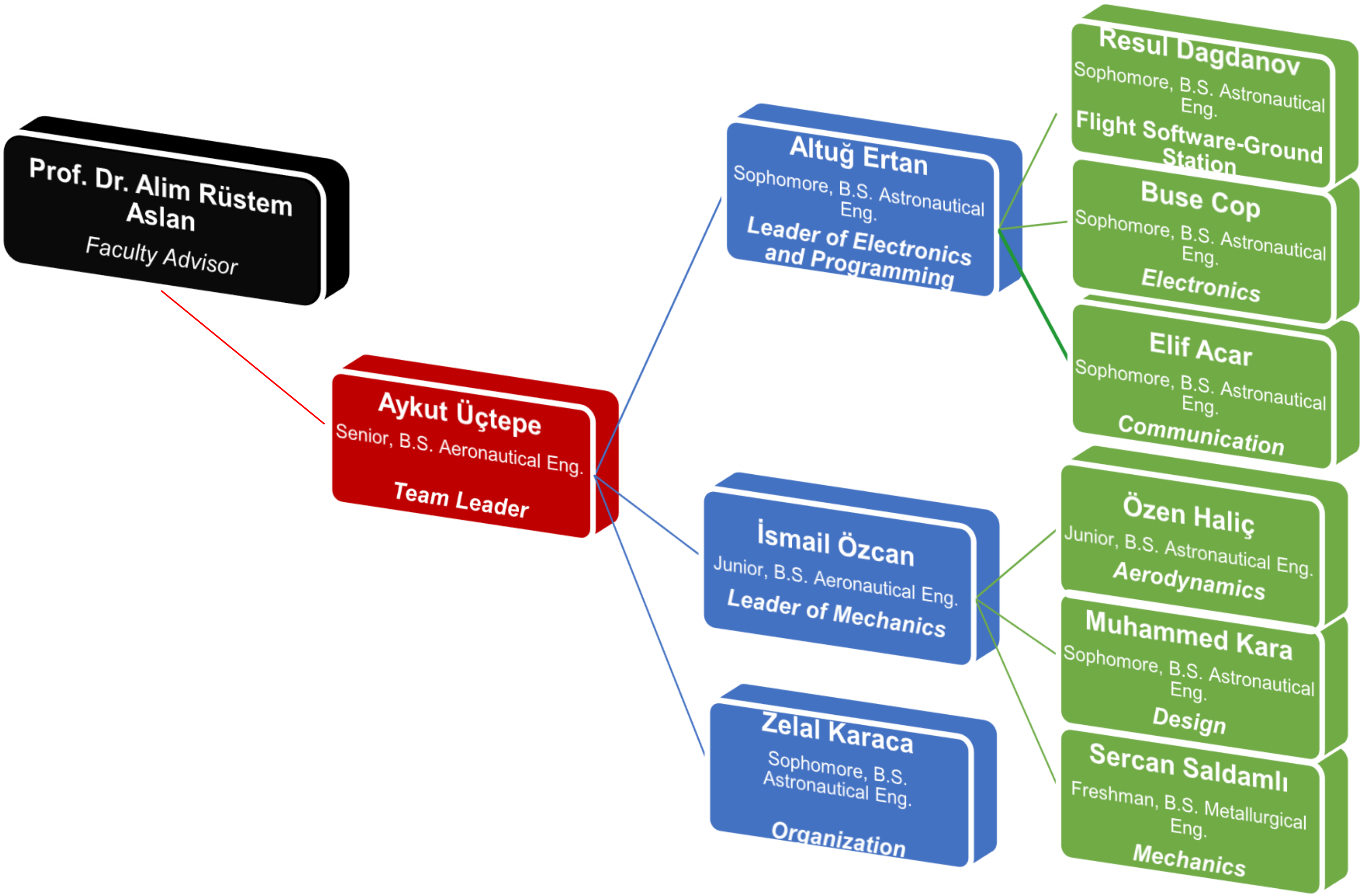
CanSat 2019
Preliminary Design Review (PDR)
Outline
Version 1.5

#6203

APIS ARGE TEAM

Presentation Outline

Team Organization



Acronyms

A	Analysis
BR	Base Requirement
CanSat	Can-sized Satellite
CCDH	Container Communication and Data Handling
CDH	Communication and Data Handling
CONOPS	Concept of Operations
CPU	Central Processing Unit
CReq	Competition Requirement
D	Demonstration
DCS	Descent Control System
EPS	Electric Power System
FSW	Flight Software
G	G-force
GCS	Ground Control Station
HW	Hardware
I	Inspection
I2C	Inter-Integrated Circuit
I/O	Input/Output
ID	Identity

IDE	Integrated Development Environment
ITU	Istanbul Technical University
LED	Light Emitting Diode
MOSFET	Metal-Oxide Semiconductor Field-Effect Transistor
MS	Mechanical Subsystem
PCB	Printed Circuit Board
RC	Radio Controlled
RPM	Revolutions per minute
RP SMA	Reverse Polarity SMA
RTC	Real Time Clock
SMA	SubMiniature Version A
SPI	Serial Peripheral Interface
T	Testing
UART	Universal Asynchronous Receiver/Transmitter
USART	Universal Synchronous/Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
VM	Verification Method

Systems Overview

Aykut ÜÇTEPE

Mission Summary

Main Objectives

The mission will explore the use of auto-gyro/ passive helicopter recovery descent control of a science payload when released from the launch vehicle. During descent, payload shall send sample data to ground station via transmitter module.

