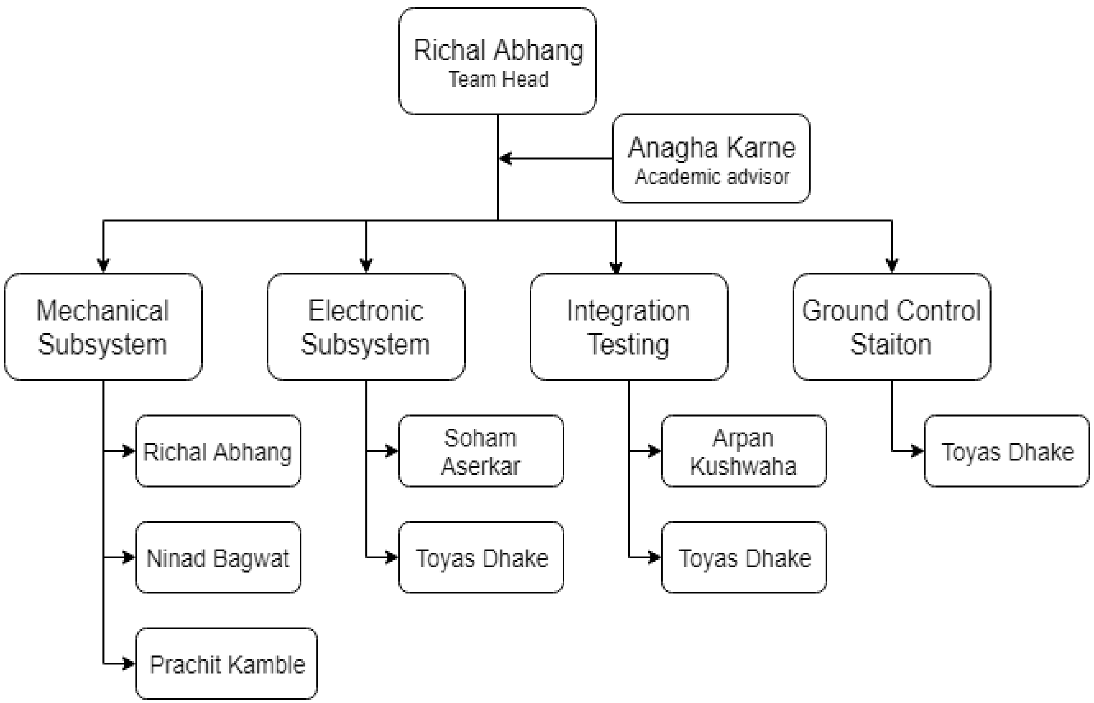
CanSat 2019
Preliminary Design Review (PDR)
Version 1

Team #1086
MIT SAT

Presentation Outline

Section	Presenter
System Overview	Richal Abhang (RA)
Sensor Subsystem Design	Soham Aserkar (SA)
Descent Control Design	Richal Abhang (RA)
Mechanical Subsystem Design	Prachit Kamble (PK)
Communication and Data Handling (CDH) Subsystem Design	Toyas Dhake (TD)
Electrical Power Subsystem (EPS) Design	Soham Aserkar (SA)
Flight Software (FSW) Design	Arpan Kushwaha (AK)
Ground Control System (GCS) Design	Toyas Dhake (TD)
CanSat Integration and Test	Arpan Kushwaha (AK)
Mission Operations & Analysis	Ninad Bhagwat (NB)
Requirements Compliance	Ninad Bhagwat (NB)
Management	Prachit Kamble (PK)

MIT SAT Team Organization



Team Member	Responsibility
Richal Abhang (RA) 4th year (Mech)	DCD, CDHSD
Soham Aserkar (SA) 3rd year (EnTC)	SSD, EPSD
Ninad Bhagwat (NB) 4th year (Mech)	MSD, DCD
Toyas Dhake (TD) 4th year (Comp)	CDHSD, GCSD, SSD, FSWD
Prachit Kamble (PK) 4th year (Mech)	MSD, CIT
Arpan Kushwaha (AK) 4th year (Comp)	CIT, FSWD

Acronyms

DCD	Descent Control Design
CDHSD	Communication and Data Handling Subsystem Design
SSD	Sensor Subsystem Design
EPSD	Electrical Power Subsystem Design
MSD	Mechanical Subsystem Design
FSWD	Flight Software Design
CIT	CanSat Integration and Test
BR	Base Requirement
I2C	Inter Integrated Circuit
UART	Universal Asynchronous Receiver Transmitter
RTC	Real Time Clock
GCS	Ground Control Station
IDE	Integrated Development Environment
PLA	Poly Lactic Acid
BR	Base Requirement
IR	Infra Red
AVR	Alf and Vegard's RISC

GPS	Global Positioning System
ABS	Acrylonitrile Butadiene Styrene
ADC	Analog to Digital Converter
ARAI	Automotive Research Association of India
PPR	Pulse Per Revolution
CAD	Computer Aided Design
CFD	Computational Fluid Dynamics
NACA	National Advisory Committee for Aeronautics
FEA	Finite Element Analysis
SMA	SubMiniature Version A
CDR	Critical Design Review

A	Analysis
I	Inception
T	Testing
D	Demonstration

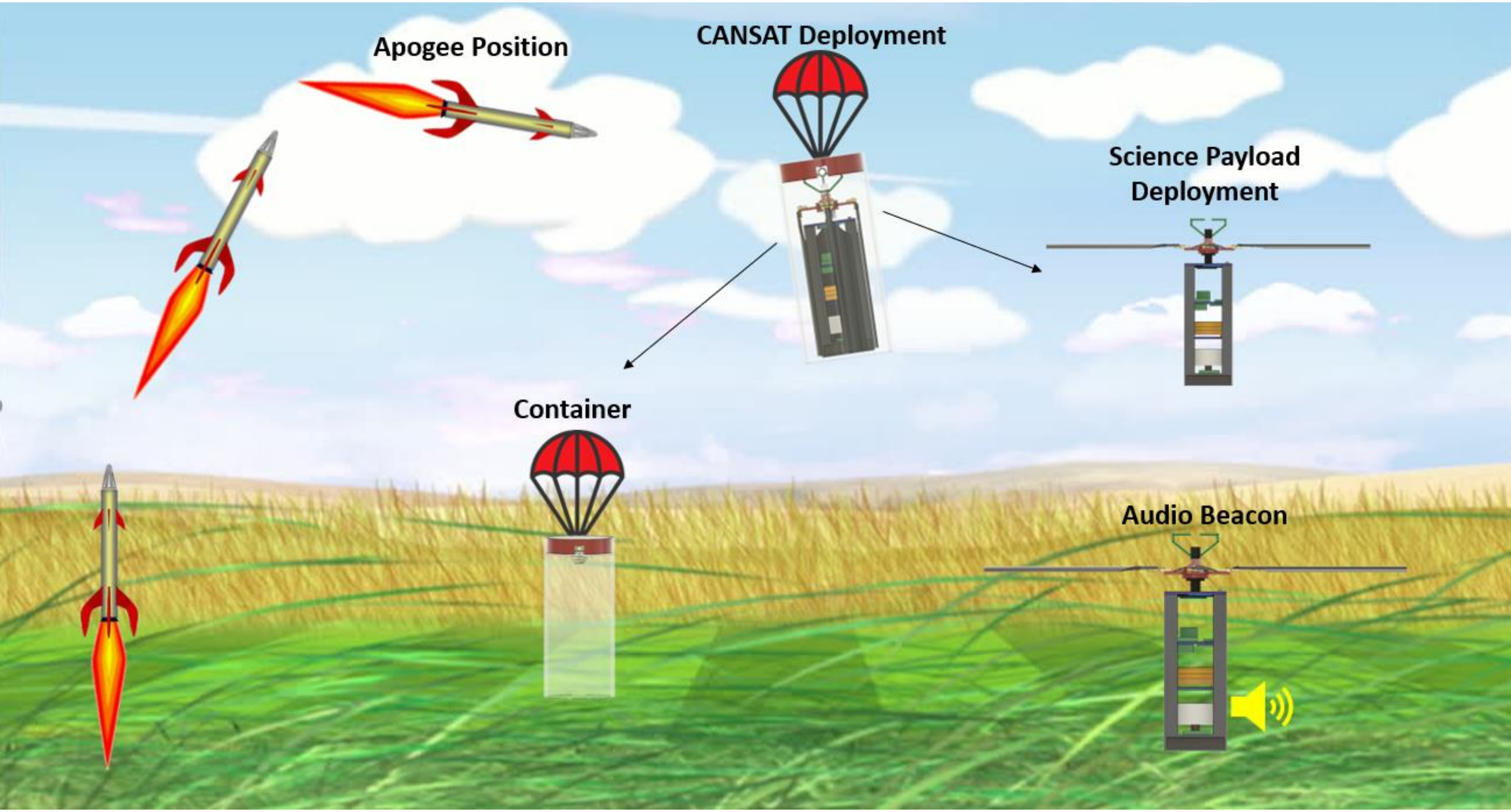
Systems Overview

Richal Abhang (RA)

Mission Summary

- **Objectives**
  - Build a CanSat having a science payload which will descend using passive auto gyro.
  - CanSat shall be launched at 670 to 725 meters height by a sounding rocket.
  - It shall release science payload at 450 meter height while descending.
  - All the CanSat data shall be displayed live at ground station.
- **Bonus**
  - Camera mounted at an angle of 45° from nadir of science payload.
  - 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**
  - We are first team to participate in CanSat Competition from our university (Savitribai Phule Pune University-SPPU). We are trying to make it yearly tradition.

Mission Summary



System Requirement Summary

Sr. No.	Requirement	Verification			
		A	I	T	D
1	Total mass of the CanSat (science payload and container) shall be 500 grams +/- 10 grams.	✔			
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	✔			
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	✔			
4	The container shall be a fluorescent color; pink, red or orange.				✔
5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	✔			
6	The rocket airframe shall not be used as part of the CanSat operations.	✔			
7	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	✔			
8	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	✔			

MIT SAT System Requirement Summary

Sr. No.	Requirement	Verification			
		A	I	T	D
9	The container shall release the payload at 450 meters +/- 10 meters.				✔
10	The science payload shall descend using an auto-gyro/ passive helicopter recovery descent control system.	✔			
11	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.	✔			
12	All descent control device attachment components shall survive 30 Gs of shock.	✔			
13	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	✔			
14	All structures shall be built to survive 15 Gs of launch acceleration.	✔			
15	All structures shall be built to survive 30 Gs of shock.	✔			
16	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.				✔

System Requirement Summary

Sr. No.	Requirement	Verification			
		A	I	T	D
17	All mechanisms shall be capable of maintaining their configuration or states under all forces.	✔			
18	Mechanisms shall not use pyrotechnics or chemicals.				✔
19	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	✔			
20	The science payload shall measure altitude using an air pressure sensor.		✔		
21	The science payload shall provide position using GPS.				✔
22	The science payload shall measure its battery voltage.				✔
23	The science payload shall measure outside temperature.				✔
24	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.				✔

System Requirement Summary

Sr. No.	Requirement	Verification A	Verification I	Verification T	Verification D
25	The science payload shall measure pitch and roll.				✔
26	The probe shall transmit all sensor data in the telemetry			✔	
27	The Parachute shall be fluorescent Pink or Orange		✔		
28	The ground station shall be able to command the science vehicle to calibrate barometric altitude, and roll and pitch angles to zero as the payload sits on the launch pad.	✔		✔	✔
29	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.			✔	✔
30	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	✔		✔	
31	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.		✔		
32	XBEE radios shall have their NETID/PANID set to their team number.			✔	

BR No.	Requirement	Verification			
		A	I	T	D
33	XBEE radios shall not use broadcast mode.		✔	✔	
34	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	✔			
35	Each team shall develop their own ground station.	✔			✔
36	All telemetry shall be displayed in real time during descent.	✔		✔	
37	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		✔		✔
38	Teams shall plot each telemetry data field in real time during flight.		✔	✔	
39	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		✔		✔
40	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	✔		✔	

System Requirement Summary

BR No.	Requirement	Verification			
		A	I	T	D
41	Both the container and probe shall be labeled with team contact information including email address.			✔	
42	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	✔		✔	
44	No lasers allowed.				✔
45	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	✔	✔		
46	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the cansat and in the stowed state.		✔	✔	
47	An audio beacon is required for the probe. It may be powered after landing or operate continuously.			✔	
48	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	✔			✔

System Requirement Summary

Sr. No.	Requirement	Verification A	Verification I	Verification T	Verification D
49	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells.		✔	✔	
50	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.			✔	
51	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.				✔
52	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.		✔		
53	The GPS receiver must use the NMEA 0183 GGA message format.	✔			
54	The CANSAT must operate during the environmental tests laid out in Section 3.5.	✔			
55	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	✔			

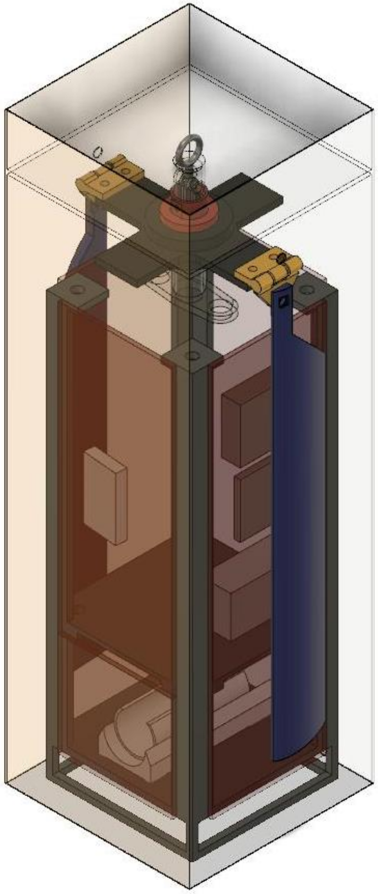
System Level CanSat Configuration Trade & Selection

Concept 1	Concept 2
Flat (Hexagonal) parachute for descent of container + Science payload	Hemispherical parachute for descent of Cansat
Reaction Wheel for stability control of Science Payload	Grid fins for stability control of Science Payload
Nichrome wire mechanism for deployment of science payload from container	Servo mechanism for deployment of science payload from container
Science payload with electronics mounted on horizontal plates	Science payload with electronics mounted on vertical plates
Hollow Cylindrical Container	Hollow square prismatic container
Four rotor auto gyro	Two rotor auto gyro
Material selected for 3D printing is Poly Lactic Acid (PLA)	Material selected for 3D printing is Acrylonitrile Butadiene Styrene (ABS)

System Level CanSat Configuration Trade & Selection

Concept 1

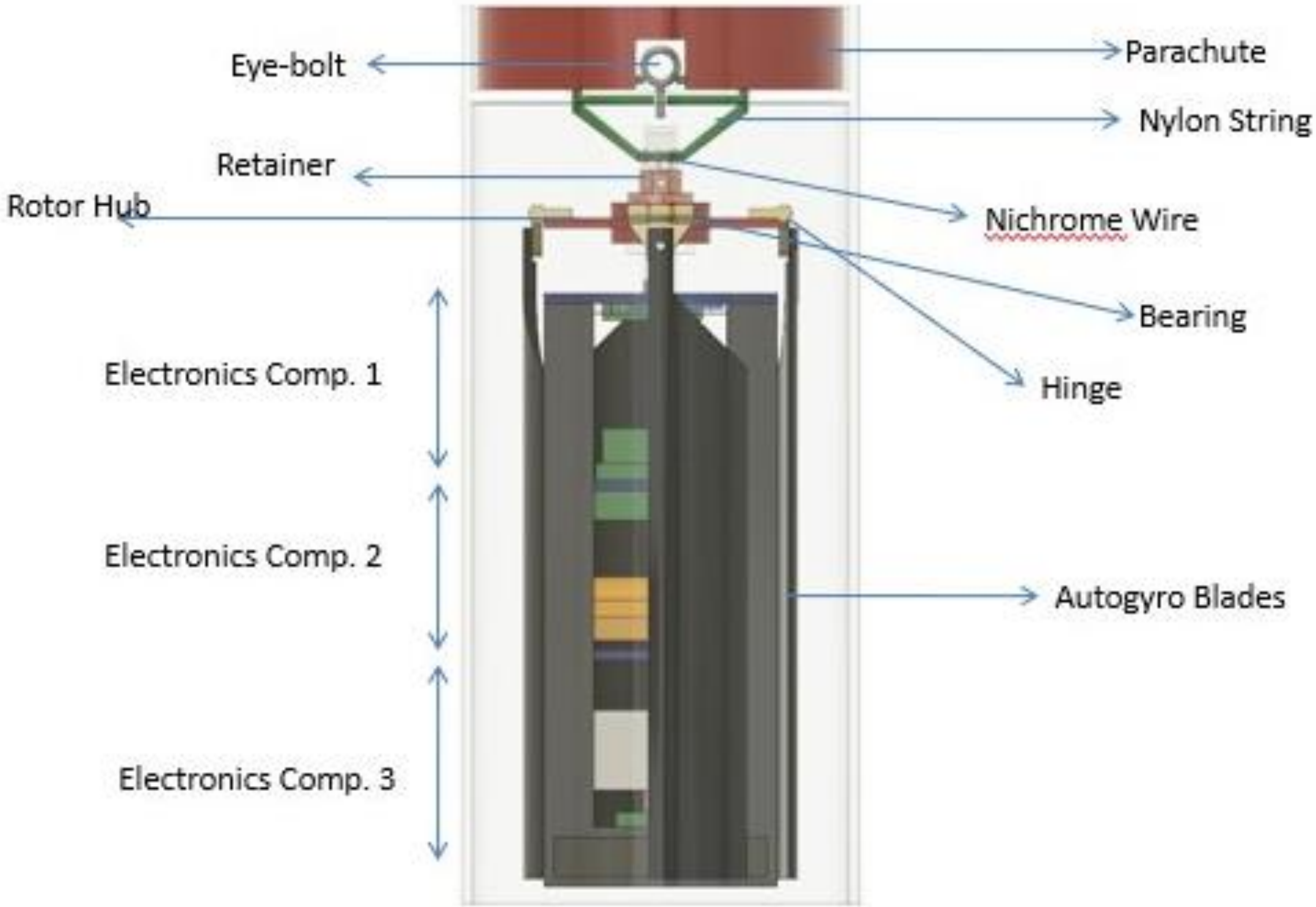
Concept 2



System Level Configuration Selection

Concept Chosen	Rationale
Concept 1	Lighter in weight Simple mechanisms Low Power consumption Easily available locally and 3D-Printable

Physical Layout



MIT SAT Physical Layout

- **Compartment 1**
  1. XBee
  2. Tachometer
  3. GY 87
  4. GPS
  5. Arduino Pro Mini
  6. Buzzer
- **Compartment 2**
  1. Battery
  2. Regulator (Buck)
- **Compartment 3**
  1. Reaction wheel
  2. Motor

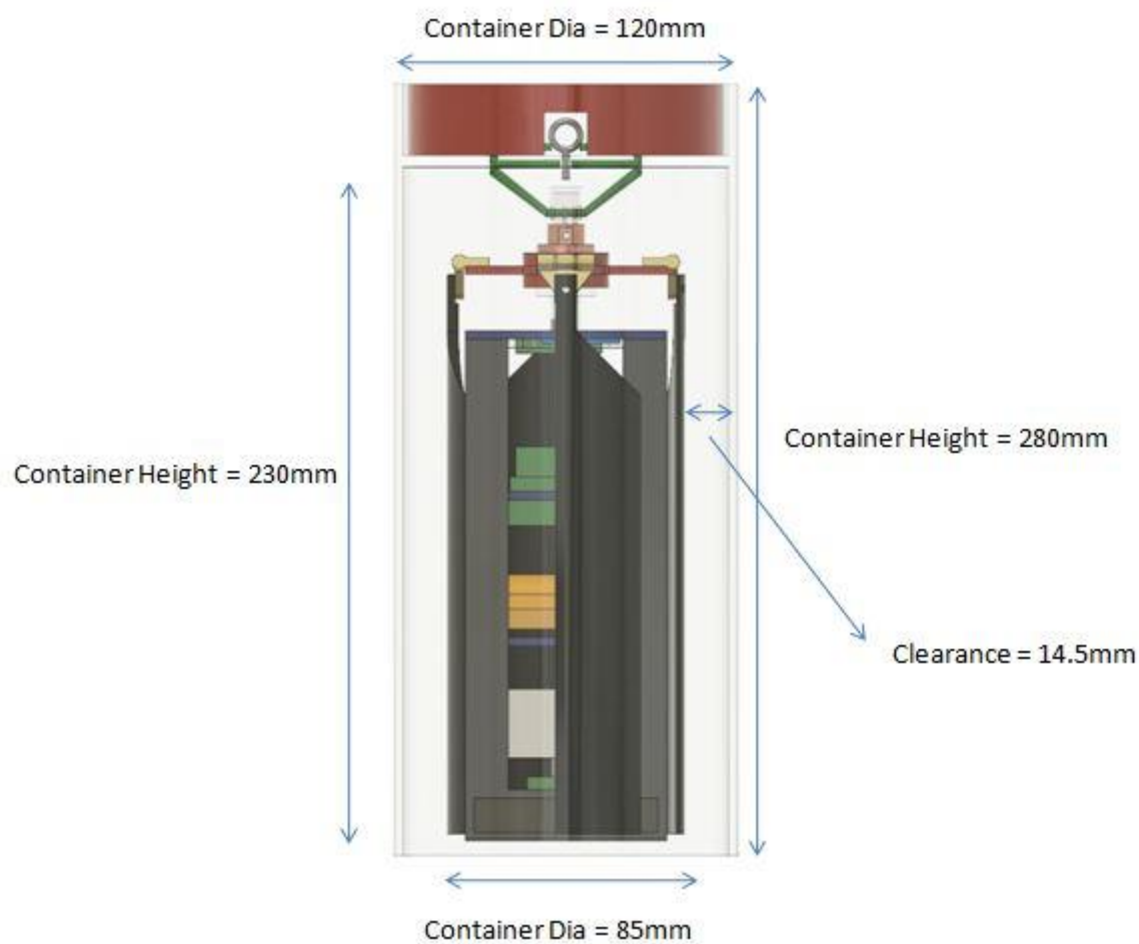
MIT SAT System Concept of Operations

Pre Launch → Launch → Apogee → Sat Deploy → Science Payload Deploy → Audio Beacon

