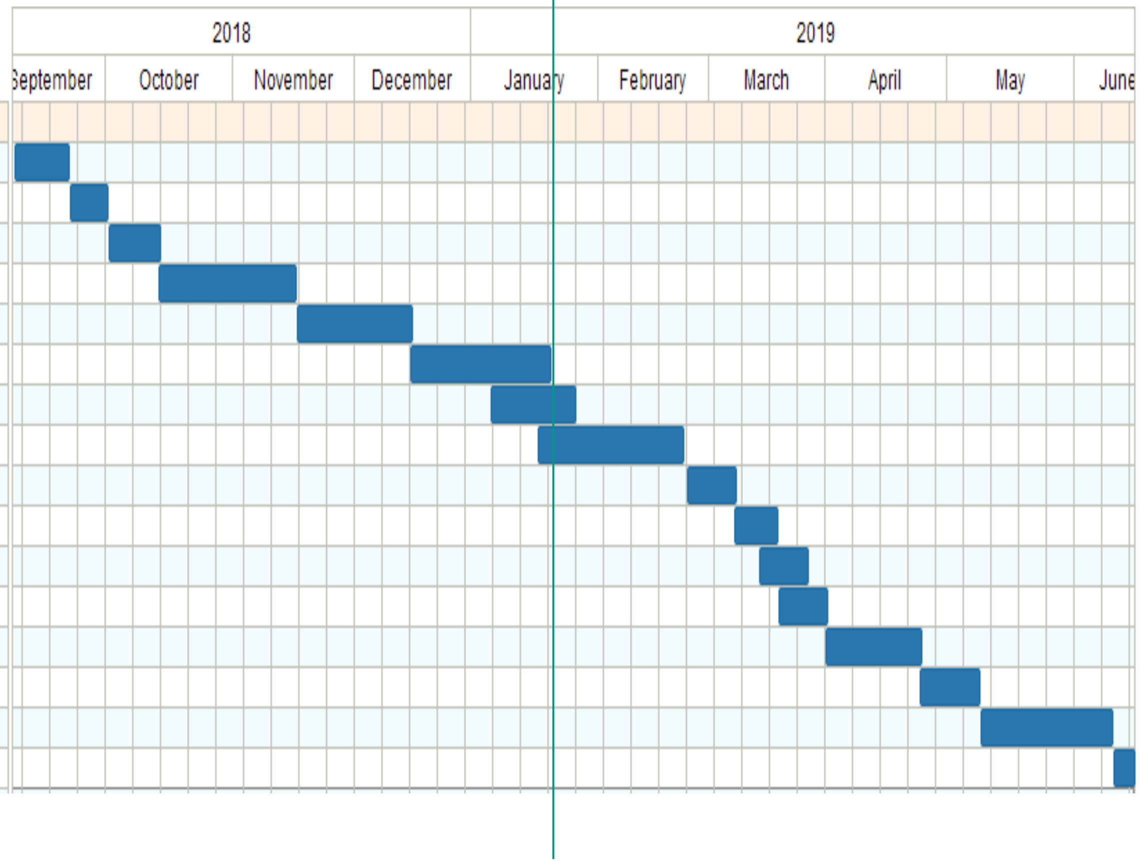
Management

Kshitij Shekhar

Program Schedule Overview (1/4)