- Just after payload is deployed from rocket, payload shall open a parachute.
- The descent rate of shall be kept at 20 meters/sec till 450 meters.
- At the 450 meters above the ground, payload shall be released from container and auto-gyro blades must be opened. After that, descent rate of the payload shall be kept between 10-15 m/s.
- Stoppage of data transmission and initiation of audio beacon after landing.
- Recovery of payload and container.

Bonus Objective

- Recording the descent of the payload with a video camera after deployment. Also, the camera should preserve its angle according to nadir direction as 45 degrees looking towards the ground. The direction of the camera relative to Earth's magnetic north should be maintained during flight with maximum +10/-10 degrees deviation and will be sent as a telemetry data. This mission is selected due to high possibility of success.

External Objectives

- Funding for project’s hardware and logistic needs.
- Funding for flight tickets which covers round trip from Istanbul to Texas.
- Promoting APIS Ar-Ge with CanSat Competition and scientific developments achieved. The aim is to gain reputation in our home university and in Turkey.
- Organizing social activities which include BBQ parties, musical activities, studio recording to improve relationship between team members.

System Requirement Summary (1/5)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-1	Total mass of the CanSat (science payload and container) shall be 500 grams +/- 10 grams.	CReq	BR-1	MS-1	Very High	√		√	
SY-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.	CReq	BR-2	MS-2	Very High	√	√	√	
SY-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.	CReq	BR-3	MS-3	Very High		√	√	
SY-4	The container shall be a fluorescent color; pink, red or orange.	CReq	BR-4	MS-4	Very High		√		
SY-5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	CReq	BR-5	MS-5	Very High	√			√
SY-6	The rocket airframe shall not be used as part of the CanSat operations.	CReq	BR-6	MS-6	Very High	√			√

System Requirement Summary (2/5)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-7	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	CReq	BR-7	MS-7 DCS-1	Very High	✓	✓		✓
SY-8	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	CReq	BR-8	DCS-3	Very High	✓		✓	
SY-9	The container shall release the payload at 450 meters +/- 10 meters.	CReq	BR-9	MS-8 DCS-5	Very High	✓		✓	
SY-10	The science payload shall descend using an auto-gyro/ passive helicopter recovery descent control system. This system shall not be motorized.	CReq	BR-10 BR-52	MS-9 DCS-2 DCS-7 SS-12	Very High	✓	✓	✓	
SY-11	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.	CReq	BR-11	DCS-4	Very High	✓		✓	
SY-12	All descent control device attachment components and structures shall survive 30 Gs of shock and 15 Gs acceleration.	CReq	BR-12 BR-14 BR-15 BR-16	MS-10 DCS-6 SS-2 SS-3 SS-4 SS-5	Very High	✓	✓	✓	

System Requirement Summary (3/5)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-13	All mechanisms shall be capable of maintaining their configuration or states under all forces.	CReq	BR-17	MS-11 SS-1	Very High	✓	✓		✓
SY-14	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	CReq	BR-13	MS-12 EPS-1	High		✓		
SY-15	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.	CReq	BR-19	MS-13	Very High		✓		✓
SY-16	The Parachute shall be fluorescent Pink or Orange.	CReq	BR-27		High		✓		
SY-17	The probe shall transmit all sensor data in the telemetry.	CReq	BR-26	CDH-7 FSW-7	Very High	✓		✓	
SY-18	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	CReq	BR-28	CDH-8 FSW-7	Very High	✓		✓	

System Requirement Summary (4/5)