- Pre Launch
  - CanSat switched on
  - Check if telemetry is functioning
- Launch
  - Launch detected by Sensors
- Apogee
  - Apogee is detected by sensors
- Sat Deploy
  - CanSat deployed due to tipping of nose cone.
- Science Payload Deploy: -
  - Sensors detect altitude less than 450m.
  - Nichrome wire is turned on.
- Audio Beacon
  - Sensors detect landing
  - Audio beacon is turned on
  - Telemetry is turned off

Launch Vehicle Compatibility

Maximum Allowed Diameter is 125mm



Launch Vehicle Compatibility

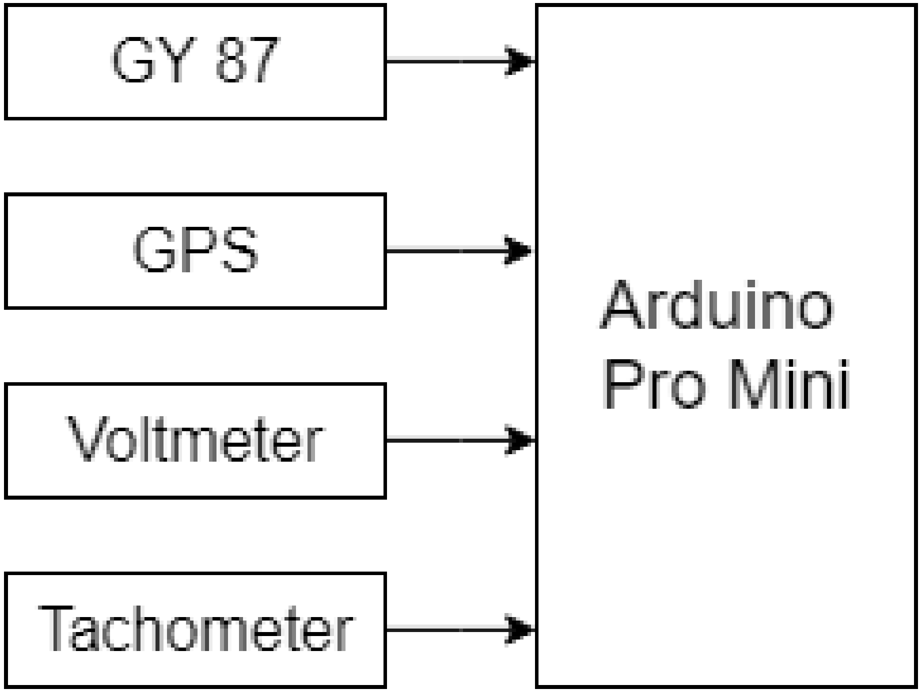
1. Maximum diameter of CANSAT is 120 mm, which is less than allowable diameter of 125 mm.
2. Maximum diameter of Science Payload is 85 mm in stowed configuration. Clearance between Container and Payload is 14.5 mm on each side.
3. Further more for easy deployment, a small stiff spring is compressed between top of Payload and the container, which will push payload out of the container upon release using Nichrome wire.
4. CLEARANCE= **14.5 mm** (each side)
5. Complete lack of any protrusions between container and the rocket frame, ensuring smooth release.

Sensor Subsystem Design

Soham Aserkar (SA)

Sensor Subsystem Overview

Selected component	Function
GY 87	Yaw, Pitch, Roll, Temperature, Air Pressure
Neo 6m	Latitude, Longitude, Altitude, RTC
Voltmeter	Measure power bus voltage
Tachometer	Measure Speed of Auto gyro rotor



Sensor Subsystem Requirements

ID	Requirement	Verification A	Verification I	Verification T	Verification D
BR-20	The science payload shall measure altitude using an air pressure sensor.			✓	✓
BR-21	The science payload shall provide position using GPS.				✓
BR-22	The science payload shall measure its battery voltage.			✓	
BR-23	The science payload shall measure outside temperature.			✓	
BR-24	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.				✓
BR-25	The science payload shall measure pitch and roll.			✓	✓
BR-26	The probe shall transmit all sensor data in the telemetry				✓
BR-44	No lasers allowed.				✓

Payload Air Pressure Sensor Trade & Selection

Name	Logic Level (V)	Weight (grams)	Power (µW)	Operation Temperature (°C)	Interface	Cost
GY 87 10DOF	+3 to +5	6	13,315.5	-40 to 85	I2C	₹ 1,090
BMP 180	+3 to +5	4	105.6	-40 to 85	I2C	₹ 350
RKI 2544	3 to 5	3	6600	-40 to 125	Analog	₹ 242

- GY 87 is an all in one module comprising of: -
  i. Barometer
  ii. Magnetometer
  iii. Gyroscope
  iv. Accelerometer
  v. Thermometer
- As it is on one board it light and needs less space.
- It reduces overhead of receiving values from different sensors.

Payload Air Temperature Sensor Trade & Selection

Name	Logic Level (V)	Weight (grams)	Power (µW)	Operation Temperature (°C)	Interface	Cost
GY 87 10DOF	+3 to +5	6	13,315.5	-40 to 85	I2C	₹ 1,090
DS18B20	+3 to +5.5	7.9	660	-55 to +125	Analog	₹ 208
LM41	+3.3 to +5	3	1800	0 to +140	Analog	₹ 50

- GY 87 is an all in one module comprising of: -
  i. Barometer
  ii. Magnetometer
  iii. Gyroscope
  iv. Accelerometer
  v. Thermometer
- As it is on one board it light and needs less space.
- It reduces overhead of receiving values from different sensors.

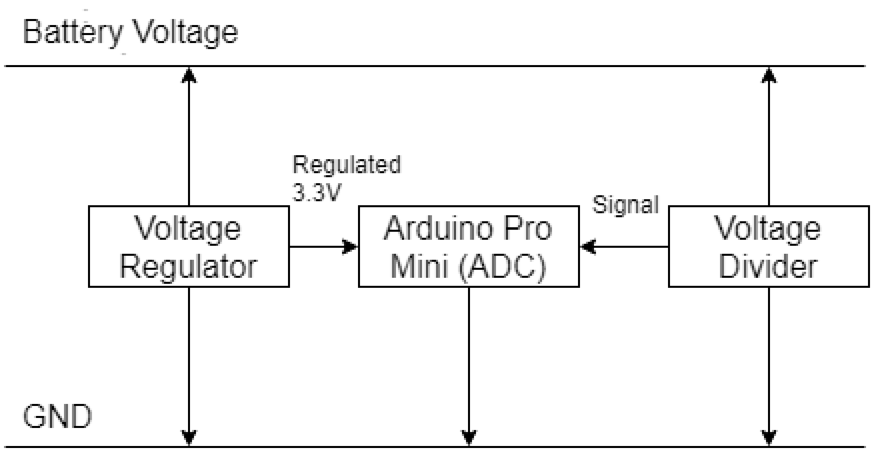
GPS Sensor Trade & Selection

Name	Logic Level (V)	Weight (grams)	Power (mW)	Operation Temperature (°C)	Interface	Cost
Neo-6M	+3.3	12	221	-40 to 85	Serial	₹ 600
L80-M39	+3 to +4.4	6	66	-40 to 85	Serial	₹ 480
Adafruit Ultimate GPS v3.0	+3.3 to +5	8	60	-40 to 85	Serial	₹ 4583

- Neo-6M was selected owing to its availability in our area and previous experience with it.

Payload Power Voltage Sensor Trade & Selection

- Voltage divider is used and it is connected to ADC of Arduino Pro Mini.
- Arduino is connected to regulated 3.3V.
- Main battery voltage is divided and then given to ADC.
- Values of resistors are kept maximum to reduce current consumption.



Pitch and Roll Sensor Trade & Selection

Name	Logic Level (V)	Weight (grams)	Power (µW)	Operation Temperature (°C)	Interface	Cost
GY 87 10DOF	+3 to +5	6	13,315.5	-40 to 85	I2C	₹ 1,090
MPU 9250	+3 to +5	5	12,780	-40 to 85	I2C	₹ 427
MPU 6050	+3 to +5	4	10,560	-40 to 85	I2C	₹ 184

- GY 87 is an all in one module comprising of: -
  i. Barometer
  ii. Magnetometer
  iii. Gyroscope
  iv. Accelerometer
  v. Thermometer
- As it is on one board it light and needs less space.
- It reduces overhead of receiving values from different sensors.

Auto-gyro Blade Spin Rate Sensor Trade & Selection

Name	Logic Level (V)	Weight (grams)	Power (mW)	Operation Temperature (°C)	Interface	Cost
Hall Effect 3144E	3.3 to 5	10	33	-40 to 90	Digital	₹ 110
Orange 360 PPR (Magnetic)	5	160	200	-24 to 84	Digital	₹ 1540
IR sensor module	3.3 to 5	4	3.3	-40 to 85	Digital	₹ 51

- The sensor will be exposed to sunlight hence rendering IR sensors unusable.
- Thus, hall effect sensors are used.
- 3144E is lighter.

Bonus Camera Trade & Selection

Name	Voltage Level (V)	Weight (grams)	Type	Operation Temperature (°C)	Cost
Ada Fruit 3202	3 to 5	2.8	Standalone	-40 to 85	₹ 850
Pi Cam	5	30	Need R Pi	-40 to 85	₹ 590
Chinese Spy Cam	5	5	Standalone	-	₹ 440

- Ada Fruit camera though expensive than others is a standalone camera.
- As whole system is on regulated 3.3V. It was ideal choice.
- Pi Cam needs Raspberry pi and details of Chinese spy cam are not available. Moreover they operate on 5V.

Container Air Pressure Sensor Trade & Selection

- **There are no sensors on container.**
- **All the electronic system is contained inside science payload.**

Descent Control Design

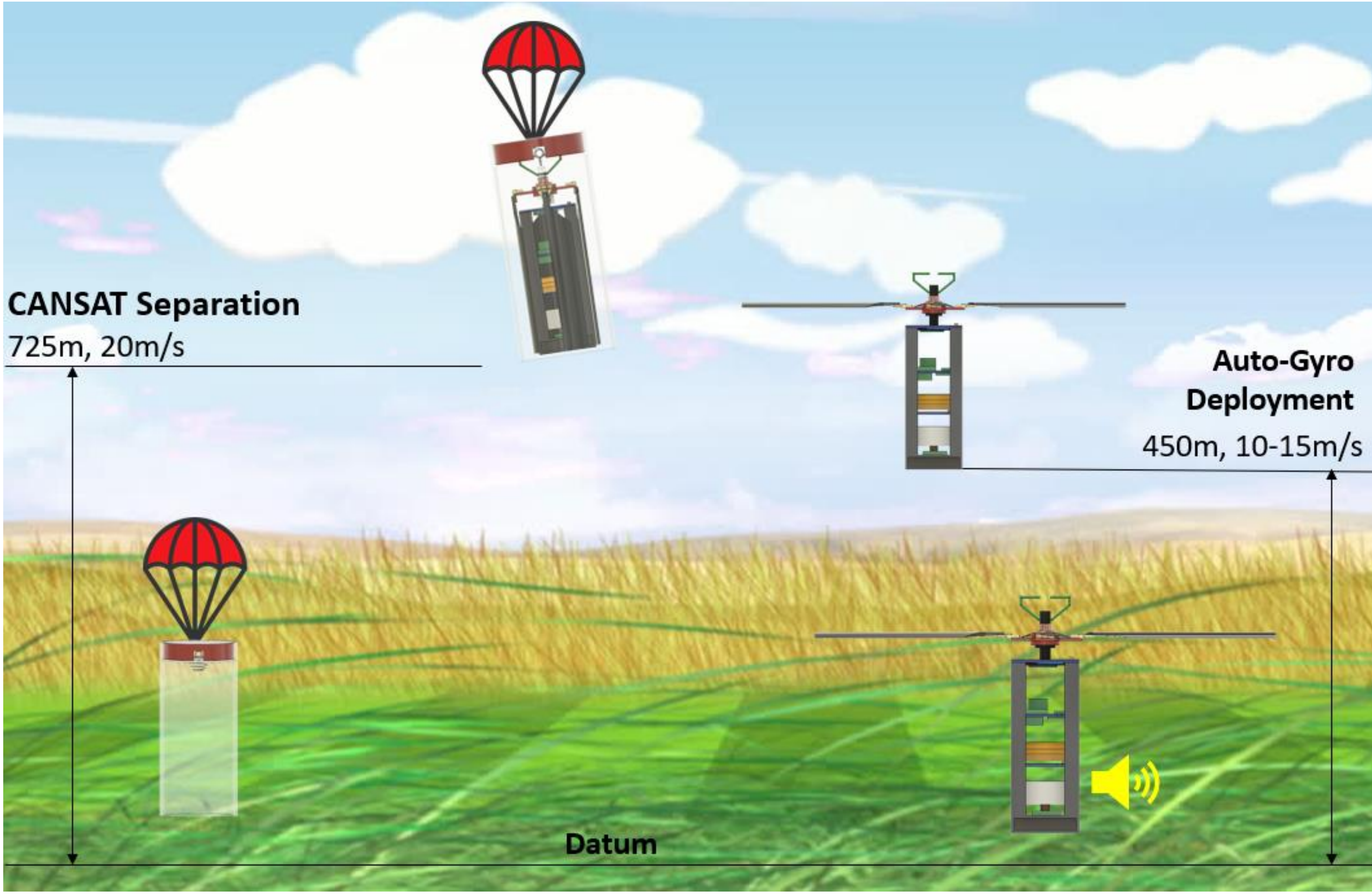
Richal Abhang (RA)

MIT SAT Descent Control Overview

Following are the phases of Descent:

Sr. No.	Phase	Height (meters)	Mechanism	Descent Rate (m/s)	Design considered
1.	Launch of rocket	670-725	Rocket	-	-
2.	Deployment of CanSat	670-725	Parachute	20	Hexagonal Parachute
3.	Deployment of Science payload	450	Passive Auto-Gyro	10-15	Nichrome wire+ Nylon rope
4.	Activation of located Audio Beacon	0	Landing of Science Payload	0	Buzzer

MIT SAT Descent Control Overview



MIT SAT Descent Control Requirements

ID	Requirements	Verification			
		A	I	T	D
BR 7	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	✔			
BR 8	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	✔			
BR 9	The container shall release the payload at 450 meters +/- 10 meters.				✔
BR 10	The science payload shall descend using an auto-gyro/ passive helicopter recovery descent control system.	✔			
BR 11	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.	✔			
BR 12	All descent control device attachment components shall survive 30 Gs of shock.	✔			
BR 52	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.		✔		

Following are the requirements for selected mechanisms:

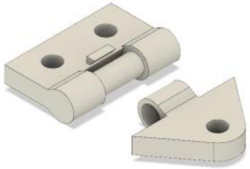
Sr. No.	Mechanisms Used	Method of Operation	Requirements	Material specification
1.	Deployment of parachute using buoyancy of Air	Passive	1) Hexagonal parachute 2) Eye bolt 3) Ropes	1) Fabric 2) Stainless Steel 3) Nylon
2.	Science payload deployment using Nichrome Wire	Active	1) Nichrome wire 2) Nylon rope 3) Battery 4) Conductive wires 5) Spring	1) Gauge 33 2) Nylon 3) 3.7 volts 4) Copper 5) 10 × 15 mm
3.	Deployment of Auto-Gyro blades using Buoyancy of air	Passive	1) Rotor Hub 2) Shaft 3) Retainer 4) Thrust bearing 5) Rotor blades 6) Hinges 7) Retainer pin	1) ABS 2) - 3) - 4) 51100 5) Poly 1500 6) ABS 7) -

Descent Control Requirements

Thrust bearing

Rotor Blade

Eye Bolt



Hinge

Hexagonal parachute

Spring

Equation for Design of Parachute

- Weight of CanSat = Drag force due to Parachute

$$M \times g = \tfrac{1}{2} \times \rho \times C_d \times A \times V^2$$

- m = Mass of CanSat = 0.5 kg
- g = Acceleration due to gravity = 9.81 m/s^2
- ρ = Density of Air = 1.225 kg/mm^3
- C_d = Coefficient of Drag = 0.8
- A = area of Parachute in mm^2
- V = Velocity of descent in mm^2

$\therefore 0.5 \times 9.81 = 0.5 \times 1.225 \times 0.8 \times A \times 225$

Hence,

$A = 0.04449\ mm^2$

Payload Descent Control Strategy Selection and Trade

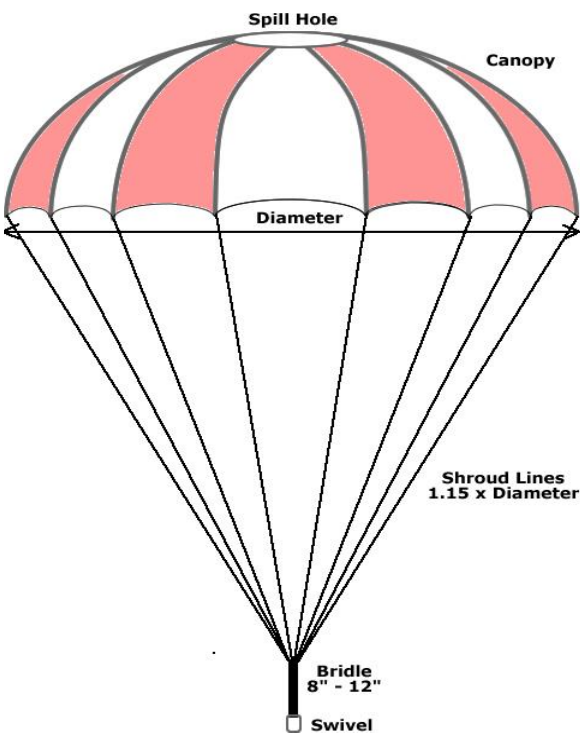
- Design parameters for Hexagon parachute
  - Spill hole diameter is taken 30% of diameter of circle in which hexagon is inscribed.
  - Spill hole diameter = d = 78 mm
  - Spill hole area = 0.0047783 mm^2
  - Total area = A’ = A +A1= 0.0492683mm^2
  - We are going to use hexagonal parachute.
  - Area of hexagon = $(3\sqrt{3}/2) \times a^2$
  - Where, a = side of hexagon
  - Hence, side of hexagonal parachute = a = 137.7 mm = <u>0.1377 m</u>

Payload Descent Control Strategy Selection and Trade

Two Designs of Parachutes and its Trade Selection

Selection	**Layout**	**Reason**	**Severity**
Selected	A (Hexagonal)	Easier to make	Critical
		More coefficient of drag	Moderate
		Less weight	High
Not selected	B (Hemispherical)	Harder to make	Critical
		Less coefficient of drag	Moderate
		More weight	High

Payload Descent Control Strategy Selection and Trade



Hemispherical Parachute (Rejected)

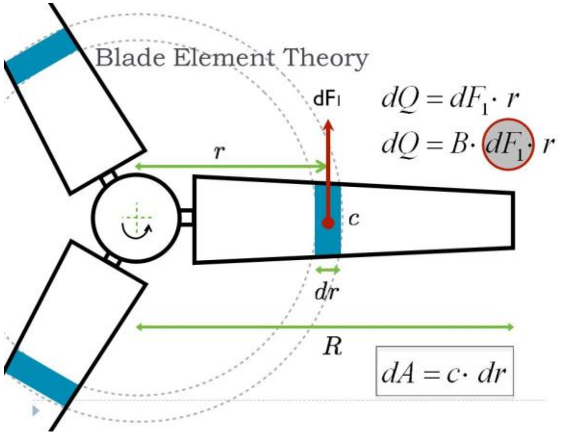
Hexagonal Parachute (Selected)

Payload Descent Control Strategy Selection and Trade

- Auto-Gyro Design Procedure
  1) Theory and Principle
  2) Calculations
  3) Airfoil selection
  4) CAD model
  5) Material selection
  6) Bearing selection
  7) Analysis
  8) CFD
  9) Manufacturing
  10) Physical Testing

1) Theory and Principle

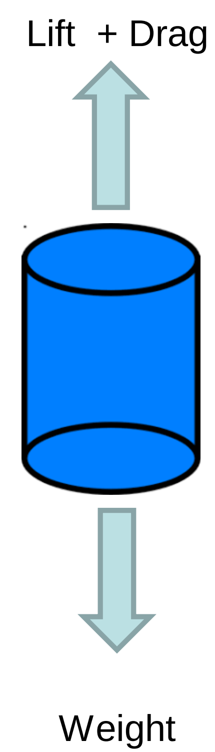
- Blade element theory (BET) is a mathematical process originally designed by William Froude (1878), David W. Taylor (1893) and Stefan Drzewiecki to determine the behaviour of propellers.
- It involves breaking a blade down into several small parts then determining the forces on each of these small blade elements.
- These forces are then integrated along the entire blade and over one rotor revolution in order to obtain the forces and moments produced by the entire propeller or rotor.