Overall Gantt Chart

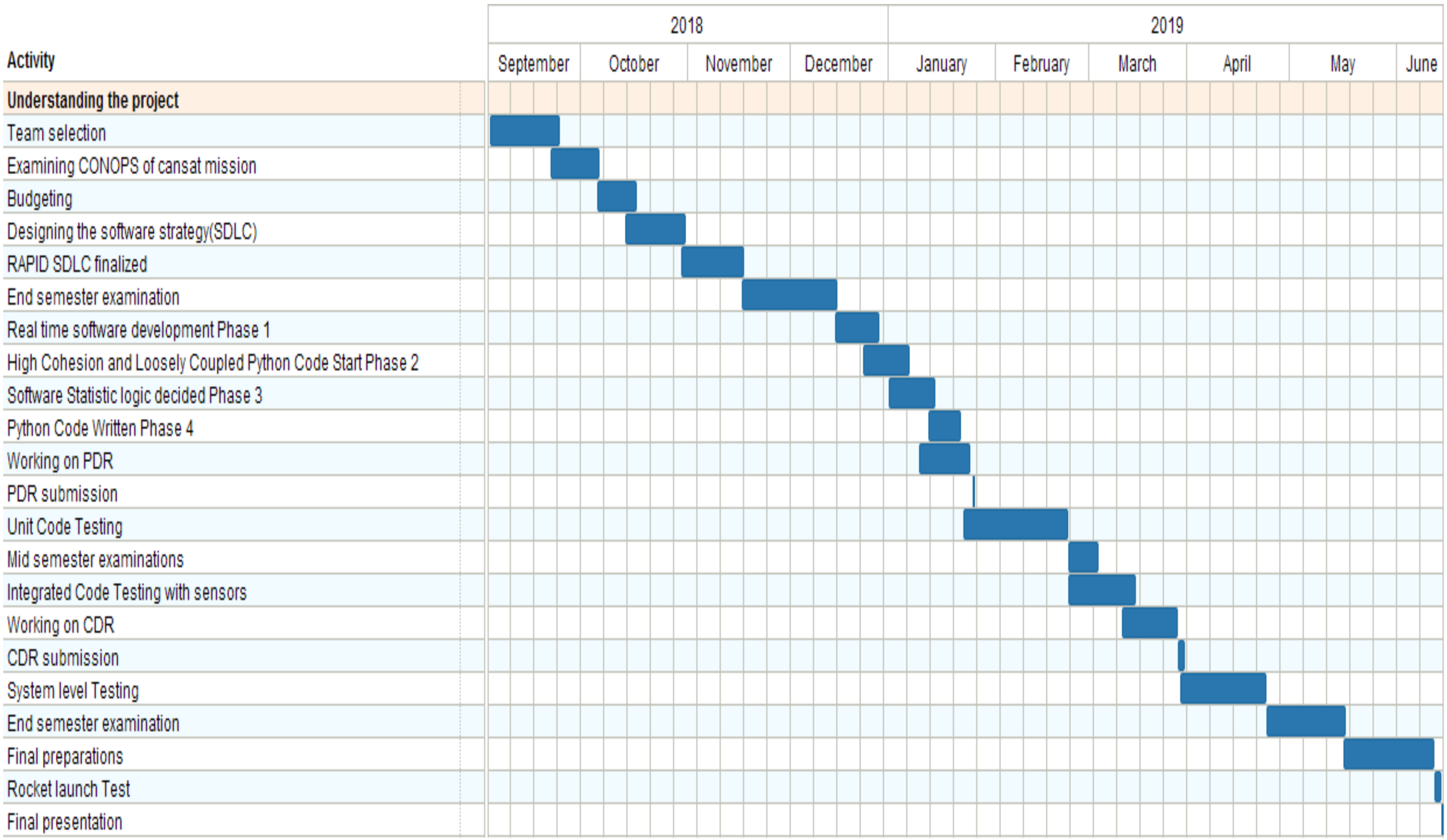
Activity	Start date	End Date
Understanding the project	**Start date**	**End date**
Team Selection	10-Sept-201..	20-Sept-201..
Examining CONOPS of cansat mission	21-Sept-201..	30-Sept-2018
Budgeting	1-Oct-2018	14-Oct-2018
Concept development	15-Oct-2018	14-Nov-2018
End semester examination	15-Nov-2018	15-Dec-2018
Procurement of facilities and materials	16-Dec-2018	20-Jan-2019
Working of PDR	5-Jan-2019	25-Jan-2019
CanSat integration	17-Jan-2019	22-Feb-2019
Mid semester examination	23-Feb-2019	7-Mar-2019
Design finalisation	8-Mar-2019	18-Mar-2019
Various testing	13-Mar-2019	20-Mar-2019
Working of CDR	3-Mar-2019	29-Mar-2019
Last modifications	30-Mar-2019	24-Apr-2019
End semester examination	25-Apr-2019	7-May-2019
Final preparations	8-May-2019	11-May-2019
Final Competition	12-Jun-2019	17-Jun-2019