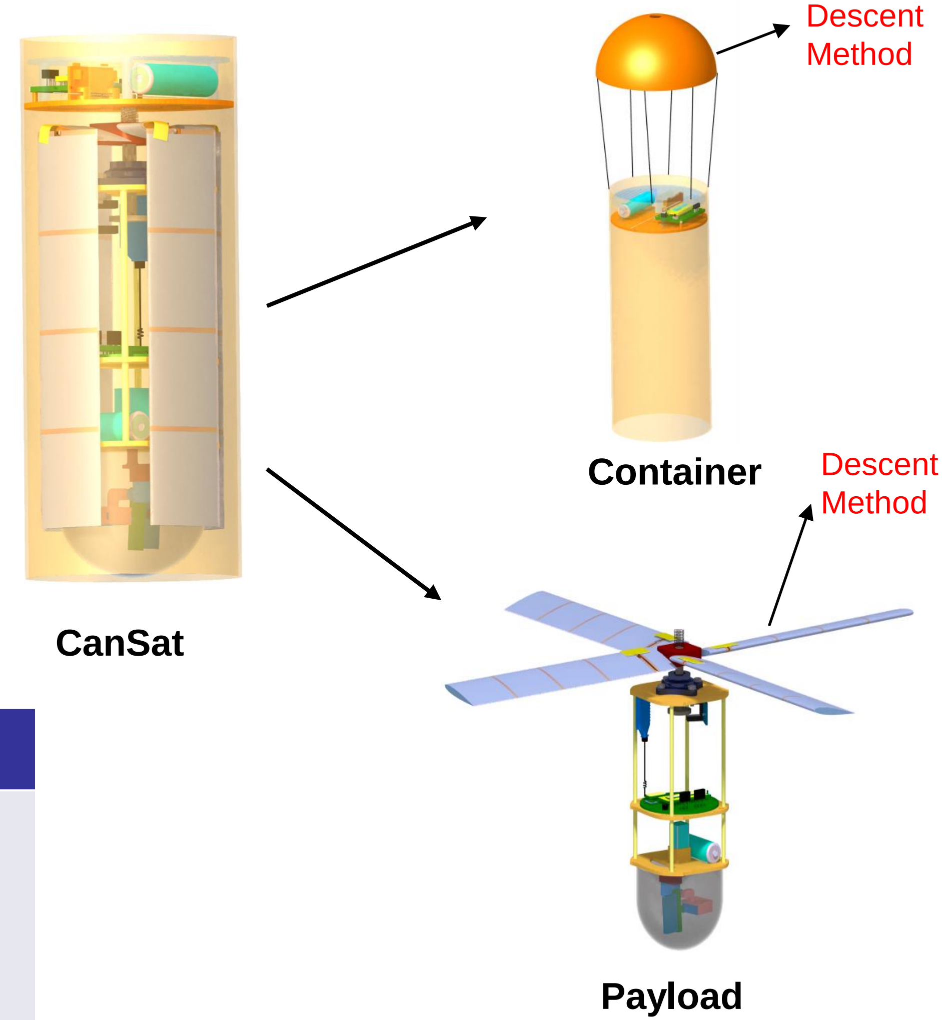
ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-19	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	CReq	BR-31	CDH-10	Very High	✓	✓		✓
SY-20	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	CReq	BR-34		High	✓			
SY-21	Each team shall develop their own ground station.	CReq	BR-35	GCS-2	Very High	✓			
SY-22	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.	CReq	BR-40	GCS-7	High		✓		
SY-23	The probe must include an easily accessible power switch and power indicator that can be accessed without disassembling the cansat and in the stowed configuration.	CReq	BR-45 BR-46	EPS-2 EPS-3	High		✓		✓

System Requirement Summary (5/5)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-24	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.	CReq	BR-49	EPS-6	Very High		✓		
SY-25	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.	CReq	BR-50	EPS-7	High		✓		✓
SY-26	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	CReq	BR-55	EPS-5	Very High	✓		✓	
SY-27	After the separation of container and payload at 450 meters, camera of the payload records a video during the descent and store the video to the SD Card.	Bonus Objective		SS-14 FSW-16	High	✓	✓	✓	
SY-28	The camera shall point downward 45 degrees from nadir of the science payload.	Bonus Objective		SS-15 FSW-17	High	✓	✓	✓	
SY-29	It shall point in one direction relative to the earth's magnetic field with a stability of +/- 10 degrees in all directions during descent.	Bonus Objective		SS-16 FSW-18	High	✓		✓	

Configuration 1 *(4 Blades)*

- Payload is designed to have proper aerodynamic structure by using plexiglass camera stabilizer cover which has shape of half ellipsoid.
- Electronic components are located on the middle layer of the payload.
- Blades are deployed through latexes and hinges.
- Each component is made up of different materials for required properties, such as layers will be made of plywood and blades will be made of styrofoam, fiberglass resin and balsa wood.



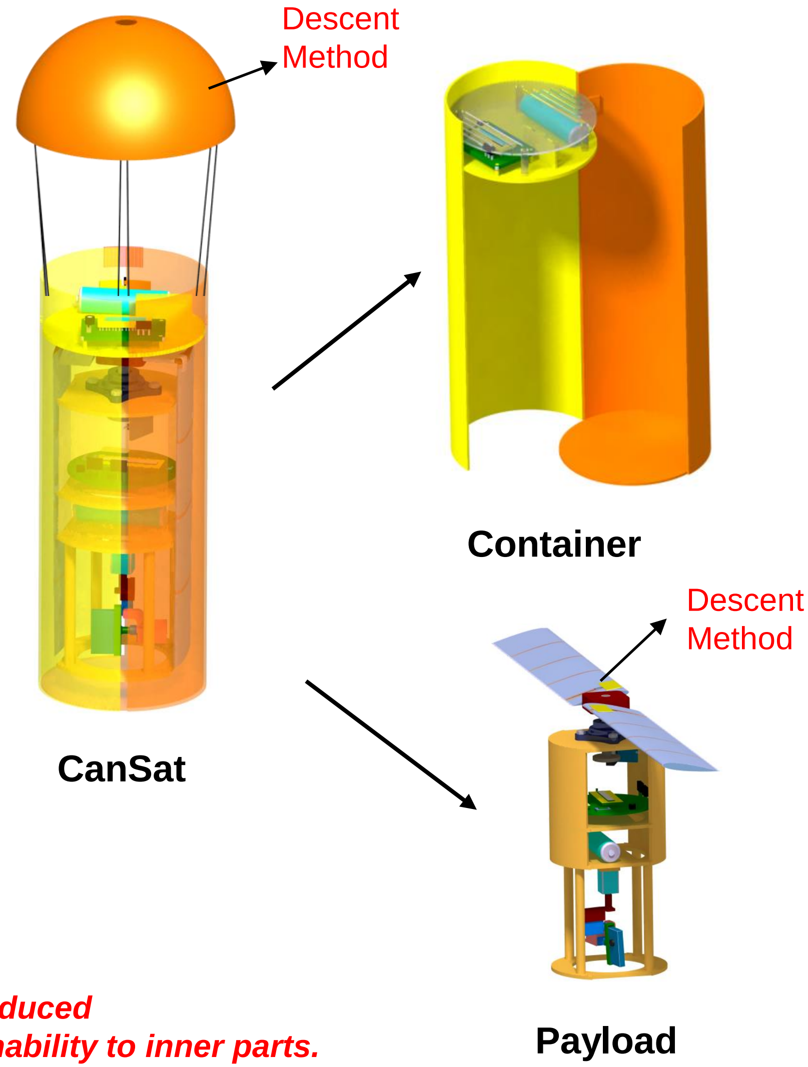
PROS	CONS
• Smooth airflow around blades. • Access to inner parts is easy. • 4 blades produce sufficient lift for safe landing with acceptable mass.	• Folding 4 blades is difficult.