Payload Descent Control Strategy Selection and Trade

2) Calculations

- Available Data for calculations:
- Area of Square = 0.0049 m^2
- Weight of CanSat = 0.5 kg
- Density of Air = 1.225 kg/m^3
- Coefficient of Drag for rectangular prism (C_d) = 1.2



CALCULATIONS:

1. Lift that should be generated by each blade of the rotor:

- $\Sigma F=0$
- **$mg= (4 \times Lift) + (0.5 \times \rho \times Vc^2 \times C_d \times A_f)$**

  $\therefore 0.5 \times 9.81 = (4 \times lift) + (0.5 \times 1.25 \times 100 \times 1.2 \times 0.0049)$

  $\therefore$ Lift = 1.1362125 N

Total lift that should be generated by Rotor system = 4 × 1.1362125 = <u>4.5448 N</u>

2. Thrust generated by sinking Auto gyro

$T = 2 \times V^2 \times A \times \rho$

Where, T = Thrust of the rotor

V = Sink speed in vertical auto gyro

A = Disk area (that is swept by the blade)

$T = 2 \times 100 \times 4 \times 0.2 \times 0.03 \times 1.225 = \underline{5.88\ N}$

Thus, <u>Lift that should be generated < lift generated</u>

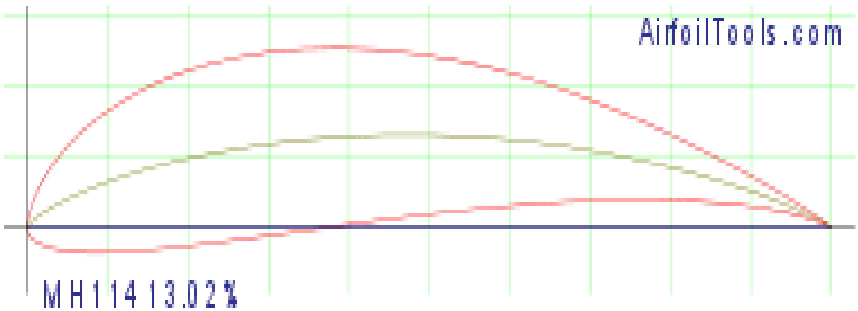
3) Airfoil Selection

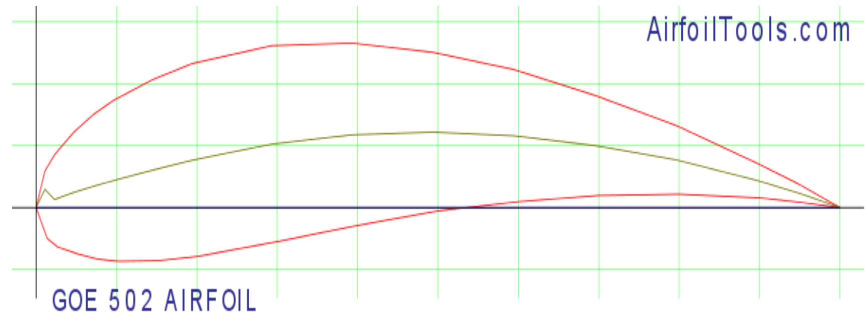
Two airfoils are selected having similar characteristics as that of required.

Selected Airfoil	Rejected Airfoil
Airfoil selected = NACA MH 114 Thickness = 13.1% Camber = 6.6% Trailing edge angle = 9.6 degree Lower Flatness = 16.5% Leading edge radius = 2.7% Efficiency = 52.1 Max Cl = 1.98 Max Cl angle = 12.0 Max L/D = 82.192 Max L/D angle = 7 Max L/D Cl = 1.719 Stall angle = 12.0 Zero Lift angle = -8.0	Airfoil Name : NACA MH 113 Thickness = 14.6% Camber = 6.9% Trailing edge angle = 10.1 degree Lower flatness = 16.6% Leading edge radius = 3.5% Efficiency = 52.4 Max Cl = 2.14 Max Cl angle = 15.0 Max L/D = 63.611 Max L/D angle = 3.5 Max L/D Cl = 1.35 Stall angle = -0.133 Zero Lift angle = -8.0

<u>Advantages of MH 114 over MH 113: High Max L/D ratio</u>

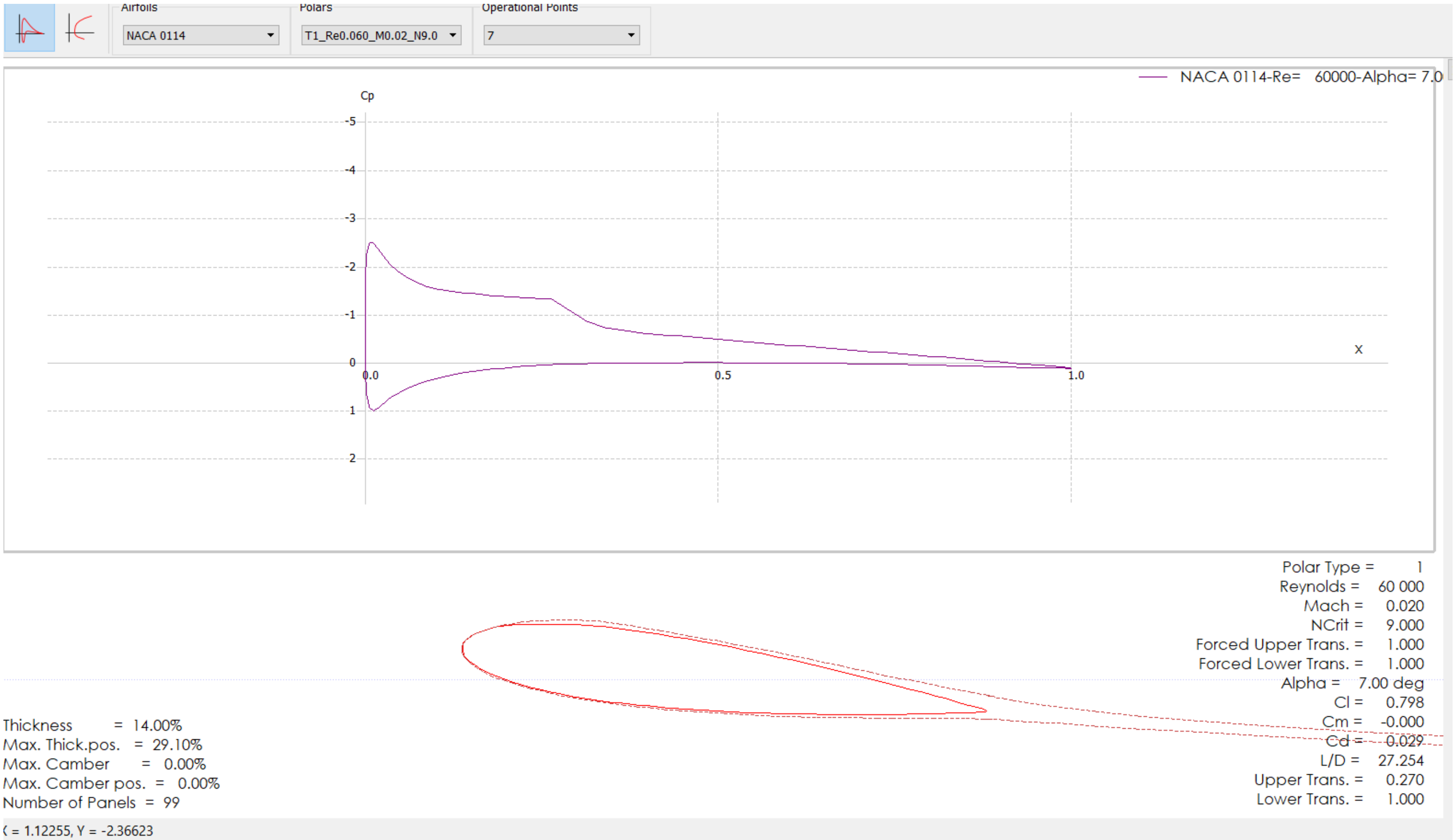
Payload Descent Control Strategy Selection and Trade



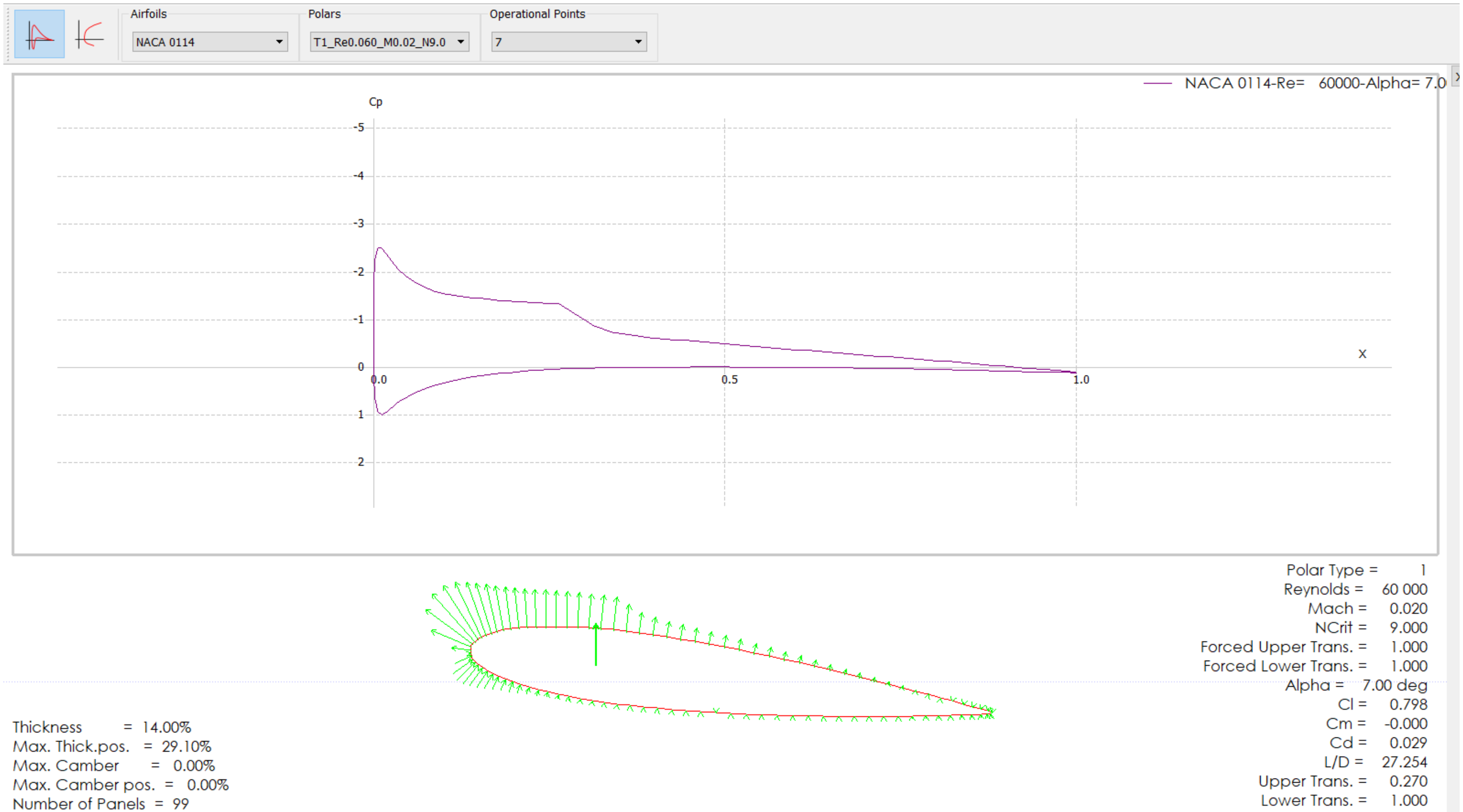


NACA MH 114 Airfoil
(Selected)

NACA MH 113 Airfoil
(Rejected)



Q Blade Software (boundary condition)



Q Blade software (Pressure condition)

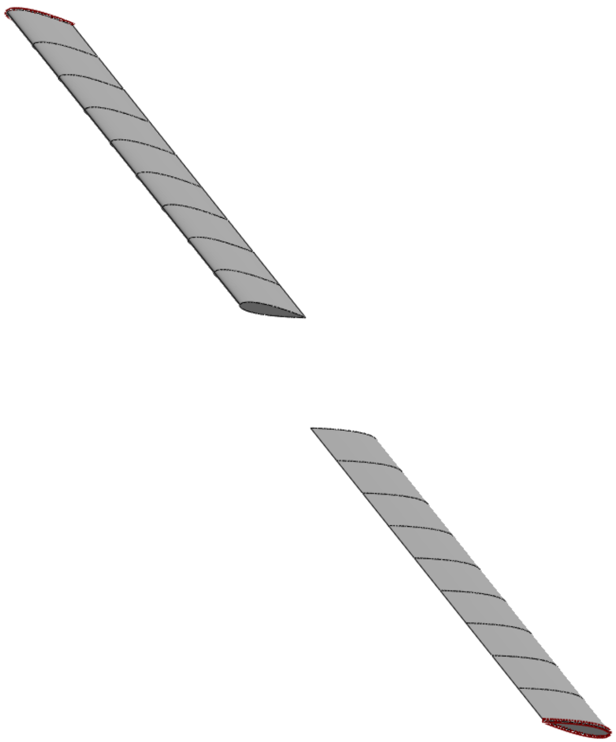
Trade selection for Auto-Gyro

Selection	Layout	Reasons	Severity
SELECTED	A (Four blades rotor)	Better Lift for Science Payload	Critical
		More L/D	Moderate
		More factor of safety	High
NOT SELECTED	B (Two blades rotor)	Doesn’t generate enough lift	Critical
		Doesn’t give Pitch stability	Moderate
		Needs more wing span	High

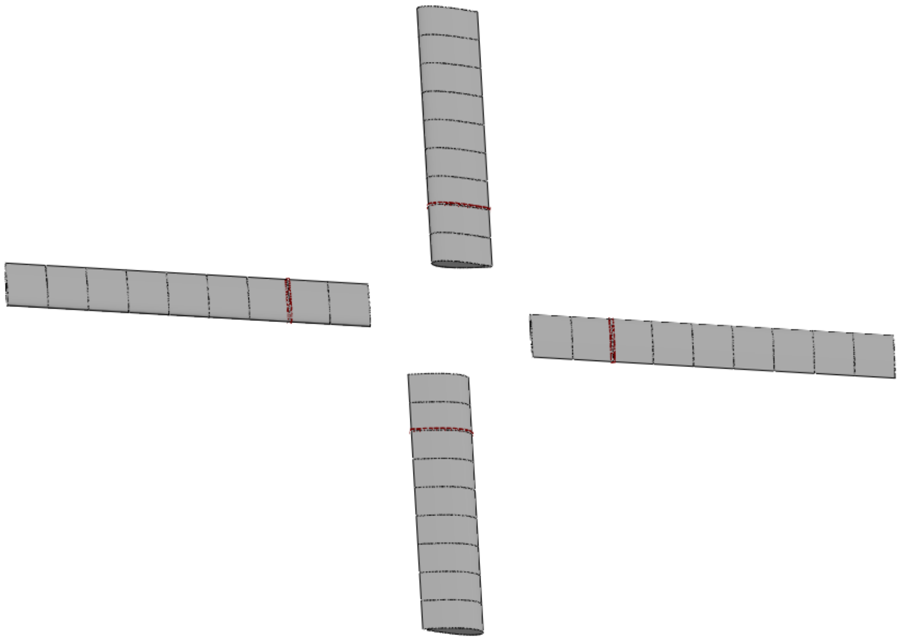
Payload Descent Control Strategy Selection and Trade

- Specification of the blade:
  - Chord length = 3 cm
  - Length of the blade = 20 cm
  - Angle of attack = 7°
  - Reynolds number = 60000
  - Mach Number = 0.02 (from Q Blade software)
  - Number of blades = 4
  - Angle of twist = 0°
  - Blade shape = Rectangular
  - Maximum snap angle for blades at hinge: 30˚

Payload Descent Control Strategy Selection and Trade

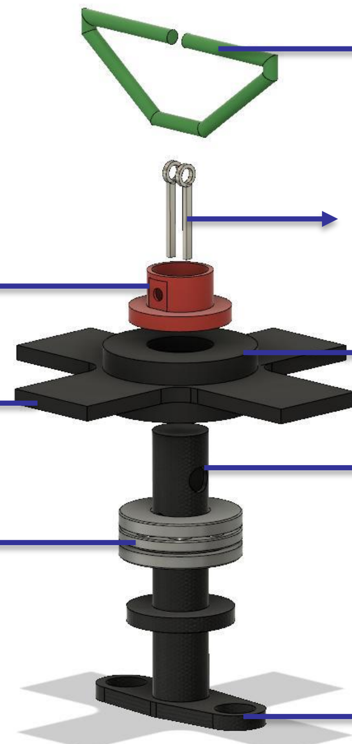


Two blades rotor
(Rejected)



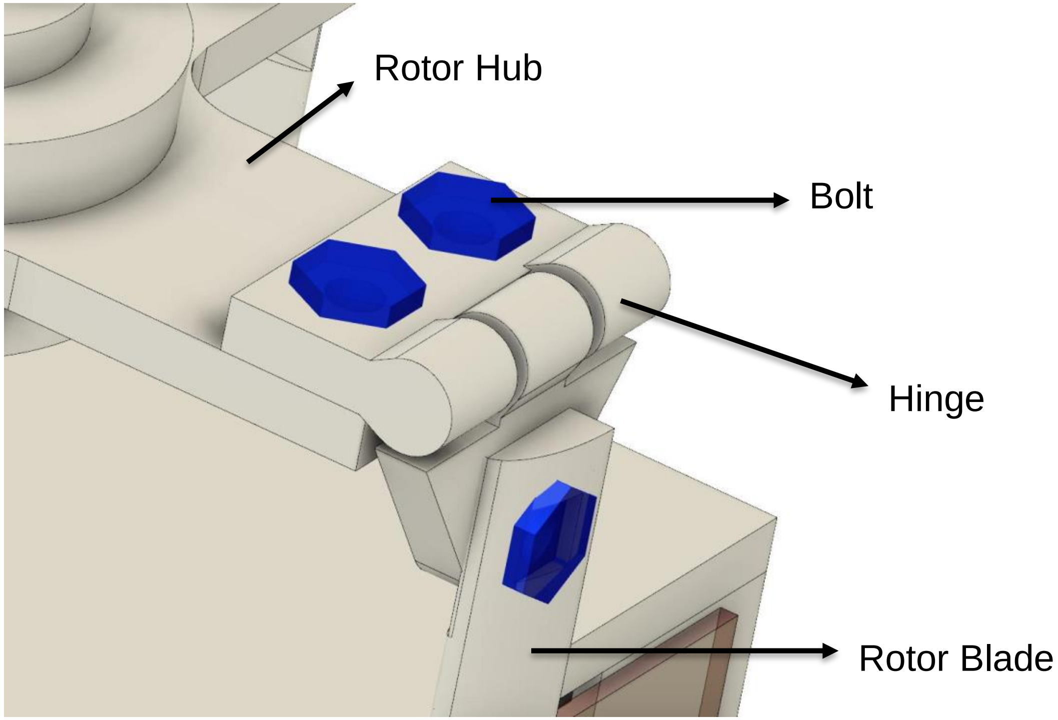
Four blades rotor
(Selected)

4) CAD model



Rotor hub Assembly

Payload Descent Control Strategy Selection and Trade



Interfacing of Blade with rotor system

5) Material selection

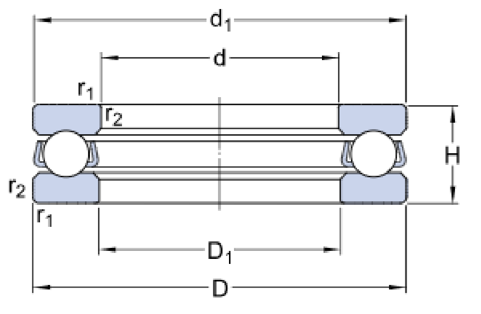
- Poly1500 is a translucent material with properties comparable to those of PP (polypropylene) and engineering plastics.
- Being impact-resistant and durable, this material is suited for rigid, functional prototypes in a large range of applications such as automotive components, electronic housings, and snap-fit assemblies.
- Surface structure: Unfinished parts typically have visible building layers on the surface but post-production finishes can achieve different effects, from high glosses to coarse textures. Stereolithography parts can be sandblasted, painted, varnished, covered and coated.