Progress: 38%

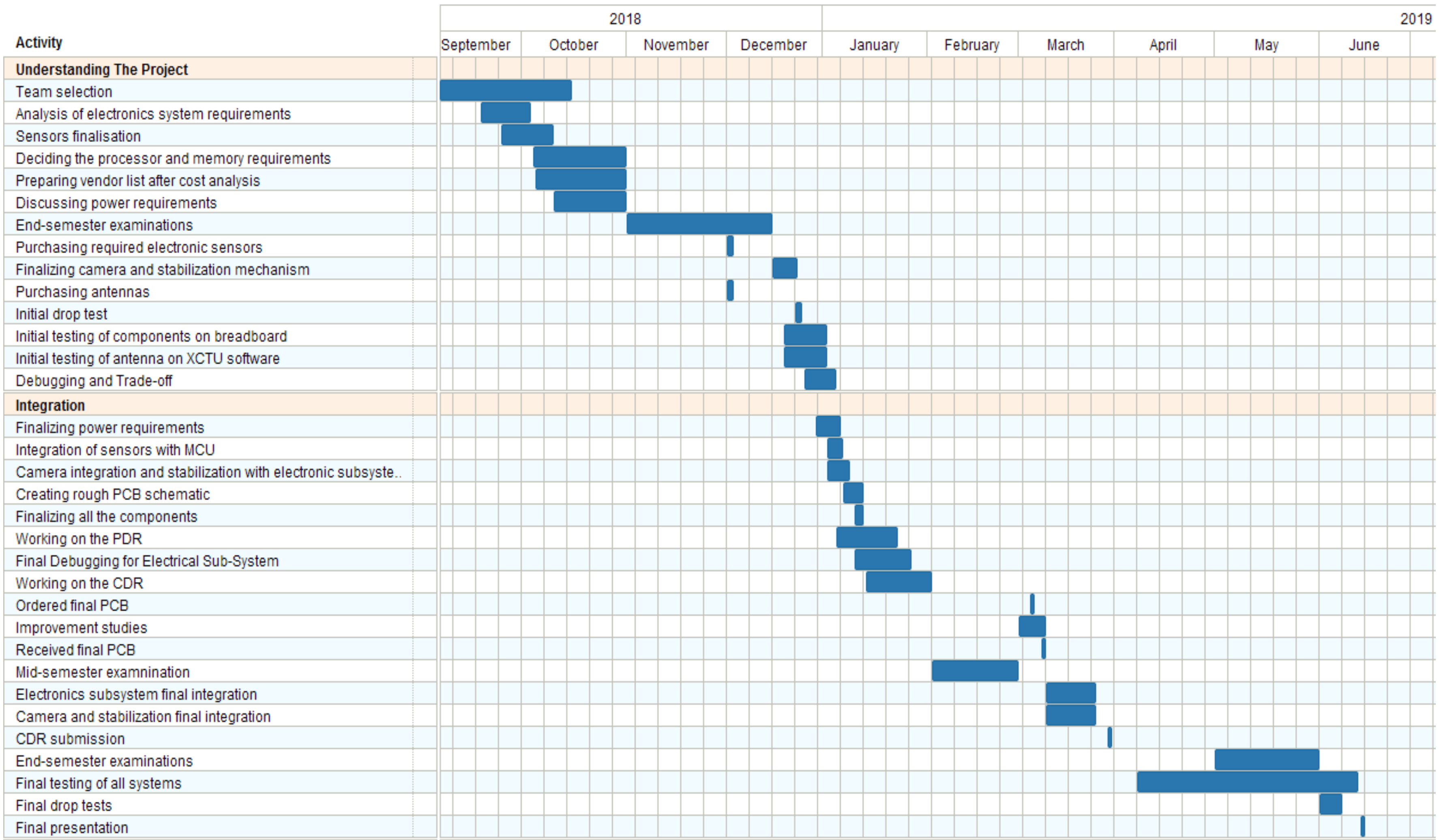
Program Schedule(Cont.) (2/4)