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

Configuration 2 *(2 Blades)*

- The camera stabilizer system is located on the middle of the payload and preserved with four sticks and bottom layer.
- Electronic components are located on intermediate and top layers.
- Blades are deployed through springs and hinges.
- All of structural parts are made of 3D printed materials except blades which are made of styrofoam, fiberglass and balsa wood.

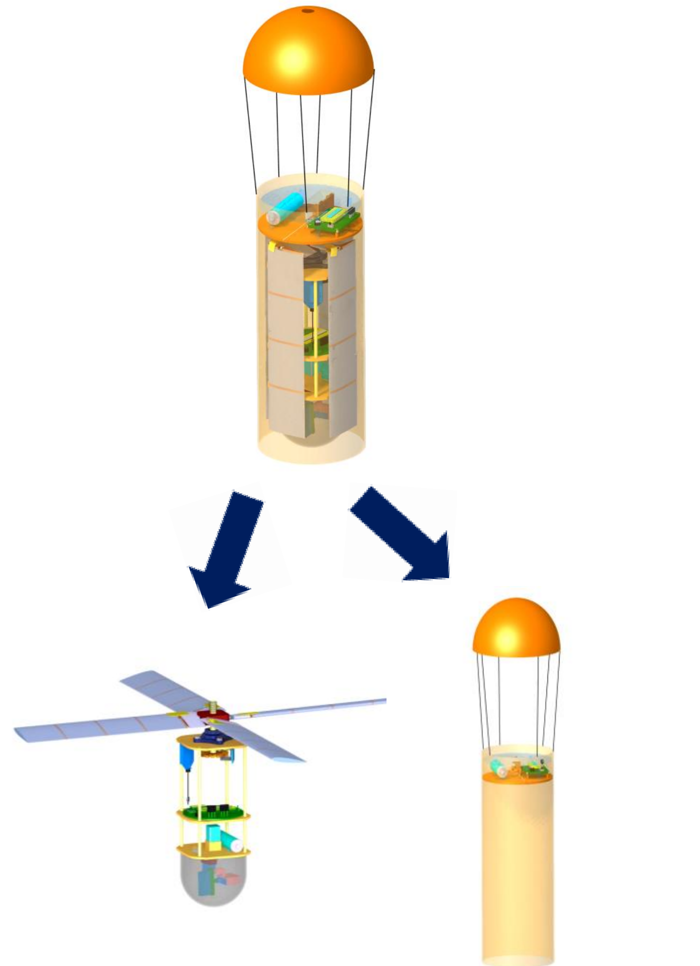
PROS	CONS
• Electronic components have preserved by major cover structure. • Easy to manufacture.	• The needed blade radius for safe landing is too long to easily fit in the container. • Center of mass is at the upper part of the payload.



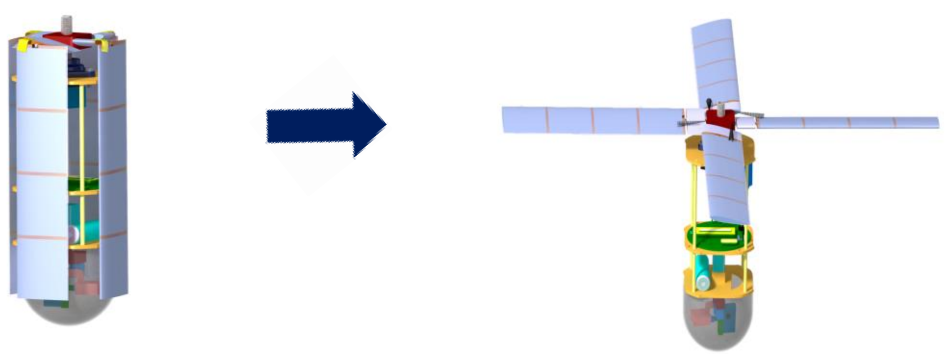
Configuration 1 is selected due to better aerodynamic structure, produced sufficient lift for safe landing with less blade radius and easier reachability to inner parts.