Data sheet:

MEASUREMENT	VALUE	STANDARD
Density	1.18 – 1.2 g/cm³	
Tensile Strength	30 – 32 MPa	ASTM D638M
Tensile Modulus	1227 – 1462 MPa	ASTM D638M
Elongation at Break	15 – 25%	ASTM D638M
Flexural Strength	41 – 46 MPa	ASTM D790
Flexural Modulus	1310 – 1455 MPa	ASTM D790
Notched Izod Impact	48 – 53 J/m	ASTM D256A
Hardness (Shore D)	80 – 82	ASTM D2240
Heat Deflection Temperature	52 – 61°C	ASTM D648 @ 0.46 MPa

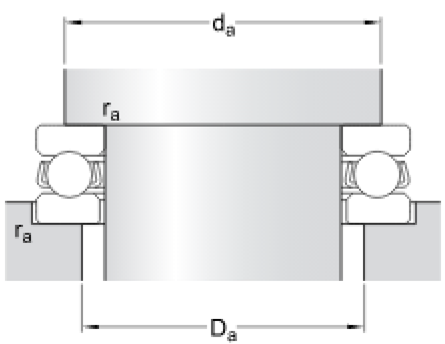
6) Bearing Selection

Dimensions:



d		10	mm
D		24	mm
H		9	mm
d_1	≈	24	mm
D_1	≈	11	mm
$r_{1,2}$	min.	0.3	mm

Abutment Dimensions:



d_a	19	mm
D_a	15	mm
r_a	0.3	mm

Payload Descent Control Strategy Selection and Trade

Calculation data:

Basic dynamic load rating	C		8.71	kN
Basic static load rating	C_0		12.2	kN
Fatigue load limit	P_u		0.45	kN
Reference speed			9500	r/min
Limiting speed			13000	r/min
Minimum load factor	A		0.0012	

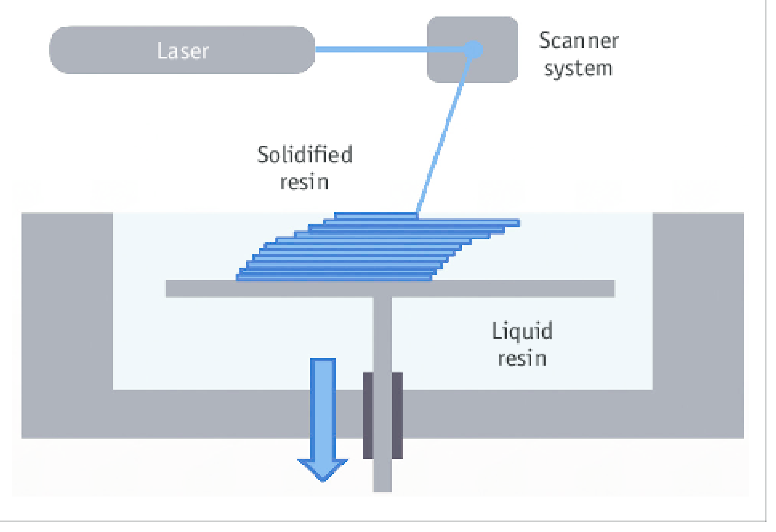
Mass:

Mass bearing (including seat washer where applicable)			0.02	kg

SKF 51100 Thrust ball bearing is selected

7) Manufacturing

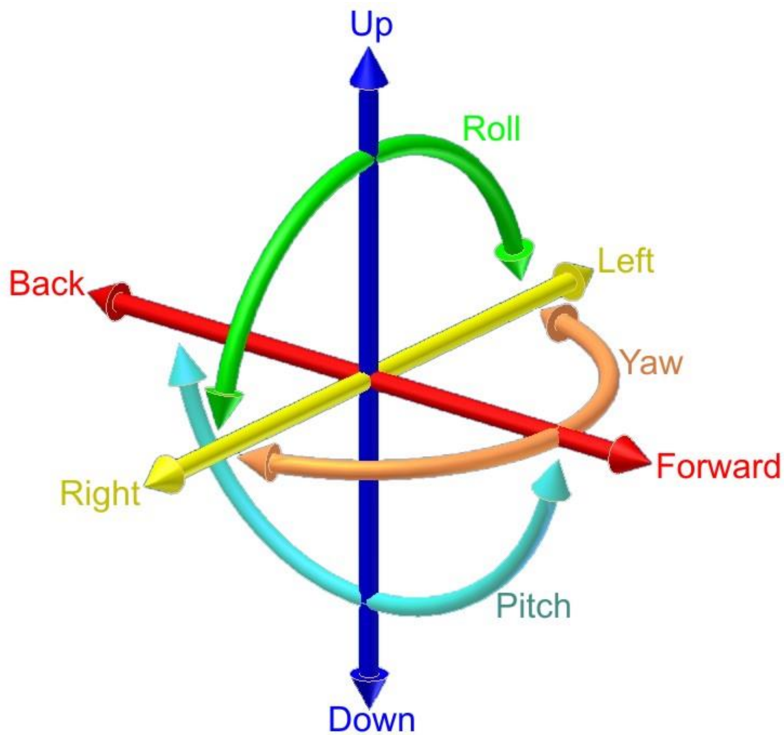
- ***Stereolithography*** is a form of 3D printing technology used for creating models, prototypes, patterns, and production parts in a layer by layer fashion using photopolymerization, a process by which light causes chains of molecules to link, forming polymers.
- Those
- polymers then make up the body of a three-dimensional solid.



Theory

- While the CanSat is descending, gusts of wind or rocket instabilities can cause the CanSat and thus the science payload to wobble or rotate in three directions namely: **Yaw, Roll and Pitch**.
- During descent it can translate or change its location from one point to another and it can rotate meaning it can roll around its own axis.
- Poorly designed CanSats can become unstable during descent.
- Cylindrical CanSats are symmetric about a line from top face to bottom face. We can call this line the roll axis and the motion about this axis is called a rolling motion.
- The **Centre of Gravity (C.G.)** lies along the roll axis.
- For a stable descent C.G. should be located at the lower part of the payload.

Payload Descent Stability Control Strategy Selection and Trade



Three Directions of Rotation

Our Design considerations

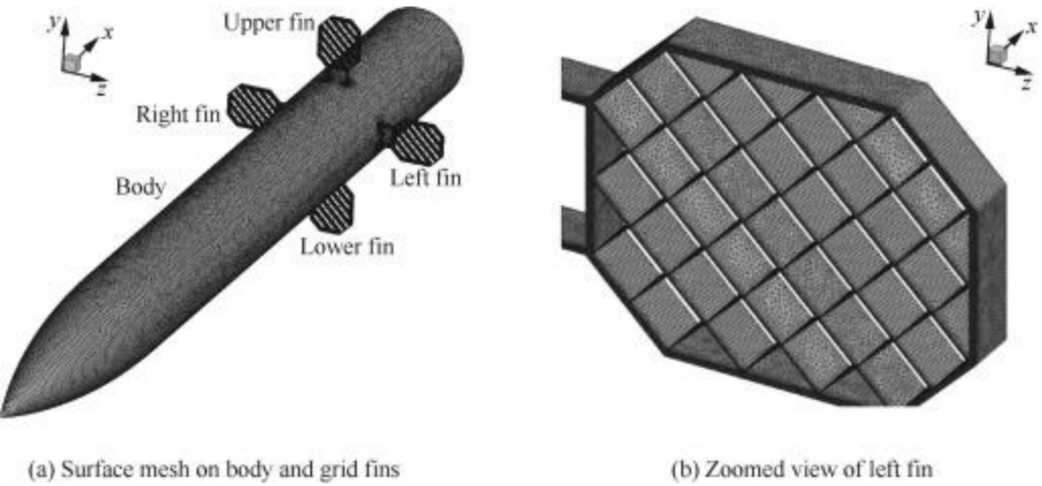
Sr. No.	Motion	Operation method	Mechanism	Requirements
1.	Rolling Motion	1) Active	Reaction wheel	1) Reaction wheel 2) Motor 3) Battery 4) Copper conductors
		2) Passive	Cuboidal shape of Science payload	1) 7 × 7 cm frontal area
2.	Yawing Motion	Passive	By keeping the C.G. of payload as low as possible	-

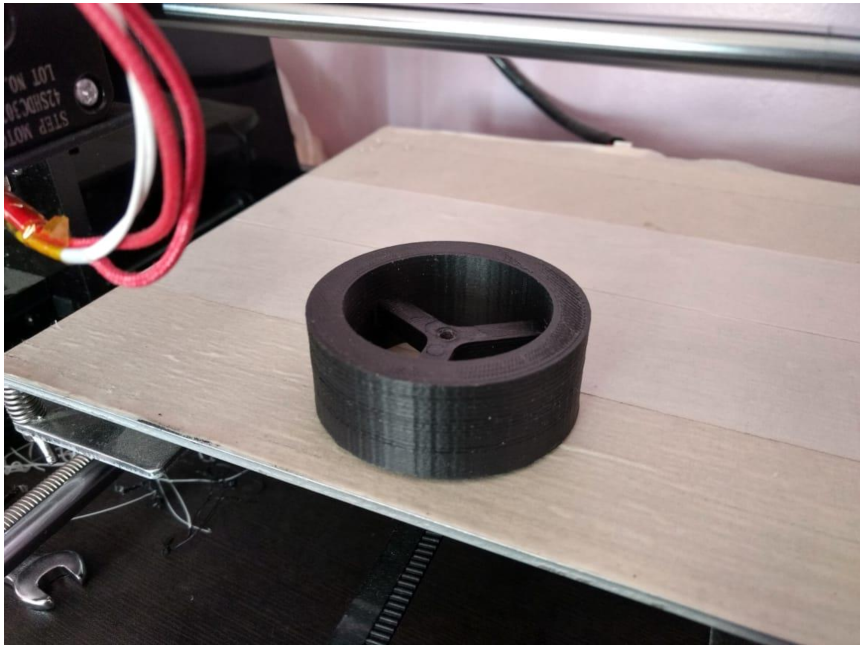
Payload Descent Stability Control Strategy Selection and Trade

For active control system trade selection

Selection	Layout	Reasons	Severity
SELECTED	A (Reaction Wheel)	Less weight	Critical
		Easy Mechanism	Moderate
		Single Motor used	High
NOT SELECTED	B (Grid Fins)	More weight	Critical
		Complex Mechanism	Moderate
		Two or more servo motors required	High

Payload Descent Stability Control Strategy Selection and Trade





Grid Fins
(Rejected)

Reaction Wheel
(Selected)

Payload Descent Stability Control Strategy Selection and Trade

Calculations for reaction wheel

Aim : Point at magnetic North in azimuthal direction

Design Values:

- $\omega_c = 2\pi$ rad/s ≡ Angular velocity of CanSat
- $I_c = 2 \times 10^{-5}$ g mm^2 ≡ Moment of inertia of CanSat
- $I_w = 0.2 \times 10^{-5}$ g mm^2 ≡ Moment of inertia of reaction wheel

∴ Selected motor is sufficient for this operation.

$$- I_c \times \omega_c = - I_w \times \omega_w$$

('-' sign represents opposite sense of direction)

$\omega_w = -(I_c \times \omega_c)/(I_w) = 62.8$ ≡ Angular velocity of reaction wheel

Feedback from:

- Gyro sensor gives Angular Velocity ω_c
- Magnetic compass gives Position with respect to magnetic North
- $\delta\theta = 0$,
- $\delta\theta = \theta n - \theta_{act}$
- **Nadir Direction is maintained by keeping the centre of gravity (C.G) of Science payload as low as possible.**

MIT SAT

Descent Rate Estimates

- The Payload is deployed from the CanSat at the rate of 20m/s
- It then continues to decelerate up to 10 m/s where the thrust of the Auto-gyro is equal to the weight of the payload.
- Following are the values acquired during calculations:
  - a = (Thrust generated- lift that should be generated)/mass of the payload

  $\therefore$ a = (5.88 – 4.54)/ 0.5 = 1.96 m/s^2
  - V = u – a*t

  $\therefore$ 10 = 20 – 1.96 * t

  $\therefore$ t = 5.1 s
  - h = u*t – (0.5 * a * t^2)

  $\therefore$ h = 76.51 m

  $\therefore$ Average velocity of the payload = 15.001 m/s
- Above calculations are based on constant thrust (5.88 N) although Thrust is a function of Rotor RPM.
- Variation of thrust according to rotor RPM is thus being studied.

Mechanical Subsystem Design

Prachit Kamble (PK)

CanSat container

Structural elements		
Sr. no.	Element	Material
1.	Cover shell + Plate	ABS plastic
2.	Parachute	Fabric
3.	Eye bolt	Stainless steel
Interface elements		
1.	Element	material
2.	Payload and container	Nylon-6 rope

Science Payload

Structural elements		
Sr. No.	Element	Material
1.	Frame	ABS plastic
2	Plates × 4	ABS plastic
3.	Hub assembly	ABS plastic
4.	Thrust Bearing	Pressed steel
5.	Blades × 4	Poly 1500 plastic
6.	Nichrome wire	Nichrome
Interface elements		
1.	Element	Material
2.	Hinge	ABS plastic
3.	Hub and Bearing	Super glue
4.	Shaft and frame	M4 × 15 bolt and Lock Nut
5.	Plates and frame	M3 × 10

Mechanical Sub-System Requirements

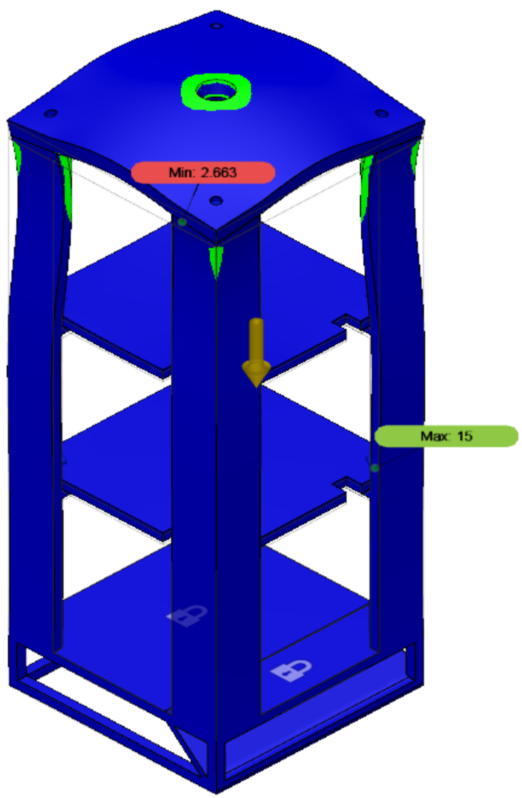
ID	Requirement	Verification			
		A	I	T	D
BR 1	Total mass of the CanSat (science payload and container) shall be 500 grams +/- 10 grams.	✔			
BR 2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	✔			
BR 3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	✔			
BR 4	The container shall be a fluorescent color; pink, red or orange.				✔
BR 5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	✔			
BR 6	The rocket airframe shall not be used as part of the CanSat operations.	✔			
BR 13	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	✔			
BR 14	All structures shall be built to survive 15 Gs of launch acceleration.	✔			

Mechanical Sub-System Requirements

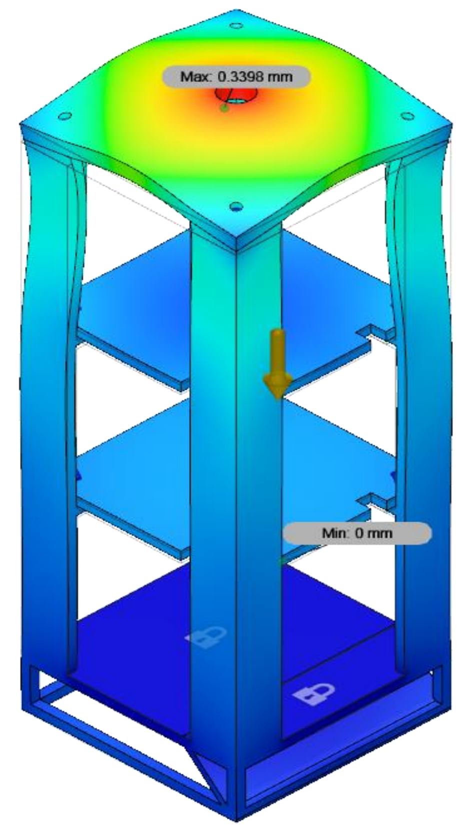
ID	Requirement	Verification			
		A	I	T	D
BR 15	All structures shall be built to survive 30 Gs of shock.	✔			
BR 16	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	✔			
BR 17	All mechanisms shall be capable of maintaining their configuration or states under all forces.				✔
BR 18	Mechanisms shall not use pyrotechnics or chemicals.	✔			
BR 19	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	✔			
BS 41	Both the container and probe shall be labelled with team contact information including email address.			✔	

Mechanical Sub-System Requirements

Analysis results for 30 Gs force



Factor of Safety FEA

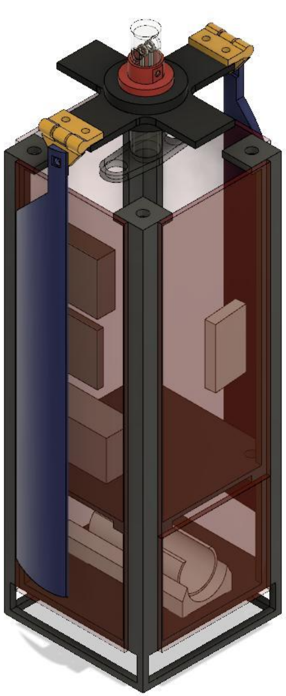


Displacement FEA

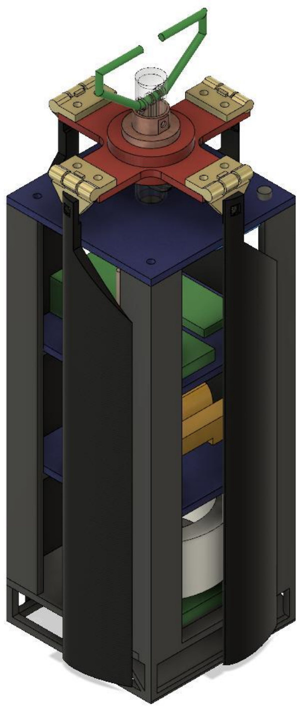
Payload Mechanical Layout of Components Trade & Selection

Trade selection for the payload

Selection	Layout	Reasons	Severity
SELECTED	A (Horizontal Plate structure)	Less mass of frame.	Critical
		Closer distribution of mass hence less moment of inertia (less work for reaction wheel)	Moderate
		Easier to assemble and disassemble.	High
NOT SELECTED	B (Vertical Plate structure)	Higher mass of frame.	Critical
		Further distribution of mass, more moment of inertia.	Moderate
		Relatively difficult to assemble and disassemble	High



Vertical plate payload structure
(Rejected)



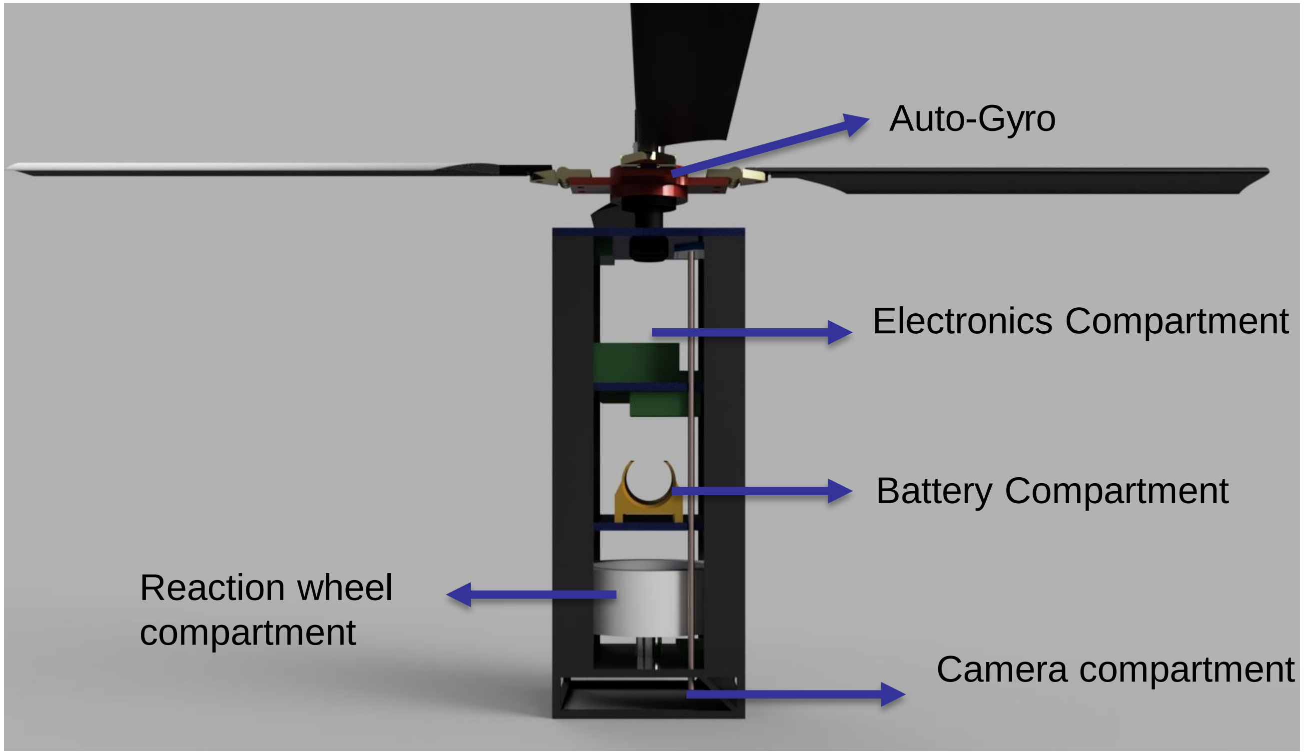
Horizontal Plate payload structure
(Selected)