Software



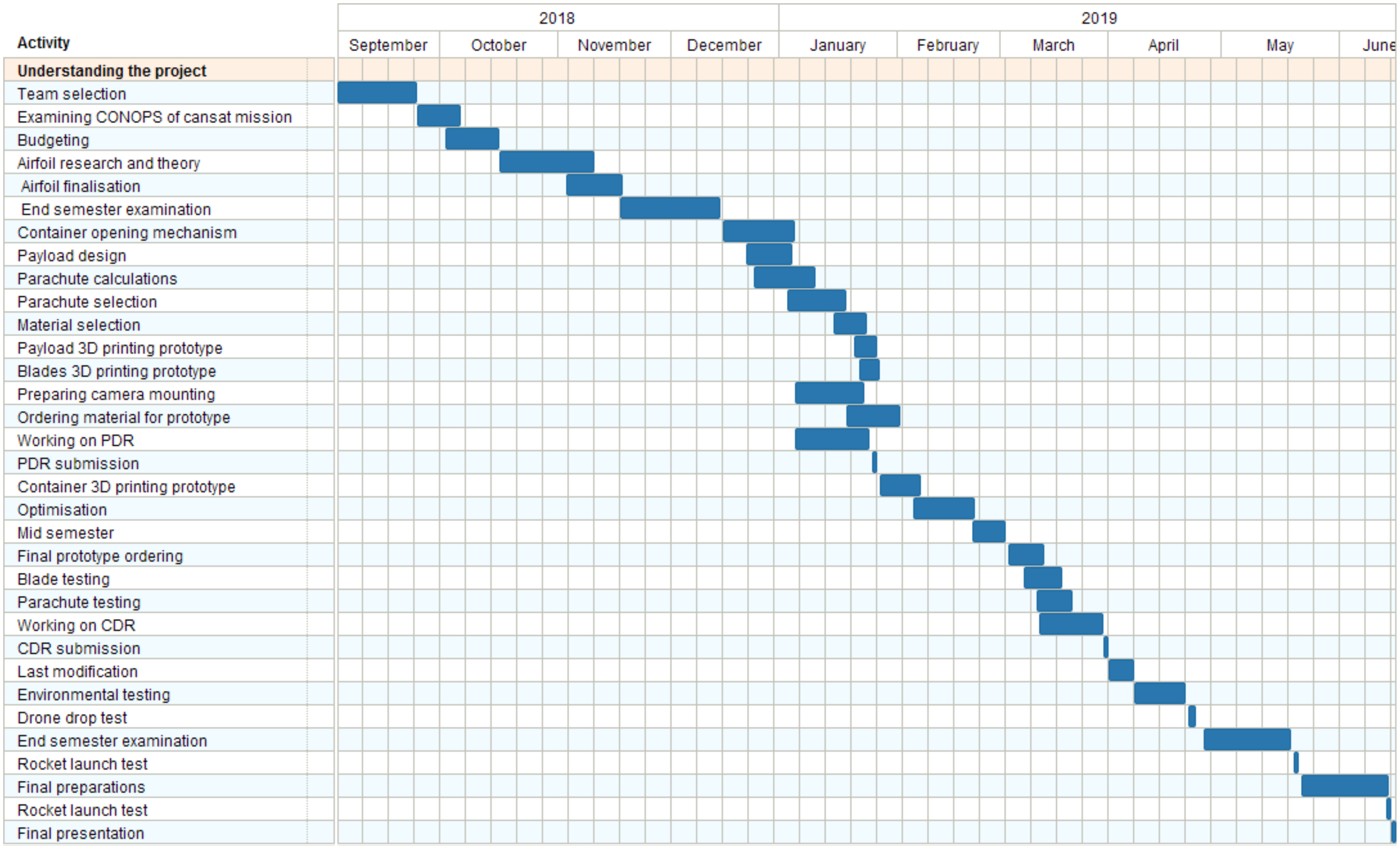
Program Schedule(Cont.) (3/4)