System Level Configuration Selection

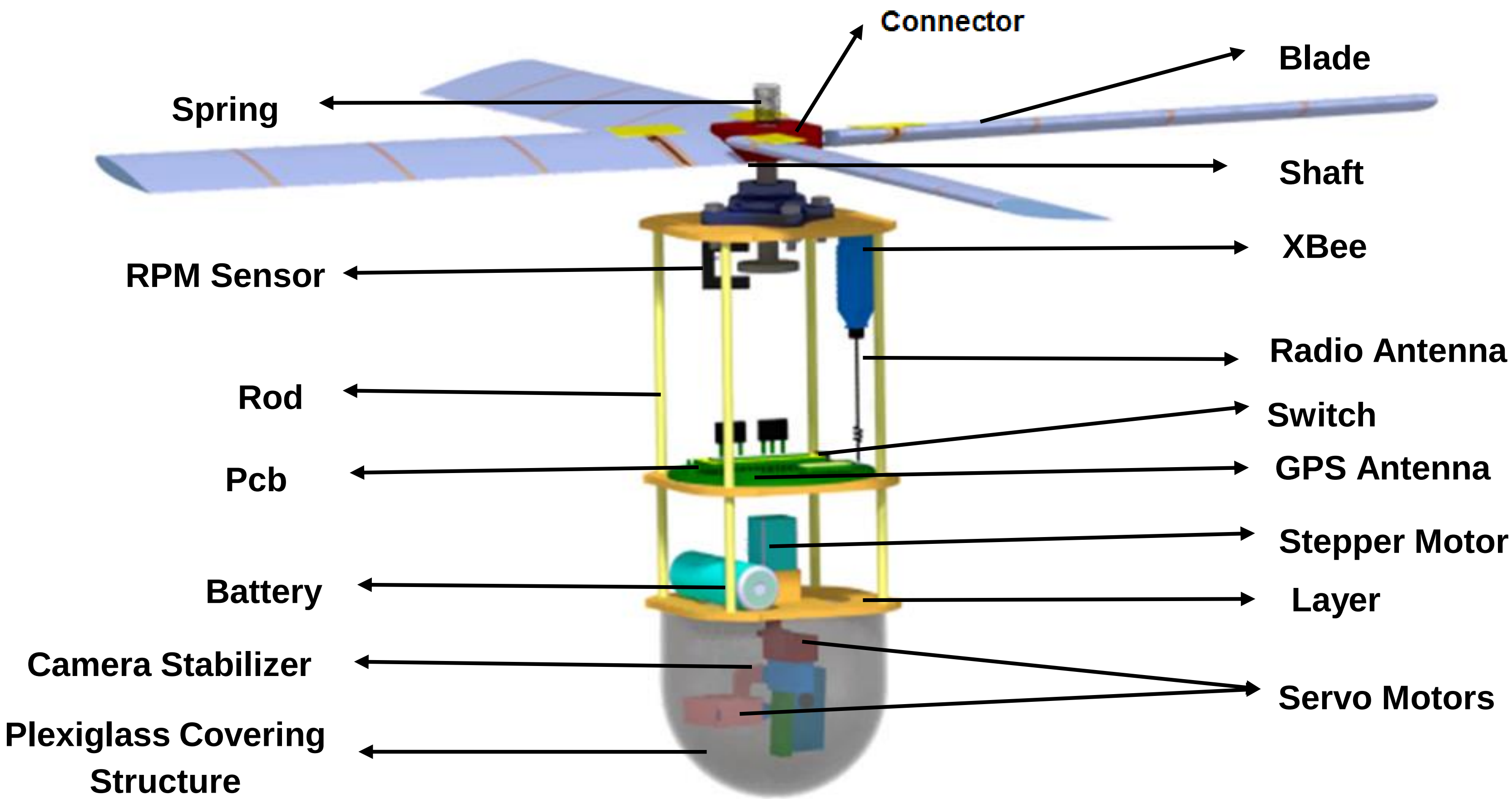
Configuration 1 (SELECTED)



- Camera vision angle is not blocked owing to the transparency feature of plexiglass camera stabilizer cover.
- Camera stabilizer protection mechanism makes the shape of payload aerodynamical. Also, it provides durability at the impact moment with ground.
- Access to electronics is easy, electronic layer will be isolated from outside after installation is completed.
- Great number of parts of payload are made by composite materials which have high rate of strength/weight.
- Auto-gyro system has 4 blades with a blade radius short enough to fit in the container without additional folding
- Since the center of mass of the Cansat is located near the payload bottom layer, the more stable flight is expected.