Payload Mechanical Layout of Components Trade & Selection

Structural material selection

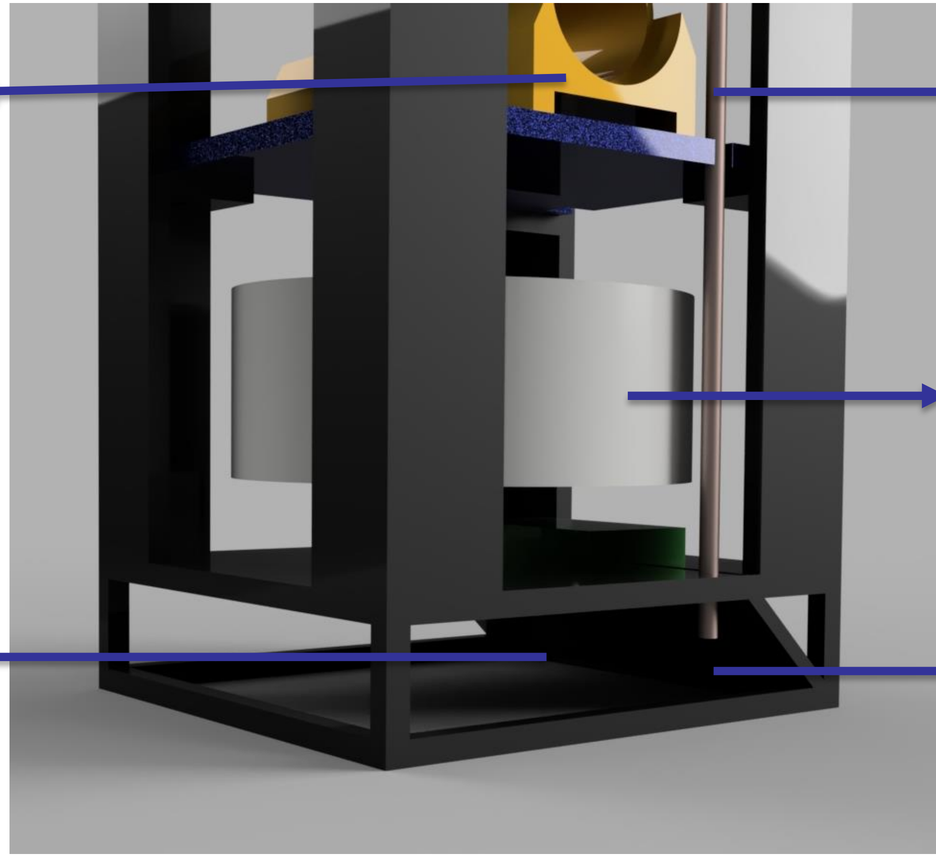
Sr. No.	Component	Material	Reasons
1.	Container Shell + Plate	ABS Plastic	•Lightweight, sufficiently strong. •Easily available locally and 3D-Printable
2.	Science Payload Frame	ABS Plastic	•Lightweight, sufficiently strong. •Easily available locally and 3D-Printable
3.	Science Payload Plates.	ABS Plastic	•Lightweight, sufficiently strong. •Easily available locally and 3D-Printable
4.	Science Payload Covering	450 micron Polypropylene sheets	•Easily available, cheap. •Heat and moisture resistant.
5.	Rotor Blades	Poly1500	•Gives good surface finish with stereolithography •Density lower than competitors like perform and TUSK etc.
6.	Rotor Hub Assembly	ABS Plastic	•Lightweight, sufficiently strong. •Easily available locally and 3D-Printable

Payload Mechanical Layout of Components Trade & Selection



Different Compartment of Science Payload

Payload Mechanical Layout of Components Trade & Selection



Battery Mount

XBee antenna

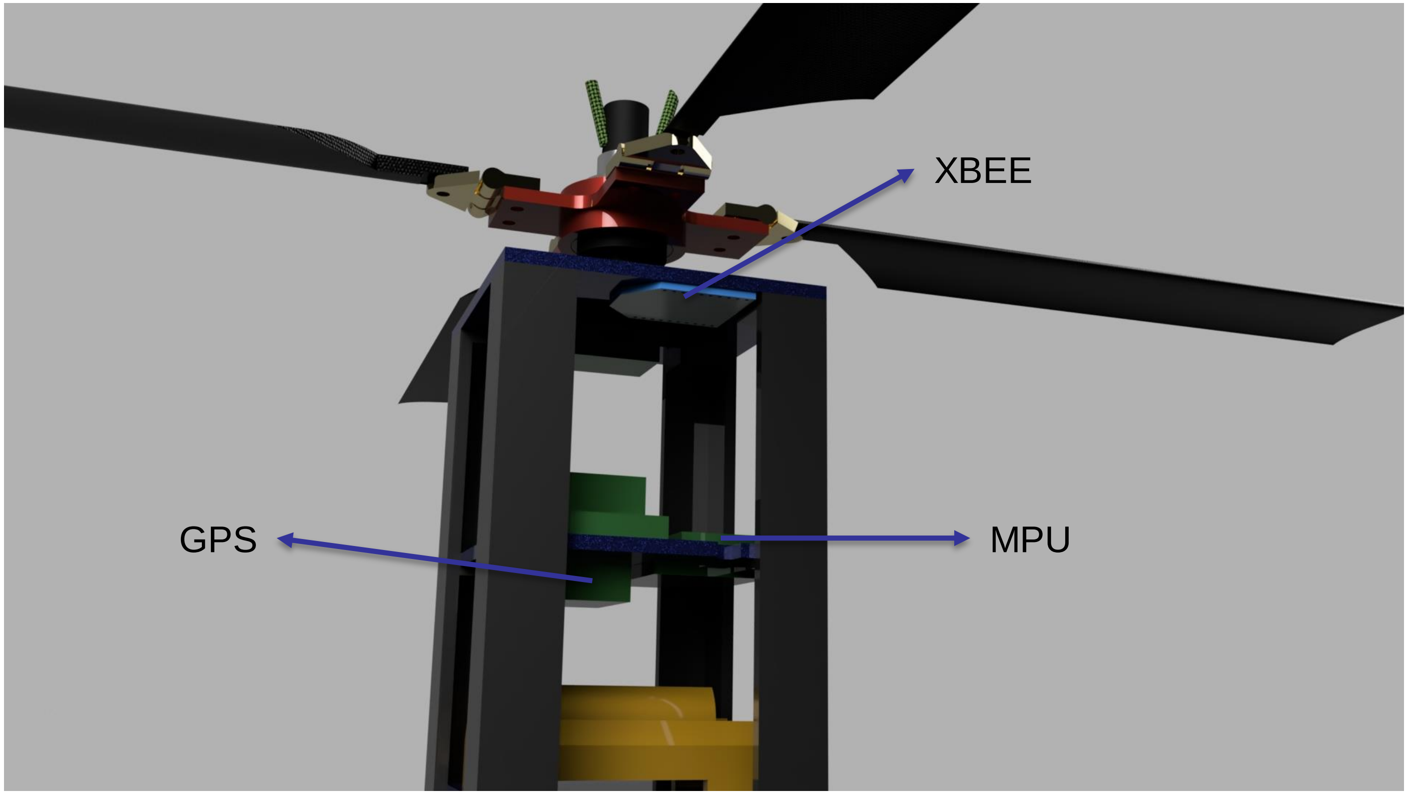
Reaction wheel

Power Indicator and Switch

Camera at 45˚

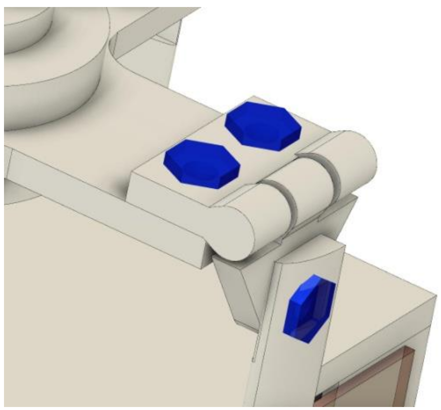
Battery, Reaction wheel and Camera Compartment

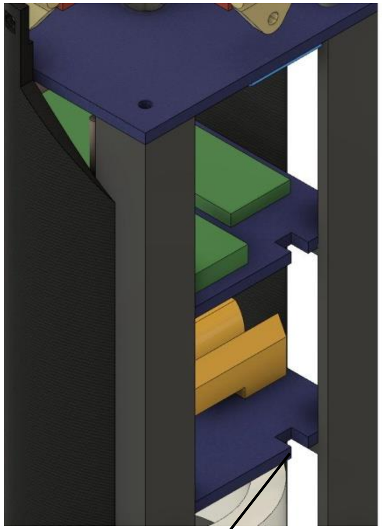
Payload Mechanical Layout of Components Trade & Selection



Electronics Compartment

Payload Mechanical Layout of Components Trade & Selection





Slot for electrical wires

Interfacing of mechanical components

Manufacturing Process

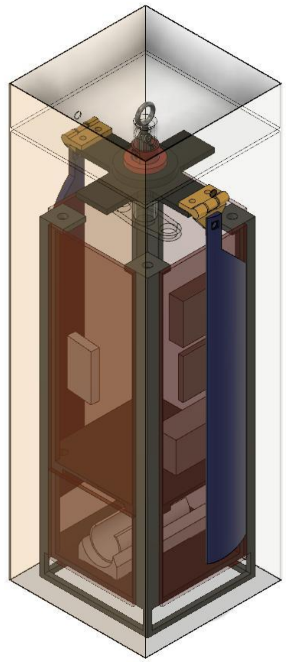
- ***3D printing*** is any of various processes in which material is joined or solidified under computer control to create a three-dimensional object, with material being added together (such as liquid molecules or powder grains being fused together), typically layer by layer.
- 3D printed objects can have a very complex shape or geometry and are always produced starting from a digital 3D model or a CAD file.

Payload Pre Deployment Configuration Trade & Selection

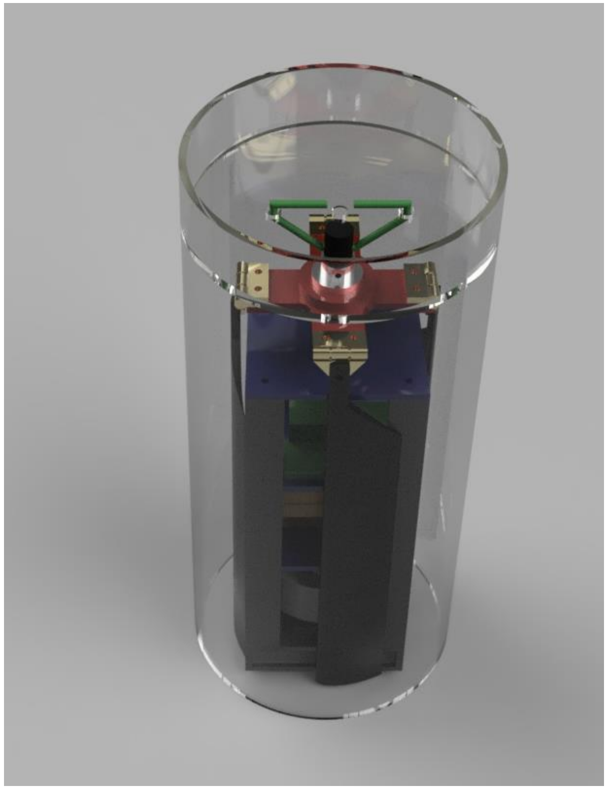
Trade selection for Pre Deployment Configuration

Selection	Layout	Reasons	Severity
SELECTED	A (Cylindrical configuration + science payload)	Gives more space for blades in folded condition	Critical
		Better geometrical tolerances	Moderate
		Light in weight	High
NOT SELECTED	B (Cuboidal configuration + science payload)	Doesn’t give any tolerances	Critical
		More weight	Moderate
		Have sharp edges	High

Payload Pre Deployment Configuration Trade & Selection



Cuboidal container + Science payload (Rejected)



Cylindrical container + Science Payload (Selected)

Payload Pre Deployment Configuration Trade & Selection

Pre Deployment Configuration

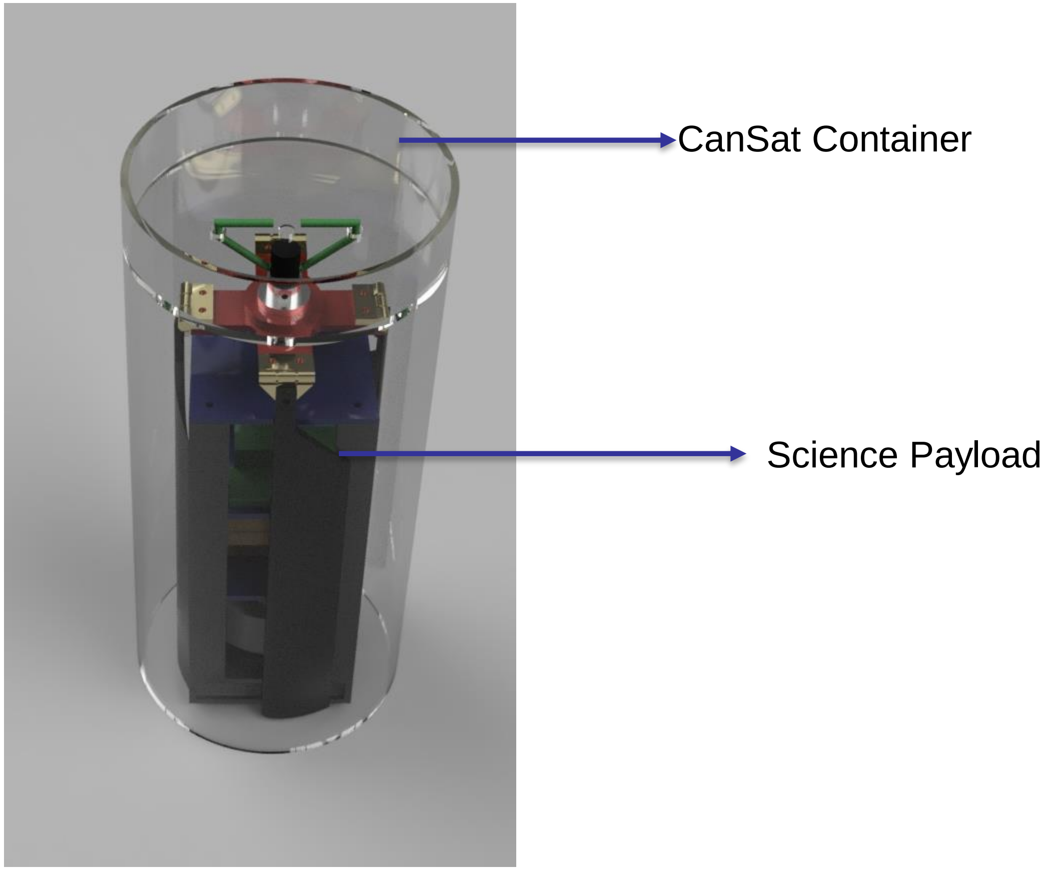
- Blades of the autogyro are attached to hinges which can be folded downwards.
- Blades have positive locking in upper direction, to avoid over-tilting of the rotor disc.
- Payload is suspended with the help of a Nylon rope from the container.
- Nylon rope diameter is selected such that :

A) It should be strong enough to sustain payload weight as well as shocks and jerks during launch.

B) It should be thin enough to be cut by the heating of nichrome wire.

- The science payload is seated against a lightweight spring which will assist the payload while ejecting from the container shell.
- The Nylon rope will hold the science payload to the container shell against gravity as well the spring force.

Payload Pre Deployment Configuration Trade & Selection



Payload Pre Deployment Configuration

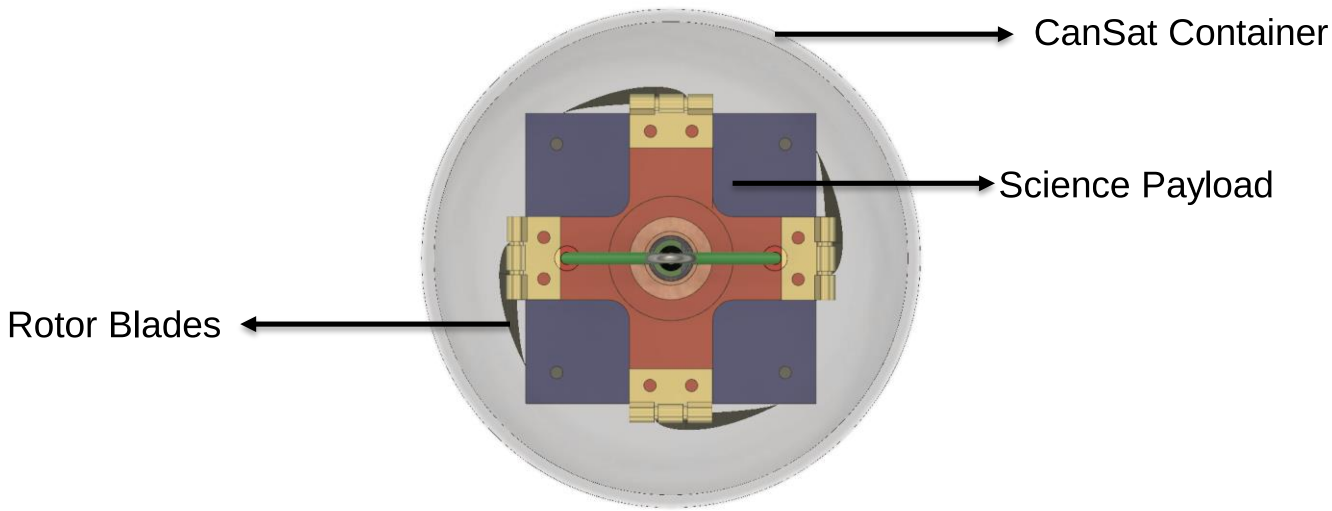
Payload Pre Deployment Configuration Trade & Selection

Container

Science Payload

Launch Configuration

Payload Pre Deployment Configuration Trade & Selection



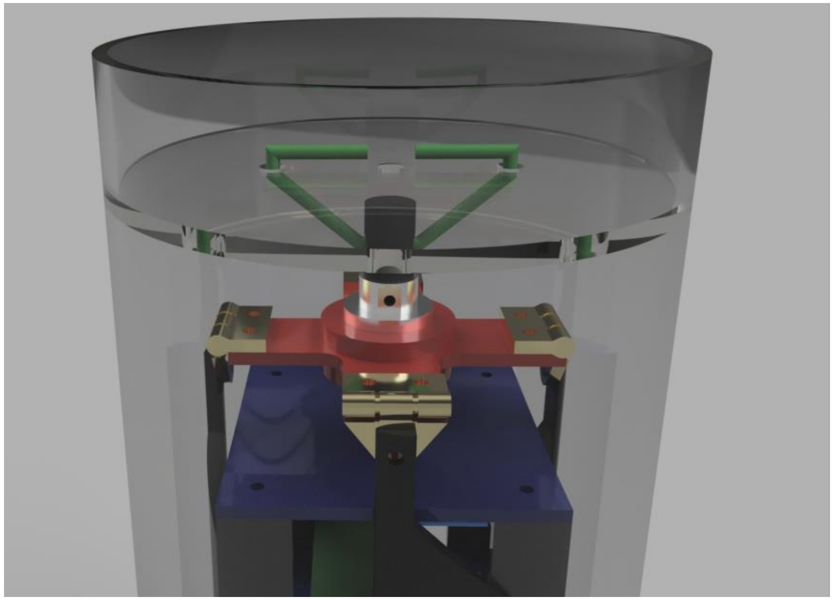
Top view of CanSat showing clearances

Payload Deployment Configuration Trade & Selection

Mechanism trade selection used for payload deployment

Selection	Layout	Reasons	Severity
SELECTED	A Active method (Nichrome wire) + Passive method (spring)	Less Weight	Critical
		Easy mechanism	Moderate
		More Reliable	High
NOT SELECTED	B (Servo Mechanism)	More weight due to additional servo	Critical
		Space consuming	Moderate
		More Power consuming	High

Payload Deployment Configuration Trade & Selection



Nichrome Wire Mechanism (Selected)

Servo Motor Mechanism (Rejected)

Payload Deployment Configuration Trade & Selection

Mechanism trade selection for deployment of Auto-Gyro System

Selection	Layout	Reasons	Severity
SELECTED	A (Deployment due to buoyancy)	Less Weight	Critical
		No power consumption	Moderate
		No mechanism required	High
NOT SELECTED	B (Servo Mechanism)	More weight due to additional servo	Critical
		Space consuming	Moderate
		More Power consuming	High

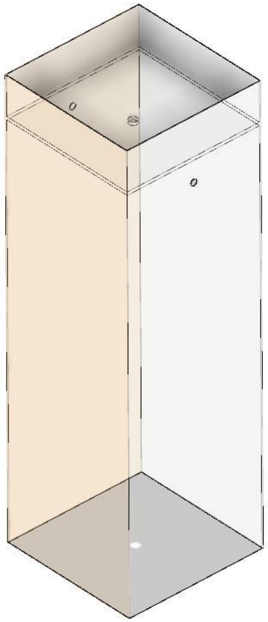
Container Mechanical Layout of Components Trade & Selection

Trade selection for Container of CanSat

Selection	Layout	Reasons	Severity
SELECTED	A (Cylindrical configuration)	No sharp edges	Critical
		Manufacturing is easy	Moderate
		Less weight	High
NOT SELECTED	B (Cuboidal configuration)	Sharp edges	Critical
		More cost for manufacturing	Moderate
		Heavy	High

Container Mechanical Layout of Components Trade & Selection

Cylindrical CanSat Container (Selected)



Cuboidal CanSat Container (Rejected)

Container Mechanical Layout of Components Trade & Selection

Mechanical layout of components mounted on Cylindrical container

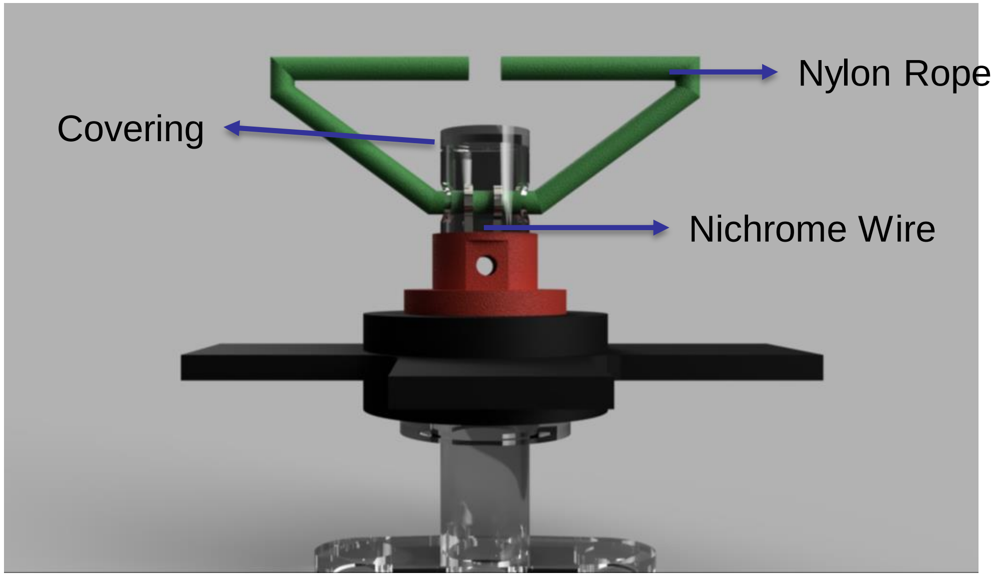
Sr. No.	Name of the Component	Specification	Purpose
1.	Eyebolt + Nut	Stainless steel	To Fasten Parachute
2.	Nylon Rope	Nylon	To hold the science payload before deployment
3.	Spring	10 × 15 mm	To keep the science payload in loaded/ strained condition before deployment

Payload Release Mechanism

Payload release mechanism requirements

Sr. No.	**Components required**	**Specification**	**Purpose**
1.	Nylon rope	Nylon	To hold science payload before deployment
2.	Nichrome wire	Gauge 33	To burn the Nylon wire
3.	Battery	3.7 volts	To provide current
4.	Conducting wires	Copper	To carry current
5.	Spring	10 ×15 mm	To give push to payload during deployment

Payload Release Mechanism



Nichrome Wire Mechanism for Payload Deployment

Payload Release Mechanism

Working of Payload release mechanism (Active mechanism)

i. The science payload is hang to Nylon rope which is passed through the CanSat cylindrical container.
ii. Payload has covered Nichrome wire which surrounds the Nylon rope and is given electrical connections.
iii. When 450 meters height is achieved by the CanSat, currents starts flowing through the Nichrome wire thus heating it.
iv. The heat generated due to resistance of Nichrome wire is less than melting point of Nichrome wire but more than melting point of Nylon.
v. Thus the Nylon rope is melted within seconds breaking it and releasing the Science payload.
vi. Then CanSat container descents with parachute and science payload descents with passive auto-gyro.