Electronics



Program Schedule(Cont.) (4/4)

Mechanical



Detailed Program Schedule (1/4)

Milestone	Start Date	End Date	Duration	Assigned to
A team of 10 members was formed by taking interviews. Based on how much they have learned from the study session held.	10 Sept 2018	20 Sept 2018	11 Days	❖ Bhavya Arya ❖ Sourav Bhattacharjee
Understanding the mission, and studying every aspect of the CanSat guide for 2019. The mission statement was analyzed and preparation for the competition was begun.	21 Sept 2018	30 Sept 2018	10 Days	❖ Entire team
Sensor finalization was done. Analysation of processor and memory requirement and discussion on power requirement was done.	25 Sept 2018	3 Nov 2018	10 Days	❖ Sourav Bhattacharjee ❖ Shikhar Makhija
Started working on airfoils and their configurations and started deciding the processor and memory requirements.	31 Sept 2018	13 Oct 2018	14 Days	❖ Snigdha Singh ❖ Bhavya Arya
Designing the software strategy.	12 Oct 2018	31 Oct 2018	20 Days	❖ Raunit Singh
Prototypes were made of ideas which were theoretically perfect, from things used in our homes on daily basis of the container opening mechanisms and tested.	14 Oct 2018	14 Nov 2018	31 Days	❖ Riyanshu Motalaya ❖ Kshitij Shekhar
Finalisation of RAPID SDLC	31 Oct 2018	15 Nov 2018	16 Days	❖ Raunit Singh
End term examinations	15 Nov 2018	15 Dec 2018	32 Days	❖ Entire team

Detailed Program Schedule (2/4)

Milestone	Start Date	End Date	Duration	Assigned to
Purchasing for required electronic sensors and antennas was done	1 Dec 2018	5 Dec 2018	6 Days	❖ Shikhar Makhija ❖ Sourav Bhattacharjee
Several preliminary designs and ideas for possible container and payload were brainstormed and discussed.	16 Dec 2018	5 Jan 2019	21 days	❖ Riyanshu Motalaya ❖ Bhavya Arya
Real time software development Phase 1 and High Cohesion and Loosely Coupled Python Code Start Phase 2 was done	14 Dec 2018	7 Jan 2018	25 Days	❖ Raunit Singh
Initial testing of components on breadboard and testing of antennas on XCTU software was carried out.	22 Dec 2018	17 Jan 2019	27 Days	❖ Shaonak Dayal ❖ Advait Paithankar
Our team research's materials which satisfies our needs like low weight , high strength , which can be 3D printed , etc. We selected materials by seeing constraints like shipping , availability and cost.	1 Jan 2019	23 Jan 2019	24 days	❖ Riyanshu Motalaya ❖ Snigdha Singh ❖ Kshitij Shekhar
Worked on Software Statistic logic decided Phase 3	3 Jan 2019	14 Jan 2019	12 Days	❖ Raunit Singh
Integration of sensors with MCU. Camera integration and stabilisation with electronic subsystem	5 Jan 2019	21 Jan 2019	17 Days	❖ Shaonak Dayal ❖ Divya Tiwari
Worked on Python Code Written Phase 4	11 Jan 2019	22 Jan 2019	12 Days	❖ Raunit Singh
Finalizing of material was done from various options available to us according to our needs.	11 Jan 2019	23 Jan 2019	13 Days	❖ Entire Team