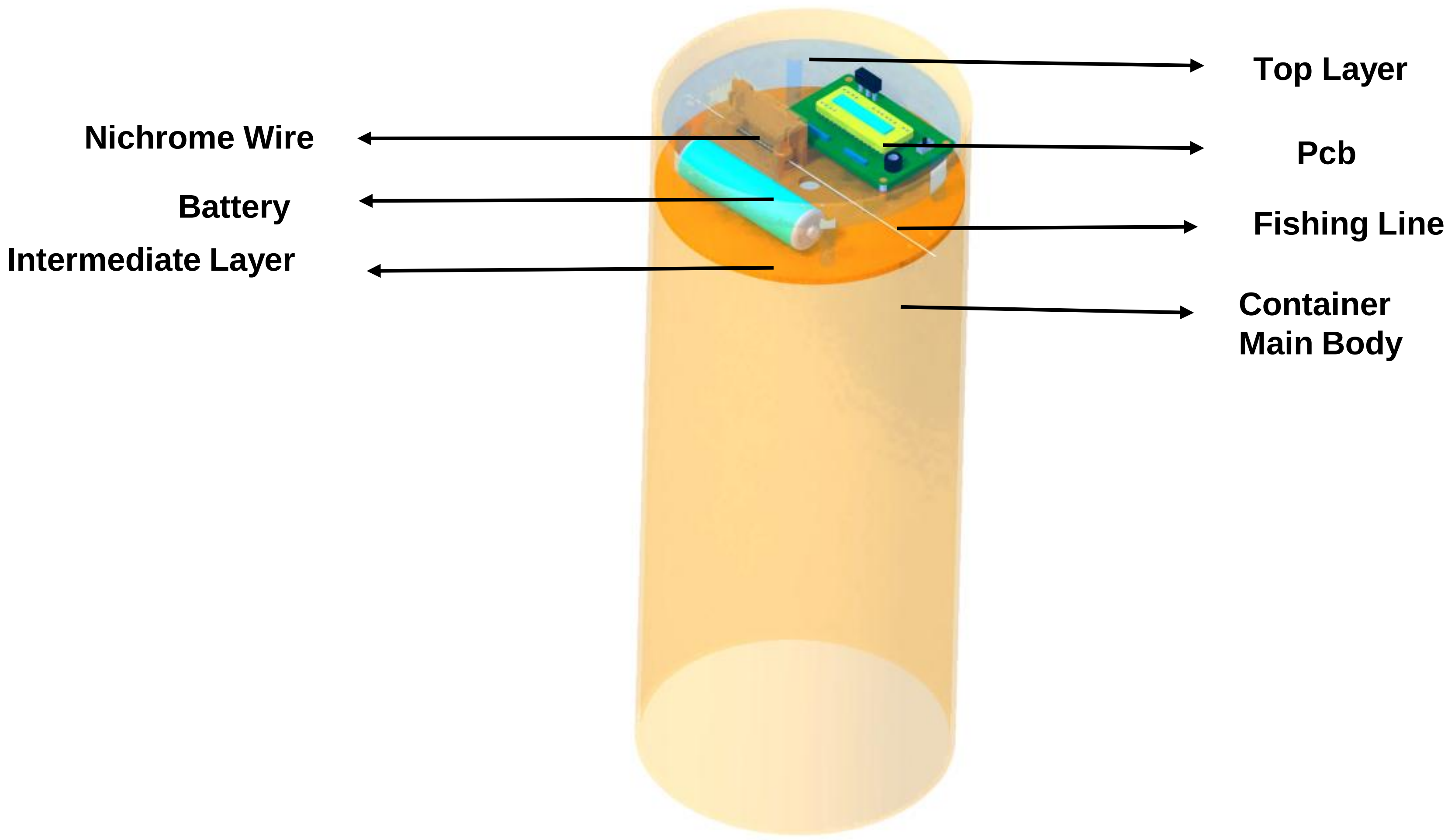


PAYLOAD



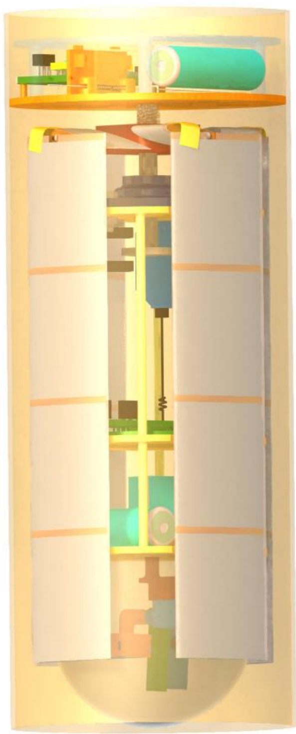
A GPS sensor with integrated antenna is used. Thus, GPS antenna is located on the PCB.