Payload Release Mechanism

Calculations for Nichrome wire

- Rn = (Wire length (inch)/ 12) × Resistance per feet
- Vp = I × Rn
- P = I × Vp

Time taken to melt Nylon rope is 1.5 sec at 3.3V which is experimentally verified.

Gauge of Nichrome wire is 33.

Container Parachute Release Mechanism

Container Parachute Release requirements

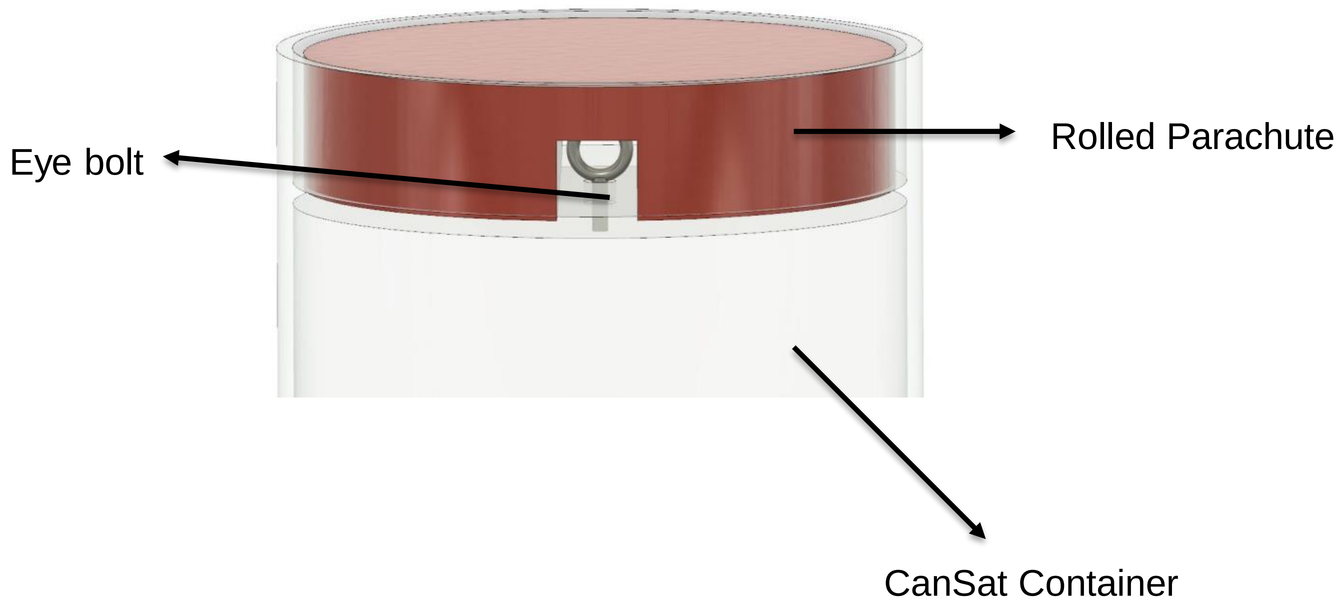
Sr. No.	Components required	Specification	Purpose
1.	Eyebolt + nut	Stainless steel	To fasten the parachute
2.	Parachute	Hexagonal Fabric (Pink or Orange)	For CanSat descent at 20 m/s +/-5m/s
3.	Nylon Ropes	Nylon	To tie parachute to eyebolt

Container Parachute Release Mechanism

Working of the Parachute release mechanism

1. The parachute is folded and kept in the upper compartment of the CanSat cylindrical container around the eyebolt.
2. As the Rocket reaches its apogee position it releases CanSat.
3. At the same time the hexagonal shaped parachute which is open to atmosphere is deployed passively due to the buoyant force.
4. Two holes are provided to the Cylindrical container for the air to enter from inside of CanSat and ensure opening of the parachute.

Container Parachute Release Mechanism



Parachute in CanSat before its deployment

Electronics Structural Integrity

- Electronic components are mounted on ABS platform by using HSS M3x10 bolts and locknuts.
- They all are enclosed inside the PVC sheet which are main walls of science payload.
- To ensure secured electronic connection everything is soldered and additionally secured by hot glue.

Mass Budget

Sr. No	Name of the component	Weight (gm)	Quantity	Total weight	Source
1.	Frame of science payload	80	1	80	Estimated
2.	Payload plates	12	2	24	Estimated
3.	Thrust Bearing	20	1	20	Data sheet
4.	Rotor hub	9	1	9	Estimated
5.	Auto-gyro blade	10	4	40	Estimated
6.	Retainer	1	1	1	Estimated
7.	Shaft	18	1	18	Estimated
8.	Hinges	1.2	4	4.8	Estimated
9.	Retainer Pin	1	1	1	Estimated
10.	M3 × 10 screws and locknuts M5 screws.	1.5+2.5	12+2	35	Estimated

Mass Budget

Sr. No.	Name of the component	Weight	Quantity	Total weight	Source
11.	Reaction Wheel	35	1	35	Measured
12.	Battery mount	10	1	10	Estimated
13.	Cansat Container	20	1	20	Estimated
14.	Science payload cover sheets	1	4	4	Measured
15.	Release spring (flashlight)	5	1	5	Estimated
16.	Nylon string	5	1	5	Measured
17.	Eye bolt	5	1	5	Estimated
18.	Parachute	15	1	15	Estimated
19.	Nichrome Wire	2	1	2	Measured
20.	GPS module	12	1	12	Estimated

Mass Budget

Sr. No.	Name of the component	Weight (gm)	Quantity	Total Weight (gm)	Source
21.	GY 87	6	1	6	Data sheet
22.	Arduino Pro Mini	4	1	4	Data sheet
23.	Xbee Pro S2C	8	1	8	Data sheet
24.	Tachometer	10	1	10	Data sheet
25.	Camera	2.8	1	2.8	Data sheet
26.	PCB	35	1	35	Estimate
27.	Battery	41	1	41	Data sheet
28.	Motor	12	1	12	Estimated
29.	Buck	8	1	8	Data sheet
30.	Covering Plate	15	1	15	Estimated
31.	Misc. and Adhesive	10	-	10	Estimated

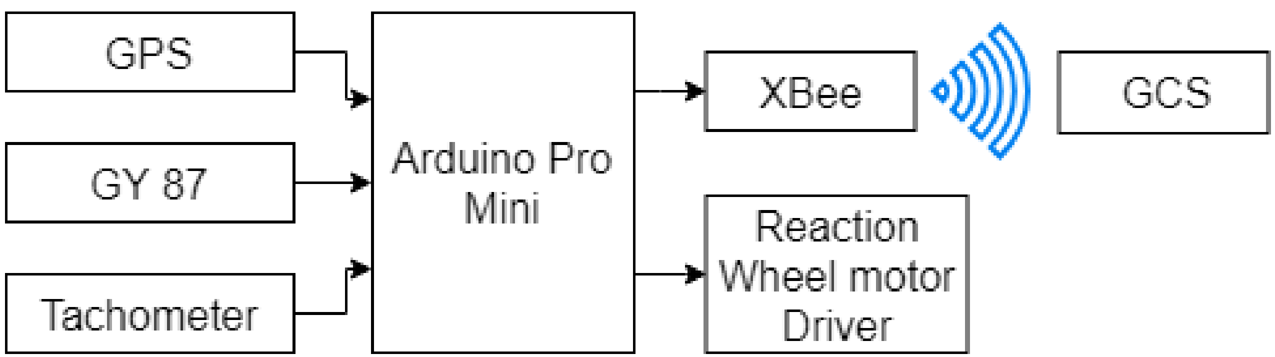
Total mass of Container + payload is 497.6 grams.

Communication and Data Handling (CDH) Subsystem Design

Toyas Dhake (TD)

Payload CDH Overview

- GPS is for getting latitude longitude and altitude of CanSat. GPS also provides current real time.
- GY 87 is a 10DOF sensor which has 3 modules- MPU6050, HMC5883, BMP180. It can give reading of yaw, pitch, roll, temperature and air pressure.
- Tachometer is to measure RPM of Auto gyro rotor.
- Reaction wheel is to stabilize CanSat.
- XBEE is to communicate with ground station.



MIT SAT Payload CDH Requirements

BR No.	Requirement	Verification A	Verification I	Verification T	Verification D
28	The ground station shall be able to command the science vehicle to calibrate barometric altitude, and roll and pitch angles to zero as the payload sits on the launch pad.	✔		✔	✔
29	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.			✔	✔
30	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	✔		✔	
31	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.		✔		
32	XBEE radios shall have their NETID/PANID set to their team number.			✔	
33	XBEE radios shall not use broadcast mode.		✔	✔	
34	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	✔			
35	Each team shall develop their own ground station.	✔			✔

Payload CDH Requirements

BR No.	Requirement	Verification			
		A	I	T	D
36	All telemetry shall be displayed in real time during descent.	✔		✔	
37	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		✔		✔
38	Teams shall plot each telemetry data field in real time during flight.		✔	✔	
39	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		✔		✔
40	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	✔		✔	
41	Both the container and probe shall be labelled with team contact information including email address.			✔	
42	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	✔		✔	
47	An audio beacon is required for the probe. It may be powered after landing or operate continuously.			✔	
48	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	✔			✔

Payload Processor & Memory Trade & Selection

Micro Controller Board	Form Factor (mm)	Cost	Weight (g)	Clock Frequency	Operating Voltage	Power (mWh)
Arduino Uno	68.6 x 53.3	₹ 299.00	25	16 MHz	5V	250
STM32F103C8T6	54 x 22	₹ 249.00	6	72 MHz	3.3V	450
Arduino Pro Mini	17.8 x 33	₹ 210.00	4	8 MHz	3.3V	120

Reasons to select Arduino Pro Mini: -

1. Operates on 3.3V, battery used in CanSat is of 3.7V hence no boost of voltage is required.
2. It is based on AVR hence it has extensive support of Arduino ecosystem.

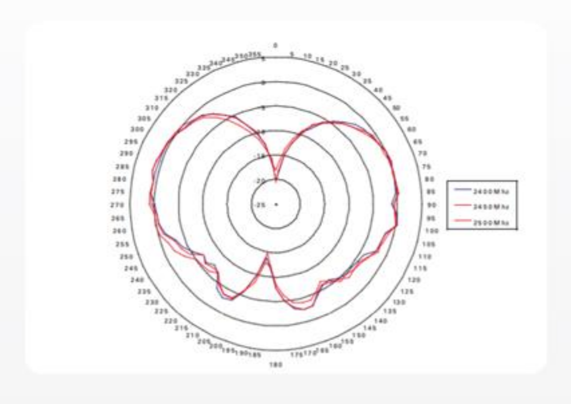
Payload Real-Time Clock

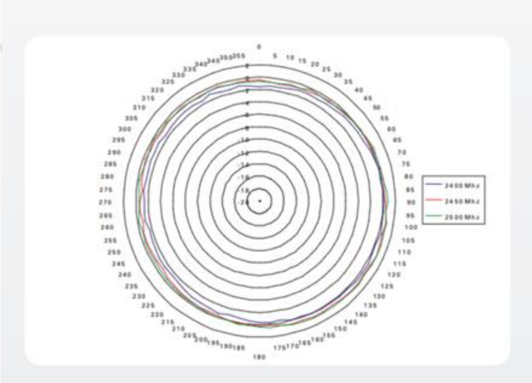
- There is no separate real time clock on CanSat.
- Real time is acquired from GPS module which is continuously broadcasted by GPS Satellite.

Payload Antenna Trade & Selection

Antenna	Gain (dBi)	VSWR	Mass (g)	Size (mm)	Polarization
XBP24CZ7SIT-004	1.5	<=2.0:1		160x18	
FXP70 Freedom Multi Standard Antenna	5	<= 1.5:1	1.2	27 x 25 x 0.8	Horizontal, Vertical
MicroSplatch Planar Antenna	3.8	<= 2.0:1		12.7 x 9.14	Horizontal, Vertical

- SMA connector is compatible with XBEE.
- Low cost.
- Easy setup.
- Resistant to weather conditions.





Payload Radio Configuration

Device	Frequency	Cost	TX Supply Current	RX Supply Current	Sensitivity	Range
XBee Pro S2C	2.4 GHz	₹ 2,299	120 mA	28 mA	-101 dBm	3.2km
XBee Pro S2B	2.4 GHz	₹ 2,471.26	205mA	47mA	-102 dBm	3.2km
XBee Pro S2A	2.4 GHz	₹ 2,477	215 mA	55 mA	-110dBm	1.6km

- Low current.
- Low power dissipation.
- Comparatively longer range.
- It is latest version.

MIT SAT Payload Telemetry Format

- Data will be transmitter at 1 Hz in burst
- The telemetry data file will be named :

  Flight_1086.csv
- Telemetry data will be transmitted with ASCII comma as delimiter and in format:

  <TEAM ID>,<MISSION TIME>,<PACKET COUNT>,<ALTITUDE>, <PRESSURE>, <TEMP>,<VOLTAGE>,<GPS TIME>,<GPS LATITUDE>,<GPS LONGITUDE>,<GPS ALTITUDE>,<GPS SATS>,<PITCH>,<ROLL>,<BLADE SPIN RATE>,<SOFTWARE STATE>,<BONUS DIRECTION>

MIT SAT Payload Telemetry Format

<TEAM ID>	Assigned team identification
<MISSION TIME>	Time since initial power up in seconds
<PACKET COUNT>	Count of transmitted packets, in case of processor reset
<ALTITUDE>	Altitude with one meter resolution
<PRESSURE>	Measured atmospheric pressure
<TEMP>	Temperature In degrees C with one degree resolution
<VOLTAGE>	Voltage of the CanSat power bus
<GPS TIME>	Time generated by the GPS receiver
<GPS LATITUDE>	Latitude generated by GPS receiver
<GPS LONGITUDE>	Longitude generated by GPS receiver
<GPS ALTITUDE>	Altitude generated by GPS receiver
<GPS SATS>	Number of GPS satellites being tracked by the GPS receiver
<PITCH>	Tilt angle in the pitch axis in degrees
<ROLL>	Tilt angle in the roll axis in degrees
<BLADE SPIN RATE>	Rate the auto-gyro blades spin relative to the science payload
<SOFTWARE STATE>	Operating state of the software
<BONUS DIRECTION>	Direction the camera is pointed relative to earth’s magnetic north

Container CDH Overview

- **There is no electronics on container.**

Container Processor & Memory Trade & Selection

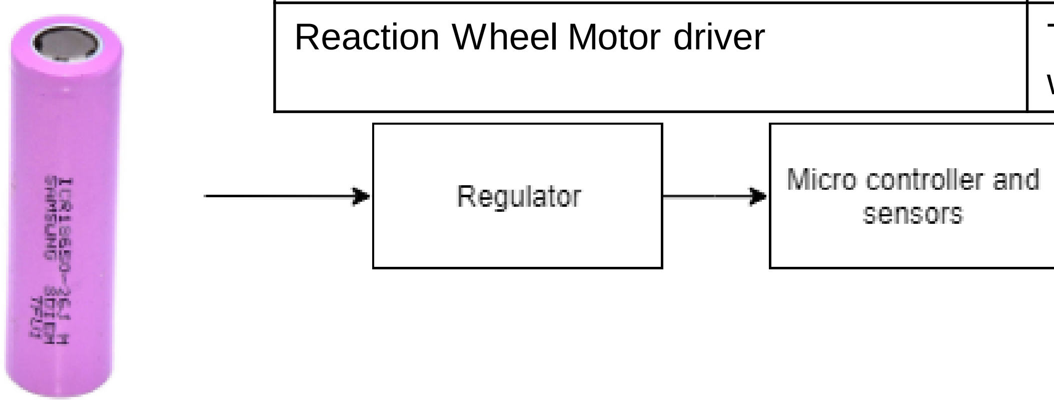
- **There is no electronics on container.**

Electrical Power Subsystem (EPS) Design

Soham Aserkar (SA)

EPS Overview

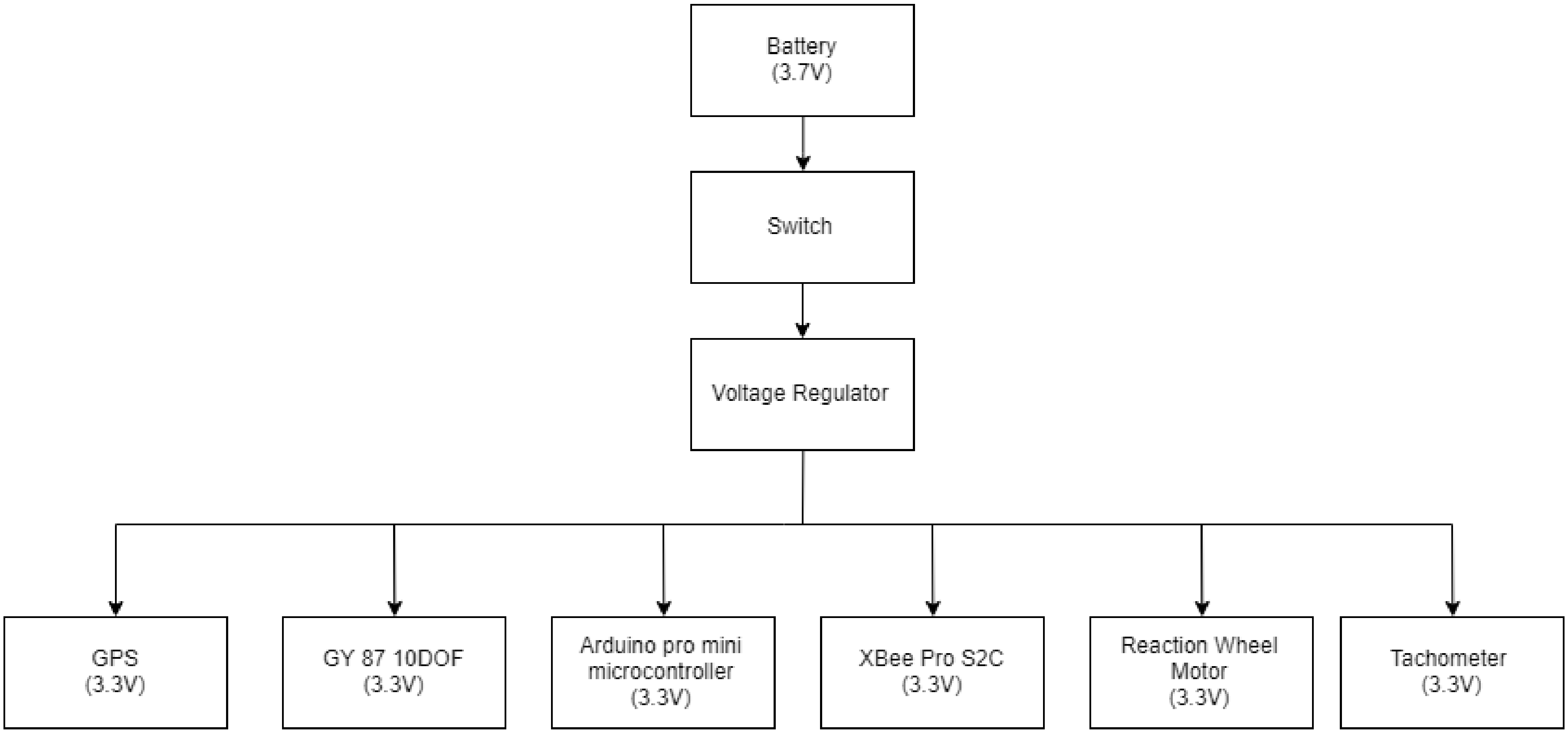
Component	Function
Switch	Turn CanSat On/Off.
Battery	Main Battery.
Arduino Pro Mini	Micro controller which controls CanSat.
XBee S2C module	To communicate with ground station
GPS Module	GPS
GY 87 Sensor	10 DOF Sensor for measurement of yaw, pitch, roll and air pressure.
Audio Beacon	Audio Beacon
Nichrome wire turn on circuit	To deploy science payload from CanSat
Regulator	Regulate 3.7V to 3.3V
Reaction Wheel Motor driver	To control RPM and Direction of Reaction wheel based on rotation od CanSat.