Detailed Program Schedule (3/4)

Milestone	Start Date	End Date	Duration	Assigned to
Finalized design for CanSat , after rejecting various designs on the basis of flaws in their mechanism. And selected the most suitable that fulfills our needs and is in accordance with the guidelines provided by CanSat competition.	3 Jan 2019	11 Jan 2019	9 Days	❖ Sourav Bhattacharjee ❖ Bhavya Arya
After all the work, we documented it and finally concocted the PDR.	18 Jan 2019	29 Jan 2019	12 Days	❖ Entire Team
Creating rough PCB schematic and then finalizing all components	22 Jan 2019	26 Jan 2019	5 Days	❖ Advait Paithankar ❖ Divya Tiwari
Final debugging for electronics system	26 Jan 2019	12 Feb 2019	18 Days	❖ Divya Tiwari ❖ Sourav Bhattacharjee ❖ Shikhar Makhija
PDR presentation will be given by our team.	8 Feb 2019	15 Feb 2019	8 Days	❖ Entire Team
Mid semester examination	15 Feb 2019	2 March 2019	16 days	❖ Entire Team
Post presentation, improvisation of designs for the CDR will be done for making it in best accordance with the guidelines.	3 Mar 209	13 Mar 2019	23 Days	❖ Entire Team
Integrated Code Testing with sensors will be done	3 Mar 2019	14 Mar 2019	12 Days	❖ Shaonak Dayal ❖ Advait Paithankar
Design will be passed after final analysis, by our team which is to be 3D printed and will be sent to printer.	5 Mar 2019	19 Mar 2019	15 Days	v Riyanshu Motalaya v Snigdha Singh v Kshitij Shekhar

Detailed Program Schedule (4/4)

Milestone	Start Date	End Date	Duration	Assigned to
Various tests will be performed on CanSat to check that we are meeting the requirements or not. Different tests are vibration, drop, environment, etc.	10 Mar 2019	25 Mar 2019	16 Days	❖ Entire Team
Ordering PCB. Final integration of electronics subsystem and camera.	15 Mar 2019	27 Mar 2019	13 Days	❖ Divya Tiwari ❖ Shaonak Dayal ❖ Advait Paithankar
CDR will be concocted after adding on the necessary improvisations on the CanSat.	15 Mar 2019	29 Mar 2019	15 Days	❖ Entire Team
Preparations as team will be giving presentation of the CDR before the experts (competition organizers).	29 Mar 2019	4 Apr 2019	6 Days	❖ Entire Team
Final preparations will be done	5 Apr 2019	20 Apr 2019	16 Days	❖ Sourav Bhattacharjee ❖ Shikhar Makhija ❖ Bhavya Arya
End semester Examinations	21 Apr 2019	7 May 2019	17 Days	❖ Entire Team
Everything will be tested for a one last time and then will be packed for competition.	8 May 2019	20 May 2019	13 Days	❖ Entire Team
Every item will be checked and packed and will be tick marked.	16 May 2019	13 Jun 2019	29 Days	❖ Sourav Bhattacharjee

Elaborate on why you are ready to proceed to the next stage.

...s

...NTS

- Telemetry has been tested
- Descent rate estimations have been done using numerical methods
- Mechanism for payload deployment and container opening have been tested
- Material selection and basic material testing has been done

MAJOR UNFINISHED WORK

- Camera stabilization mechanism to be tested.
- PCB designing
- Validation of descent rate estimation with experimental values
- Validation of FSW states/logics

READINESS TO PROCEED TO NEXT STAGE OF DEVELOPMENT

We have spent an appropriate amount of time prototyping, developing, testing, trouble-shooting and refining all our systems, and will continue to do so. Hence we feel we can face the challenges ahead.