CONTAINER

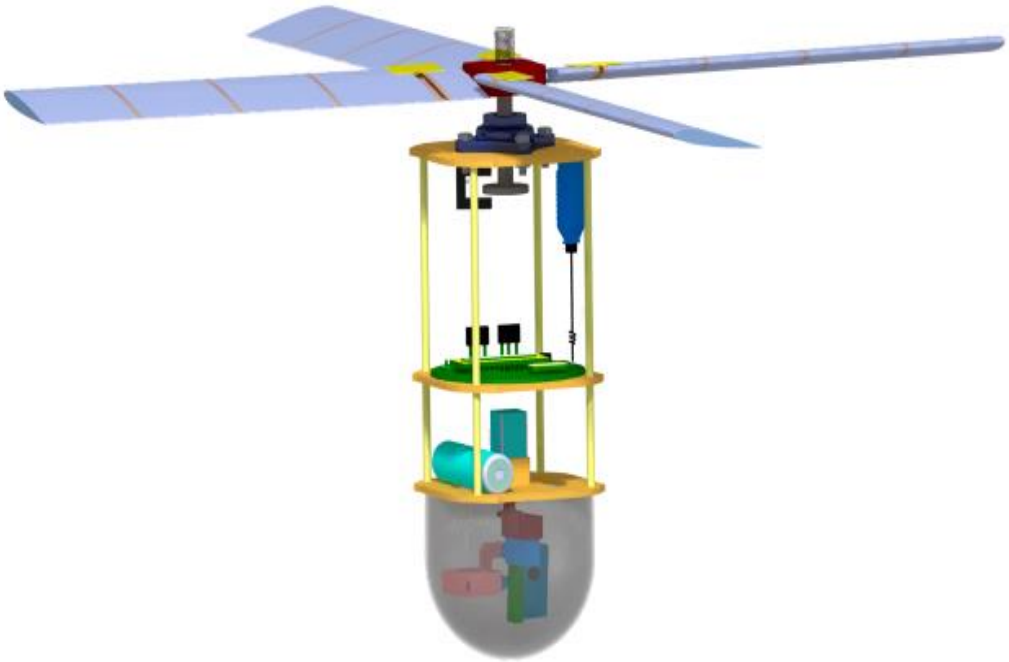

Nichrome Wire
Battery
Intermediate Layer
Top Layer
Pcb
Fishing Line
Container
Main Body