EPS Requirements

ID	Requirement	Verification			
		A	I	T	D
BR-45	The probe must include an easily accessible power switch that can be accessed without disassembling the CanSat and in the stowed configuration.	✓	✓		
BR-46	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the CanSat and in the stowed state.		✓	✓	
BR-49	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells.		✓	✓	
BR-50	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.		✓		✓
BR-51	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.		✓	✓	
BR-55	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	✓		✓	

Payload Electrical Block Diagram



Payload Power Trade & Selection

Sr. No.	Name	Operating Temp. (°C)	Weight (grams)	Type	Voltage (V)	Capacity (mAh)	Cost
1	SAMSUNG ICR18650-26J	0 to 45	70	Li- ion	3.7	2600	₹ 244
2	Duracell Procell	-20 to 45	45	Alkaline	9	310	₹ 440
3	Duracell AA	-20 to 45	34	Alkaline	1.5	2850	₹ 95

- Samsung ICR18650-26J was selected because of its capacity.
- Every element in the system works on 3.3V, hence 3.7V battery is enough.
- Duracell AA has more capacity but it has disadvantage when it comes to weight at 3.3V.

MIT SAT Payload Power Budget

Component Name	Function	Voltage (V)	Current (mA)	Operational Power (mW)	Required (mAh)
GY 87 10 DOF	Sensor Package	3.3	4.034	13.315	8
Neo-6M	GPS Module	3.3	67	221.1	134
Adafruit 3202	Camera Module	3.3	110	363	220
XBEE Pro S2C	Communicate with ground station	3.3	120	396	240
Arduino Pro Mini	Main micro controller	3.3	40	132	80
Nichrome	Detach Science payload	3.3	2000	6600	10 max(it will be on only for 2s)
Voltage Divider	Voltmeter	3.3	50	165	100
H-Bridge Motor Driver	Drive reaction wheel motor	3.3	500	1650	1000
Buzzer	Activate on landing	3.3	150	495	50
Total					1842

We have battery of 2600mAh. Power required is 1842 mAh which is well with in the limits.

Container Electrical Block Diagram

- **There is no electronics on Container.**

Container Power Budget

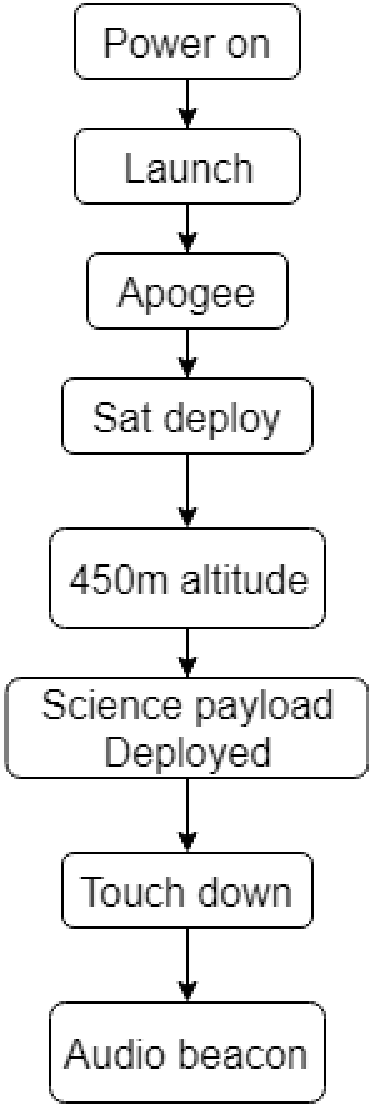
- **There is no electronics on Container.**

Flight Software (FSW) Design

Arpan Kushwaha (AK)

FSW Overview

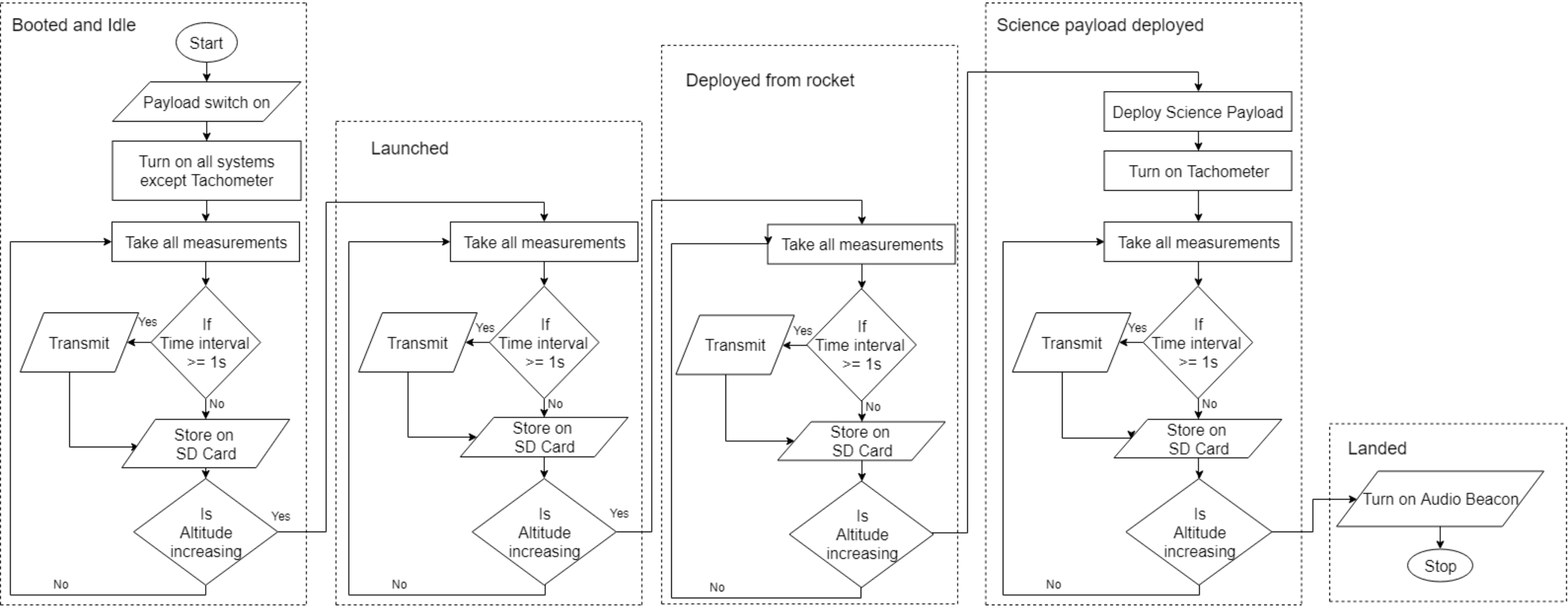
- C++ programing language is used because of its speed and flexibility.
- Arduino IDE is used because of its simplicity as well as depth of control over Arduino boards.
- Tasks of FSW are: -
  i. Make sure mechanisms are actuated at correct time.
  ii. Keep Sensors calibrated.
  iii. Take reading from sensors.
  iv. Transmit it ground station.



FSW Requirements

BR No	Requirement	Verification A	Verification I	Verification T	Verification D
9	The container shall release the payload at 450 meters +/- 10 meters.		✔		
28	The ground station shall be able to command the science vehicle to calibrate barometric altitude, and roll and pitch angles to zero as the payload sits on the launch pad.	✔		✔	
30	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.			✔	
36	All telemetry shall be displayed in real time during descent.		✔	✔	
37	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)			✔	
38	Teams shall plot each telemetry data field in real time during flight.	✔		✔	
42	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.		✔	✔	
53	The GPS receiver must use the NMEA 0183 GGA message format.		✔	✔	

Payload FSW State Diagram



Payload FSW State Diagram

- Main target is to develop system which is failproof.
- The system is not to complex hence achieving that is quite simple.
- In worst case of system being reset the current time can be taken from GPS module and system should start working properly.

Container FSW State Diagram

- **There is no electronics on container.**

Software Development Plan

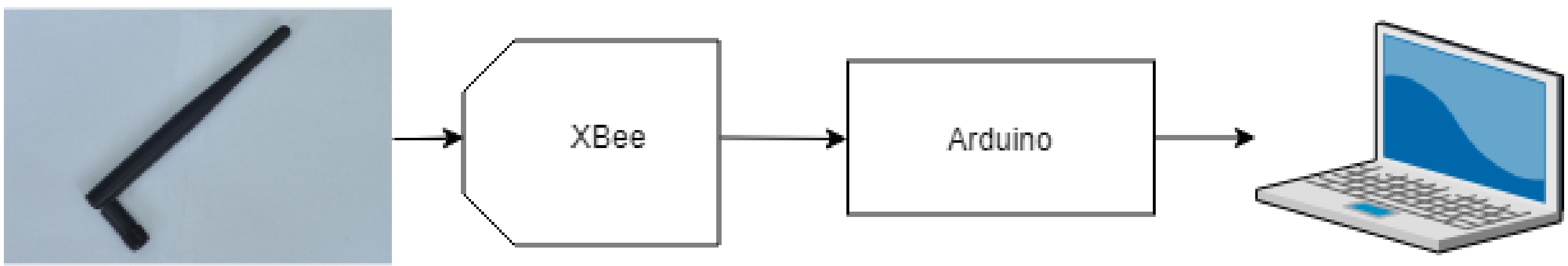
Software development plan is mainly divided in 3 part: -

1. Component level development and testing: - This part is to be done while mechanical subsystems are in design phase.
2. Integration testing: - This part is to be done when mechanical subsystems are in manufacturing phase, so that once manufacturing is complete software would be ready for final testing.
3. Final Calibration and system Testing: - Final testing calibration and testing will be done on completed CanSat

Ground Control System (GCS) Design

Toyas Dhake (TD)

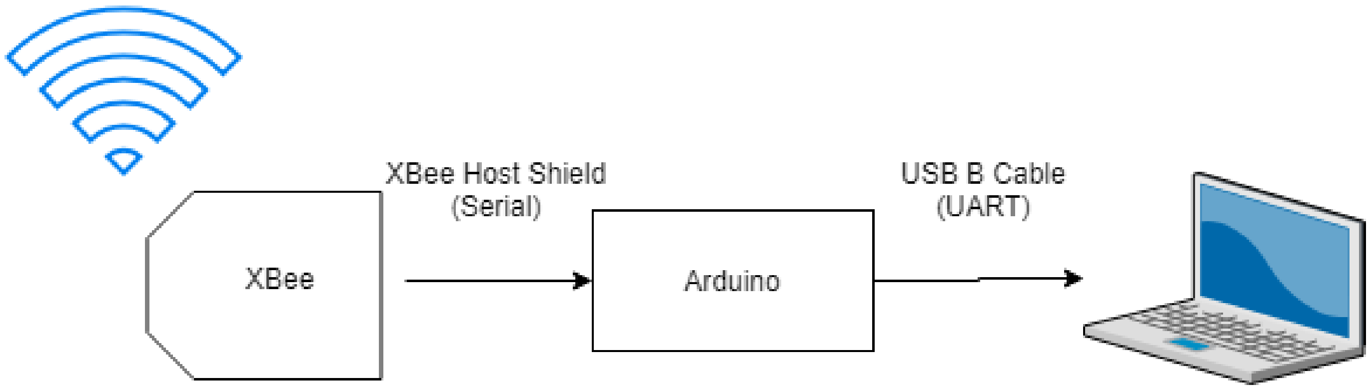
GCS Overview



MIT SAT GCS Requirements

BR No.	Requirement	Verification			
		A	I	T	D
28	The ground station shall be able to command the science vehicle to calibrate barometric altitude, and roll and pitch angles to zero as the payload sits on the launch pad.	✔		✔	
29	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.		✔	✔	
30	Telemetry shall include mission time with 1s or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	✔		✔	
35	Each team shall develop their own ground station.	✔	✔		
39	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		✔		✔
40	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.			✔	✔

GCS Design

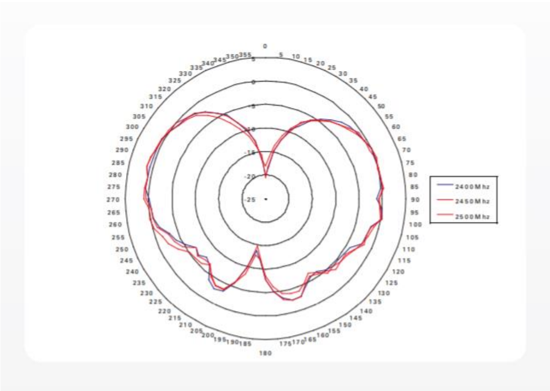


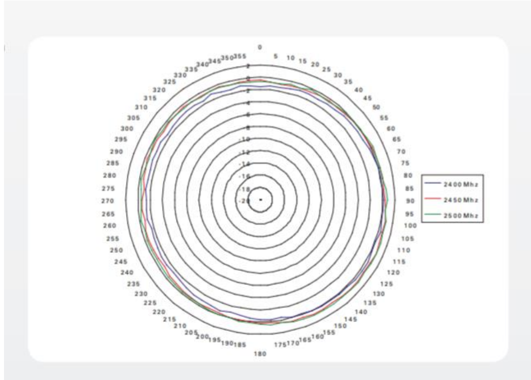
Specifications		
Battery	5 hours from full charge	
Battery drain mitigation	Only bare minimum process running	
Overheating mitigation	Umbrella	
	Laptop has decent built in cooling system. Inspected in extremely harsh conditions with thermal throttling at 80°C	
Auto Update mitigation	Keep windows up-to-date. Keep laptop on flight mode on testing site.	

GCS Antenna Trade & Selection

Antenna	Gain (dBi)	VSWR	Mass (g)	Size (mm)	Polarization
XBP24CZ7SIT-004	1.5	<=2.0:1		160x18	
FXP70 Freedom Multi Standard Antenna	5	<= 1.5:1	1.2	27 x 25 x 0.8	Horizontal, Vertical
MicroSplatch Planar Antenna	3.8	<= 2.0:1		12.7 x 9.14	Horizontal, Vertical

- SMA connector is compatible with XBEE.
- Low cost.
- Easy setup.
- Resistant to weather conditions.

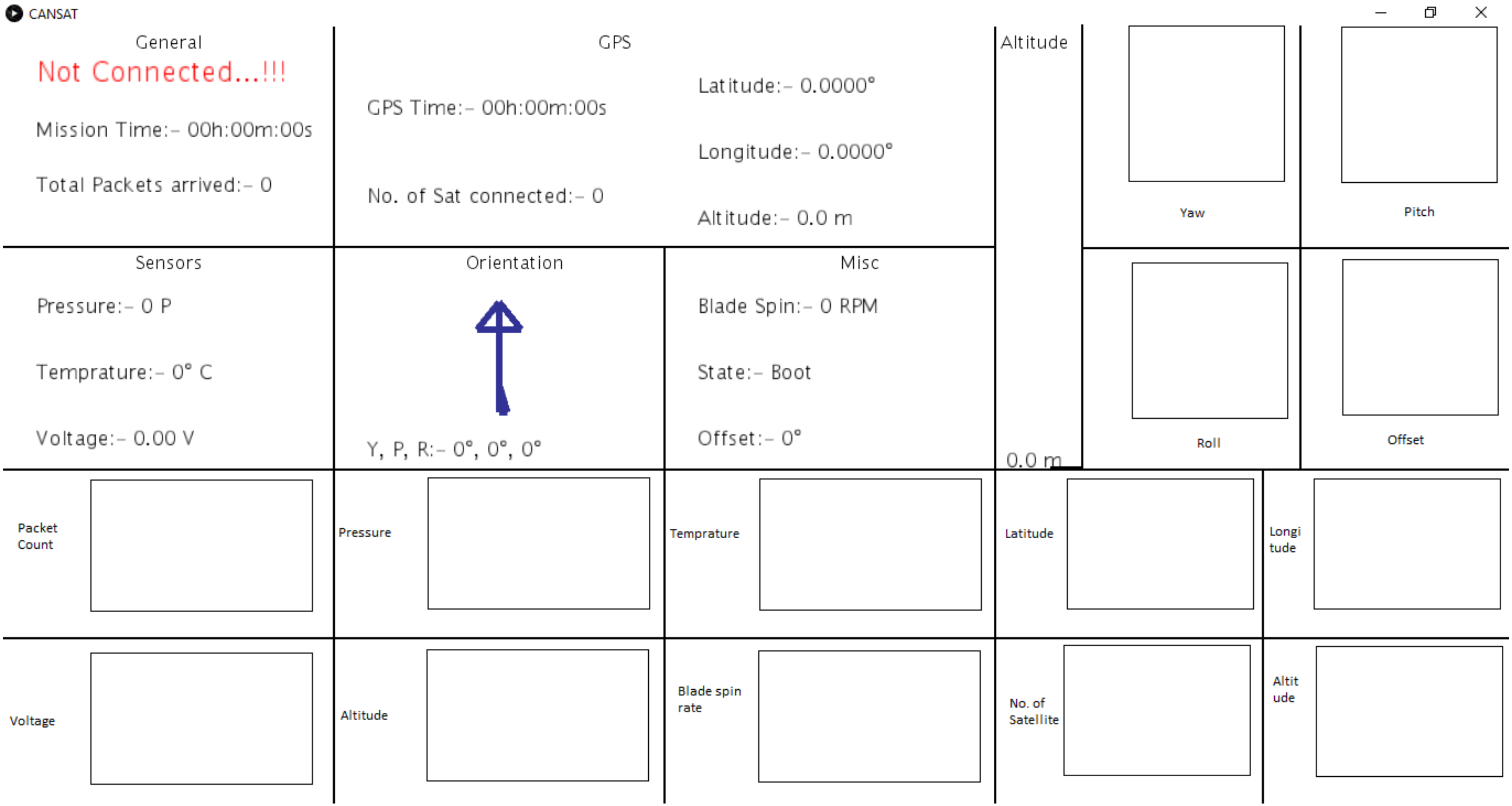




MIT SAT GCS Software

- COT Software Packages:
  - Processing 3.5.2: - Choice for Main operation and GUI of ground Station.
  - Processing Serial Library: - Processing has build in library of accessing serial ports.
  - Python 3.7.2 (SKLearn Library) : - Choice for filtering and post processing.
- .csv file Creation: - Processing has built-in library for writing csv files.
- .csv file of telemetry data will be processed used a python script then submitted to judges.
- For measuring pitch and roll angles accelerometer is used it uses earth’s gravity as reference point. Hence it wouldn’t need calibration.

Ground Station UI (Beta)



CanSat Integration and Test

Arpan Kushwaha (AK)

CanSat Integration and Test Overview

In accordance with this year's base requirements, we divided the testing phases down to the component level.

The components were then tested separately to check their outputs and when turned out to be satisfactory, only then integrated into subsystems.

After the successful testing of subsystems, the system as a whole will be implemented together.

Out of the 55 Base requirements, 31 can be tested at component level. As we progress in designing the CANSAT, we shall be conducting the tests, in compliance with the base requirement criteria.

- Sensor Subsystem-Testing and Calibrating the sensors
- CDH-Testing the Probe Radio Config (XBee Rx/Tx)
  - <10m- Lab test
  - <25m Rooftop of a building
  - <100m- Drone assist

Subsystem Level Testing Plan

- EPS Testing-
  - Testing and calibrating the buck regulator
  - Verifying the current flow and voltage levels
  - Testing and helping for current and voltage leakages

- FSW Testing
  - Sensors' calibrated and tested for achieving the most efficient code
  - To verify the data received is accurate, if not, the equations are calibrated
- Communication Testing-
  - Testing whether the XBee' communicate at and above the required distance
  - Verification healthy data transfer
- Descent Control
  - CFD
  - Wind Tunnel testing
  - Parameter Collection through electronic sensors
- Mechanical Subsystem
  - Software FEA analysis
  - Drop test
  - Vibration Test
  - Thermal Test

Integrated Level Functional Test Plan

- **Communication testing**
  1. Testing of CanSat and Ground Station commutation on highway. In order to reduce interference from Wi-Fi signals.
- **Mechanism**
  1. Testing for the surface finish using dial gauges.
  2. Testing for dimensional tolerances using slip gauges.
  3. Structural integrity test using destructive testing.

MIT SAT Environmental Test Plan

- **Drop Test**
  - Power on CanSat.
  - Verify telemetry is being received.
  - Raise CanSat by the attached cord, so that the attachment points of the cord, on the eye bolt and the parachute, are at the same height.
  - Release the CanSat.
  - Verify the CanSat did not lose power.
  - Inspect for any damage, or detached parts.
  - Verify telemetry is still being received.
- **Quadcopter will be used to drop CanSat from height.**

Environmental Test Plan

- Thermal and vibration test conducted by Automotive Research Association of India (ARAI).

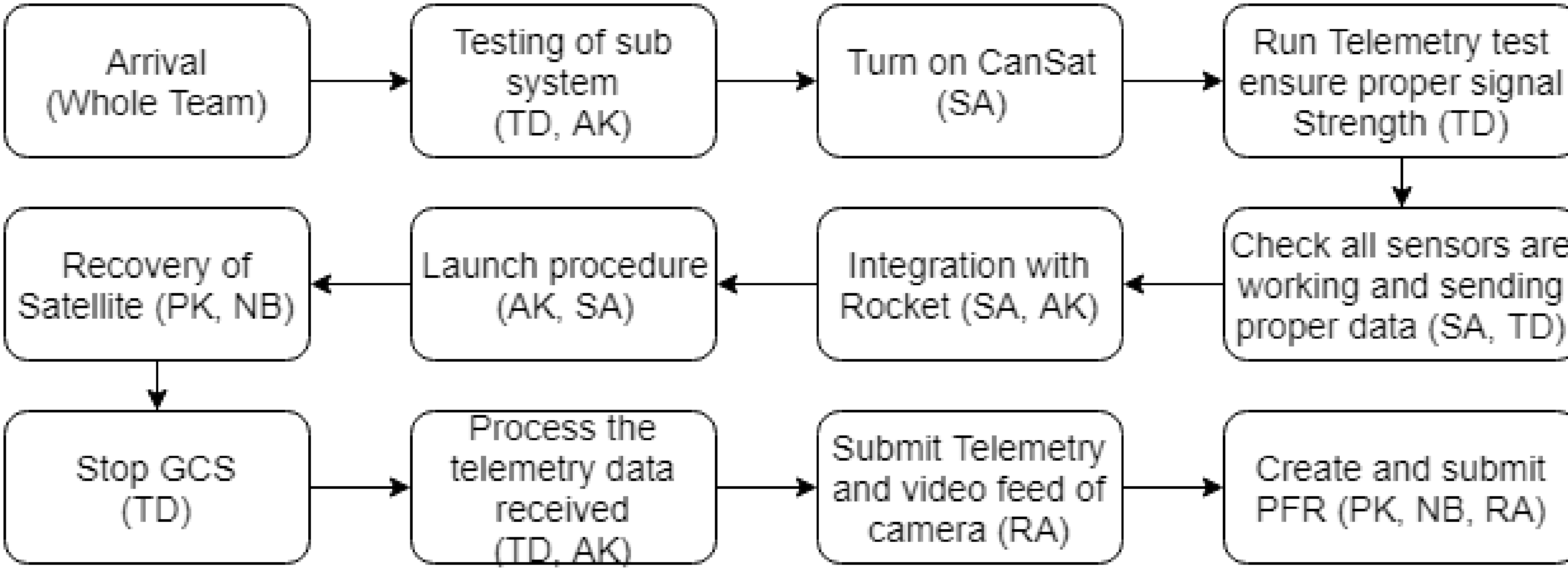
Mission Operations & Analysis

Ninad Bhagwat (NB)

Overview of Mission Sequence of Events

- **Roles and Responsibilities**
  1. Mission Control Officer: RA
  2. Ground Station Crew: TD
  3. CanSat Crew: AK, SA
  4. Recovery Crew: PK, NB

Overview of Mission Sequence of Events



Mission Operations Manual Development Plan

- **Mission operation manual will contain**
  - i. Pre Launch
    - i. Assembly of CanSat
    - ii. Operational Check CanSat
    - iii. Ground Station setup
    - iv. Operational Check Ground Station
  - ii. Launch
    - i. Launch Sequence
  - iii. Post Launch
    - i. Recovery of data from CanSat
    - ii. Telemetry data processing techniques
- **It will be ready by CDR.**

CanSat Location and Recovery

- **Following points will ensure CanSat recovery**
  1. Audio beacon will turn on touch down.
  2. GPS location from telemeter data.
  3. Bright orange color of parachute to recover of CanSat container.
  4. Recovery team will track Science payload and Container as it descends.

Requirements Compliance

Ninad Bhagwat (NB)

Requirements Compliance Overview

- Current design is developed considering all the requirements.
- Design shall be tested in ensure requirement compliance using plan explained in Integration and Test.
- Design can be changed before CDR if some of those test give negative result i.e. CanSat is not complying requirement.
- The legend gives color coding to indicate if a Requirement is met.

Comply
Partially Comply
Do not Comply

MIT SAT Requirements Compliance

BR No.	Requirement	Compliance	Compliance Reference Slide	Comments
1	Total mass of the CanSat (science payload and container) shall be 500 grams +/- 10 grams.		105	
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.		21	
3	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.		22	
4	The container shall be a fluorescent color; pink, red or orange.		72	
5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.		72	
6	The rocket airframe shall not be used as part of the CanSat operations.		72	
7	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.		37	
8	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.		37	

Requirements Compliance

BR No.	Requirement	Compliance	Compliance Reference Slide	Comments
9	The container shall release the payload at 450 meters +/- 10 meters.		37, 129	
10	The science payload shall descend using an auto-gyro/ passive helicopter recovery descent control system.		37	
11	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.		68	
12	All descent control device attachment components shall survive 30 Gs of shock.		74	
13	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.		102	
14	All structures shall be built to survive 15 Gs of launch acceleration.		74	
15	All structures shall be built to survive 30 Gs of shock.		74	
16	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.		102	

Requirements Compliance

BR No.	Requirement	Compliance	Compliance Reference Slide	Comments
17	All mechanisms shall be capable of maintaining their configuration or states under all forces.		73	
18	Mechanisms shall not use pyrotechnics or chemicals.		73	
19	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.		73	
20	The science payload shall measure altitude using an air pressure sensor.		26	
21	The science payload shall provide position using GPS.		28	
22	The science payload shall measure its battery voltage.		29	
23	The science payload shall measure outside temperature.		27	
24	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.		31	

Requirements Compliance

BR No.	Requirement	Compliance	Compliance Reference Slide	Comments
25	The science payload shall measure pitch and roll.		30	
26	The probe shall transmit all sensor data in the telemetry		114	
27	The Parachute shall be fluorescent Pink or Orange		39	
28	The ground station shall be able to command the science vehicle to calibrate barometric altitude, and roll and pitch angles to zero as the payload sits on the launch pad.		135	
29	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.		114	
30	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.		114	
31	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.		113	
32	XBEE radios shall have their NETID/PANID set to their team number.		113	

Requirements Compliance

BR No.	Requirement	Compliance	Compliance Reference Slide	Comments
33	XBEE radios shall not use broadcast mode.		113	
34	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.		164	
35	Each team shall develop their own ground station.		135	
36	All telemetry shall be displayed in real time during descent.		139	
37	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		139	
38	Teams shall plot each telemetry data field in real time during flight.		139	
39	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		134	
40	The ground station must be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.		134	

MIT SAT Requirements Compliance

BR No.	Requirement	Compliance	Compliance Reference Slide	Comments
41	Both the container and probe shall be labeled with team contact information including email address.		72	
42	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.		114	
44	No lasers allowed.		25	
45	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.		72	
46	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the cansat and in the stowed state.		72	
47	An audio beacon is required for the probe. It may be powered after landing or operate continuously.		129	
48	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.		129	

MIT SAT Requirements Compliance

BR No.	Requirement	Compliance	Compliance Reference Slide	Comments
49	Battery source may be alkaline, Ni-Cad, Ni-MH or Lithium. Lithium polymer batteries are not allowed. Lithium cells must be manufactured with a metal package similar to 18650 cells.		119	
50	An easily accessible battery compartment must be included allowing batteries to be installed or removed in less than a minute and not require a total disassembly of the CanSat.		72	
51	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.		102	
52	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.		37	
53	The GPS receiver must use the NMEA 0183 GGA message format.		28	
54	The CANSAT must operate during the environmental tests laid out in Section 3.5.		145	
55	Payload/Container shall operate for a minimum of two hours when integrated into rocket.		123	

Management

Prachit Kamble (PK)

CanSat Budget – Hardware

Component	Model	Quantity	Unit Price	Total Price (₹)	Total Price ($)
Sensor Package	GY 87	1	₹1,090	₹1,090	$15.29
GPS	Neo-6M	1	₹790	₹790	$11.08
Camera	AdaFruit 3202	1	₹3,944	₹3,944	$55.32
MicroSD Card	Samsung-EVO-FT16GBSSM	1	₹496	₹496	$6.96
SD Card Module	-	1	₹99	₹99	$1.39
XBEE	Pro S2C+ Antenna	2	₹2,299	₹4,598	$64.49
Arduino	Pro Mini 3.3V/8 MHz	1	₹250	₹250	$3.51
XBEE Adapter	CP210x-USB to UART Bridge	1	₹210	₹210	$2.95
Voltage Regulator	LM2596 DC-DC Regulator	1	₹79	₹79	$1.11

CanSat Budget – Hardware

Arduino	Uno	1	₹299	₹299	$4.19
Motor	DC-3V-250RPM	1	₹100	₹100	$1.40
Battery	Samsung 18650 3.7V 2600mAh	1	₹250	₹250	$3.51
Tachometer	Hall Effect sensor	1	₹80	₹80	$1.12
3D Printed Components					
Container	ABS Plastic	1	₹200	₹200	$2.8
Payload Structure	ABS Plastic	1	₹800	₹800	$11.2
Battery Mount	ABS Plastic	1	₹180	₹180	$2.52
Structural plates_1	ABS Plastic	2	₹120	₹240	$3.36
Structural plates_2	ABS Plastic	1	₹150	₹150	$2.1
Reaction Wheel	ABS Plastic	1	₹350	₹350	$4.9

CanSat Budget – Hardware

Hub Shaft	ABS Plastic	1	₹180	₹180	$2.52
Rotor Hub	ABS Plastic	1	₹90	₹90	$1.26
Hinge	ABS Plastic	4	₹30	₹120	$1.68
Rotor Blade	Poly1500	4	₹200	₹800	$11.2
Retainer	ABS Plastic	1	₹10	₹10	$0.14

Misc. Mechanical Components				
Parachute	1	₹250	₹10	$0.14
Nylon String	1	₹10	₹10	$0.14
Eye-Bolt	1	₹15	₹15	$0.21
Spring	1	₹10 (used)	₹10 (used)	$0.14
Bearing	1	₹250	₹250	$3.5

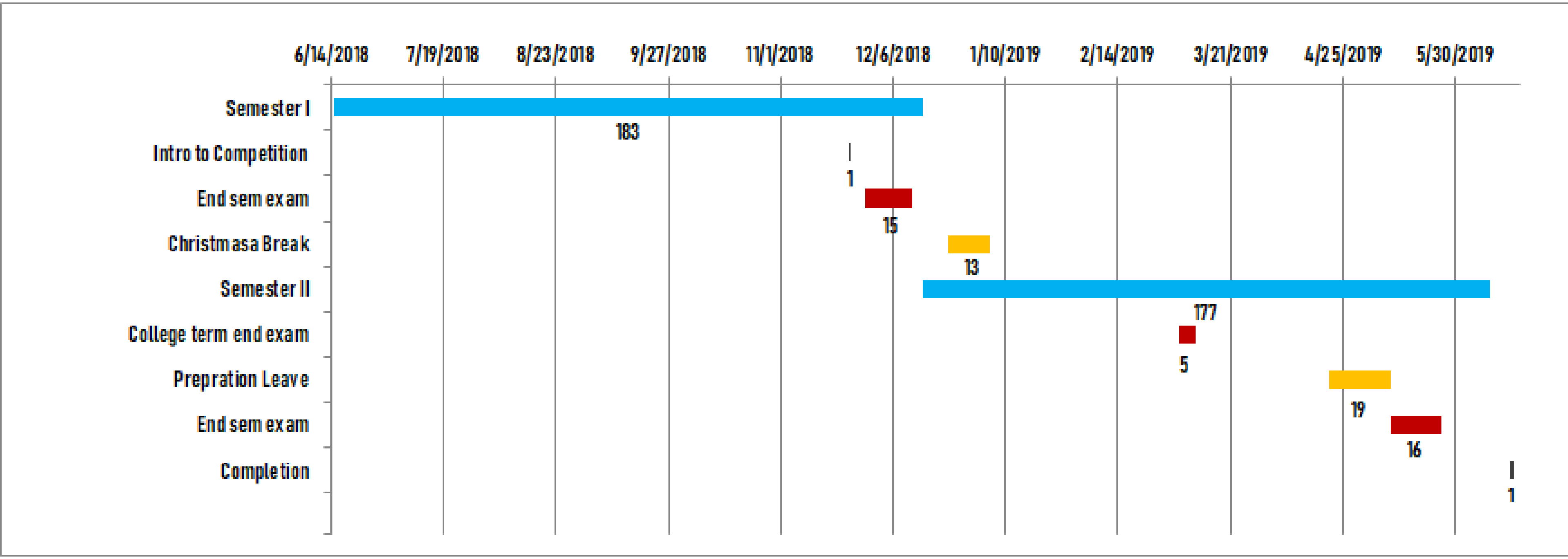
CanSat Budget – Other Costs

Object	Cost INR / USD	Sponsor
Ground Station Cost	₹2,299 / $35	-
Prototyping	~₹5,000 / $ 75	Trimension 3D
Test facilities and equipment	-	ARAI, India
Computers	-	-
Travel (per Head)	~₹61,000+misc / $ 950+misc	-

Sources of Income	
	MIT College of Engineering, Pune
	Self-sponsoring
	Others firms to be approached

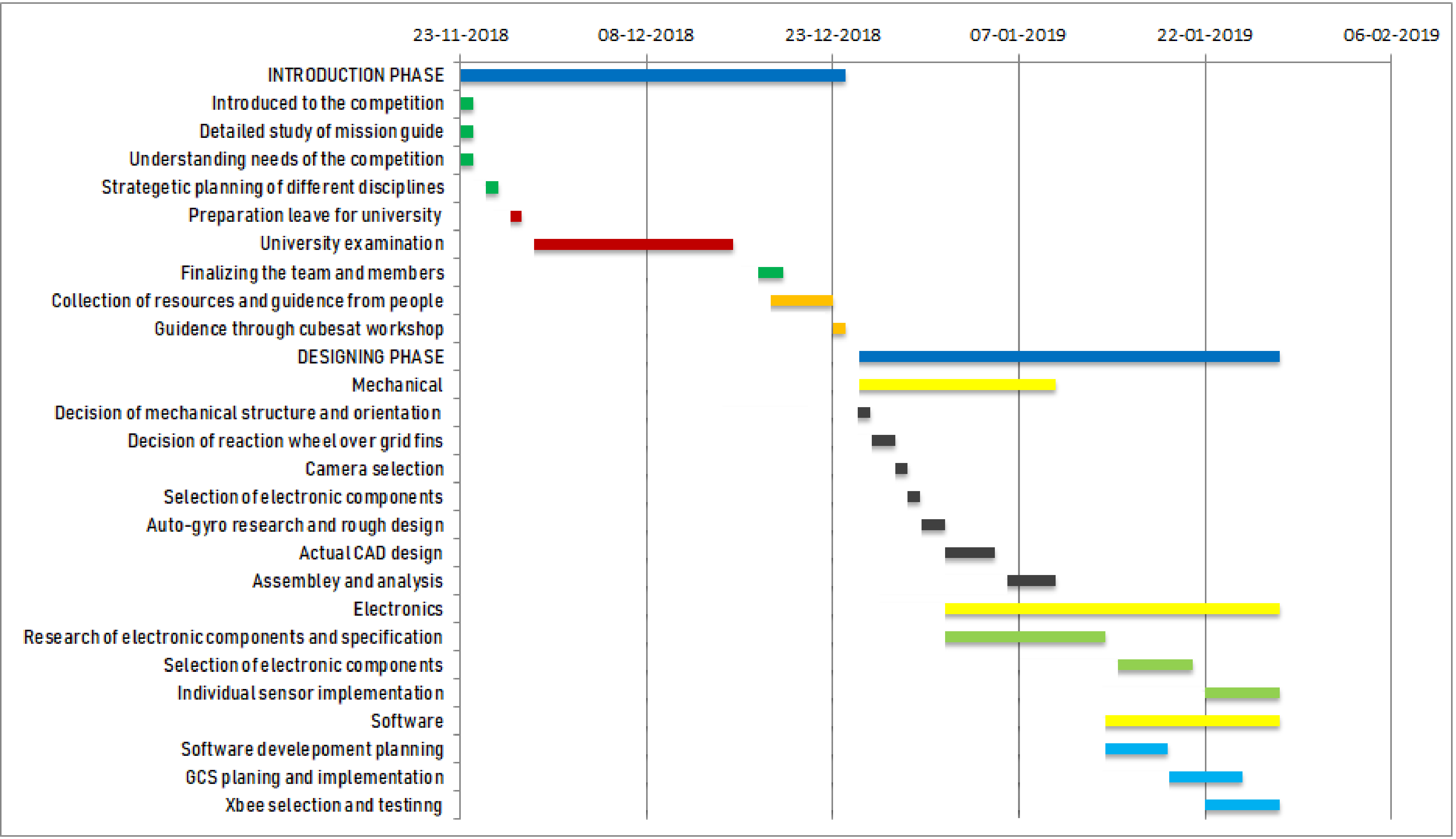
Total cost of CanSat including Prototyping cost is $ 294.47/-, this excludes ground station cost.

Program Schedule Overview

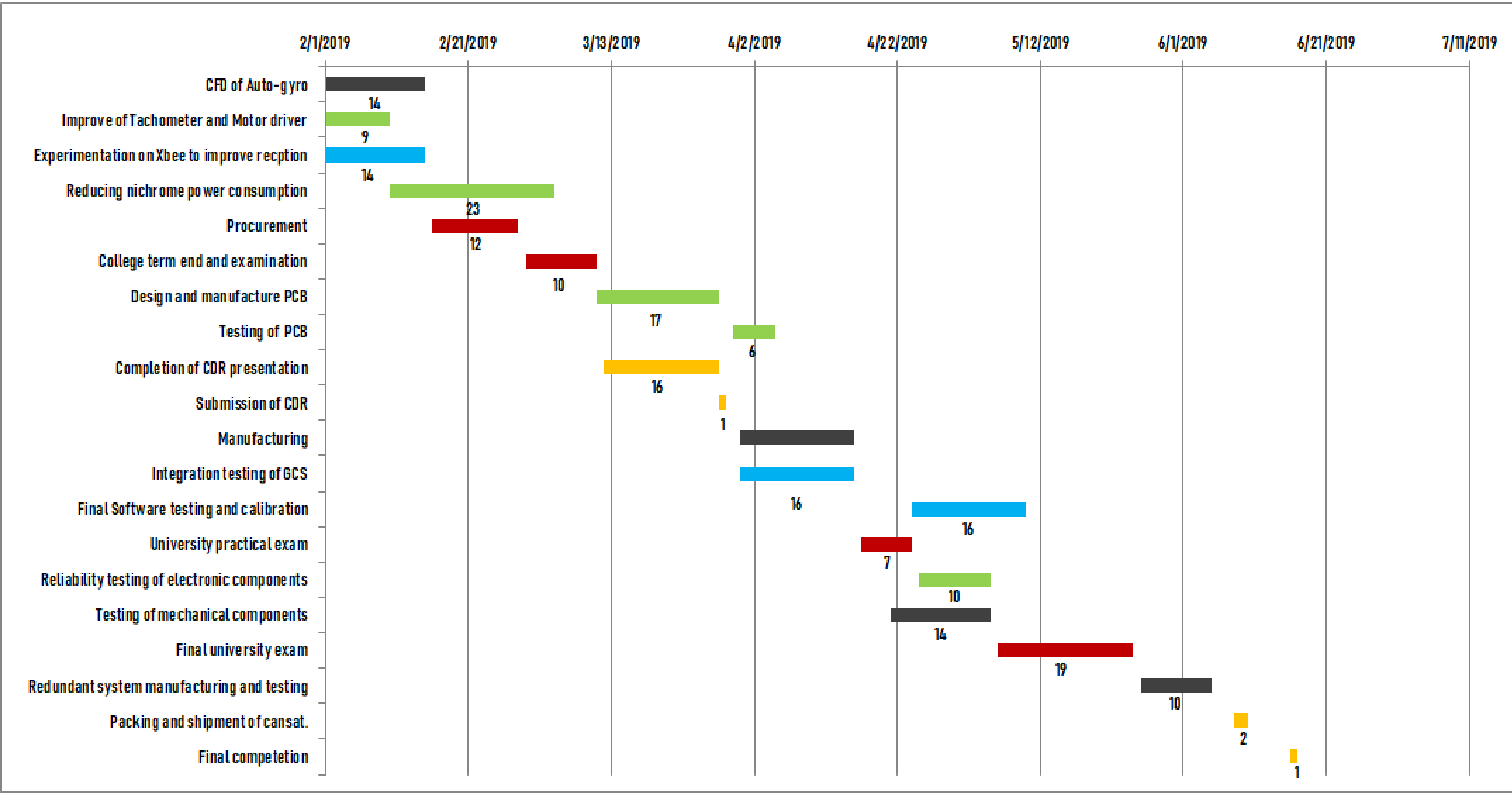


Normal working	
Potential hindrance	
No Work	
Competition related Dates	

Detailed Program Schedule (Until now)



Detailed Program Schedule (Future)



Conclusions

Major Accomplishments
• We have acquired access to testing equipment at government institute (ARAI, Air India). • Ground Station Control UI complete.

Major Unfinished Work
• All components are not procured. • CanSat manufacturing • CanSat Testing

Justification for Advancement to Next Stage
• We have acquired complete budget. • We have abided by our planned timeline.