CANSAT

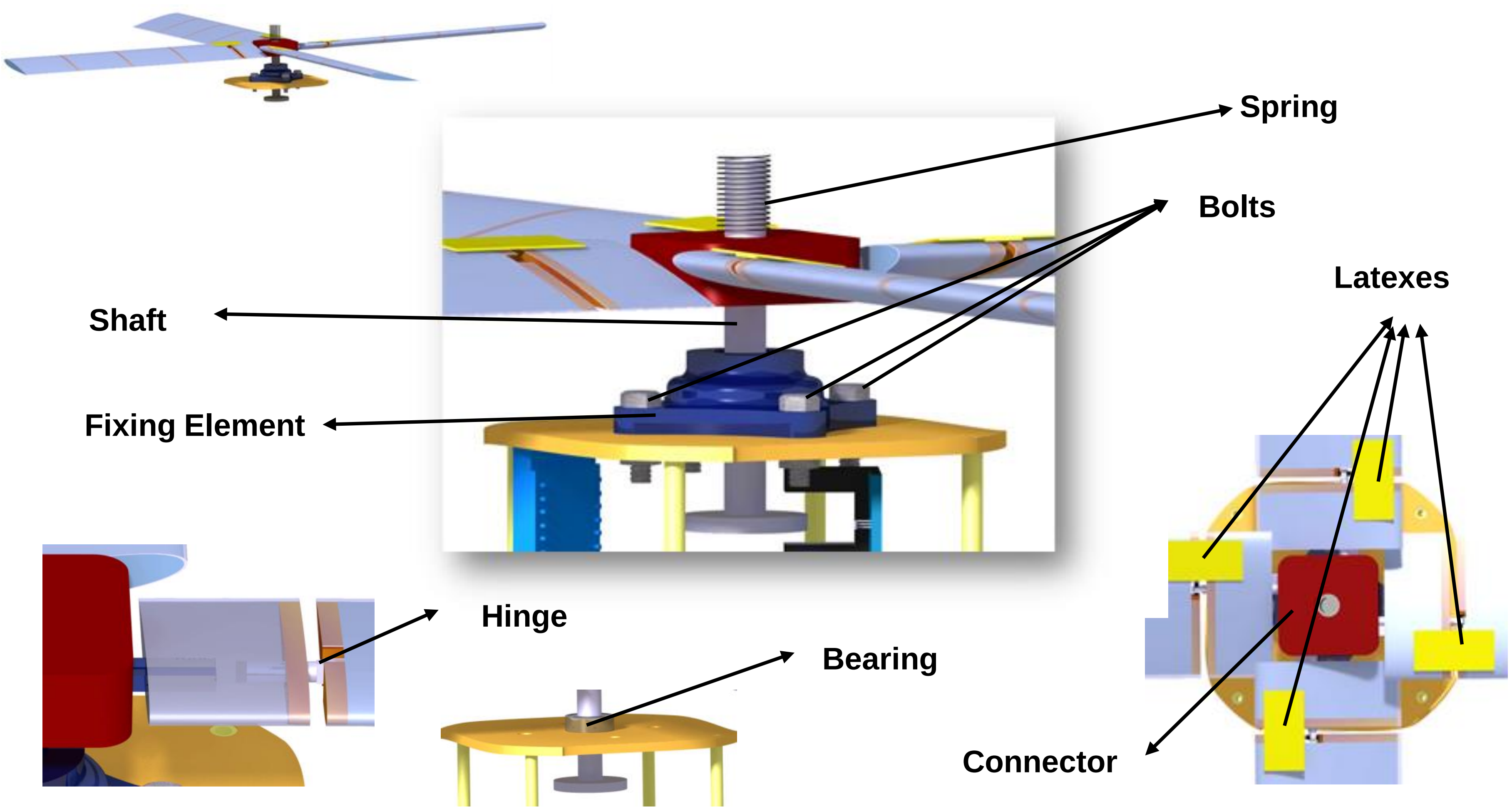
Launch Configuration



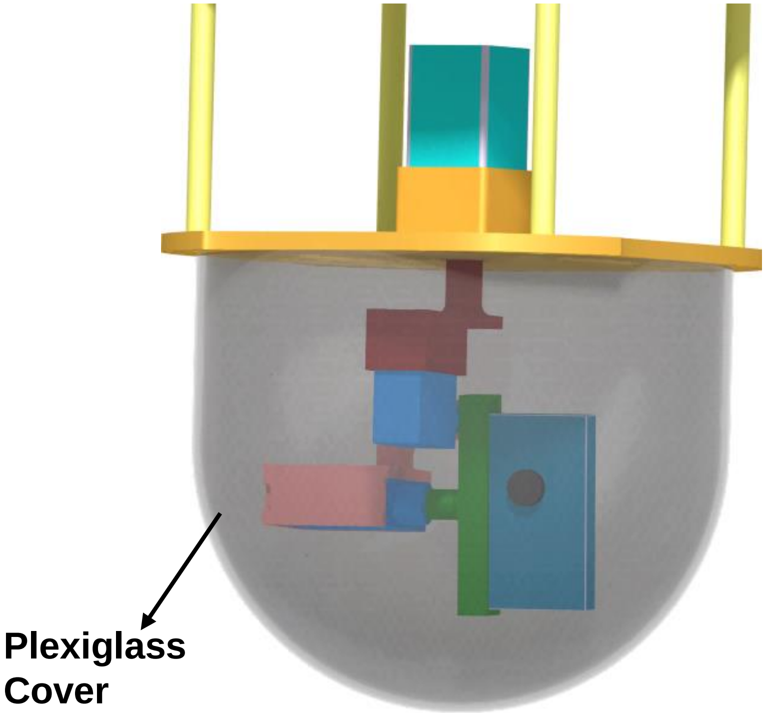
Deployed Configuration

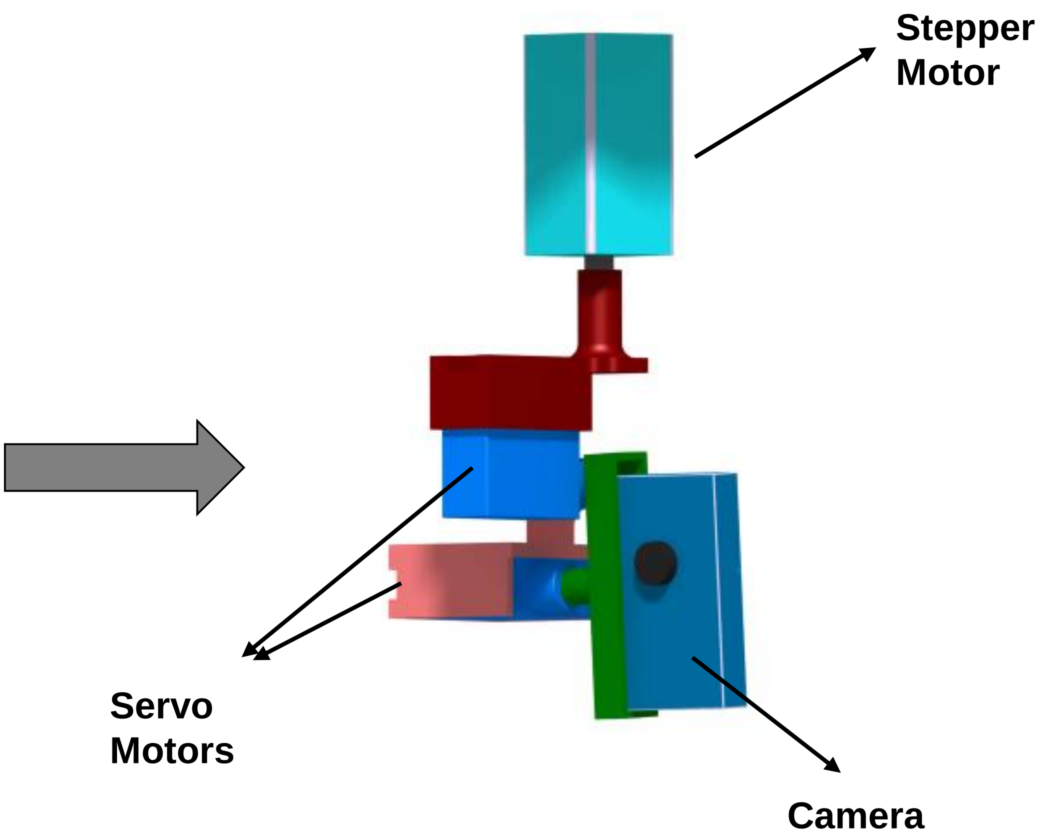


Auto-gyro Mechanism

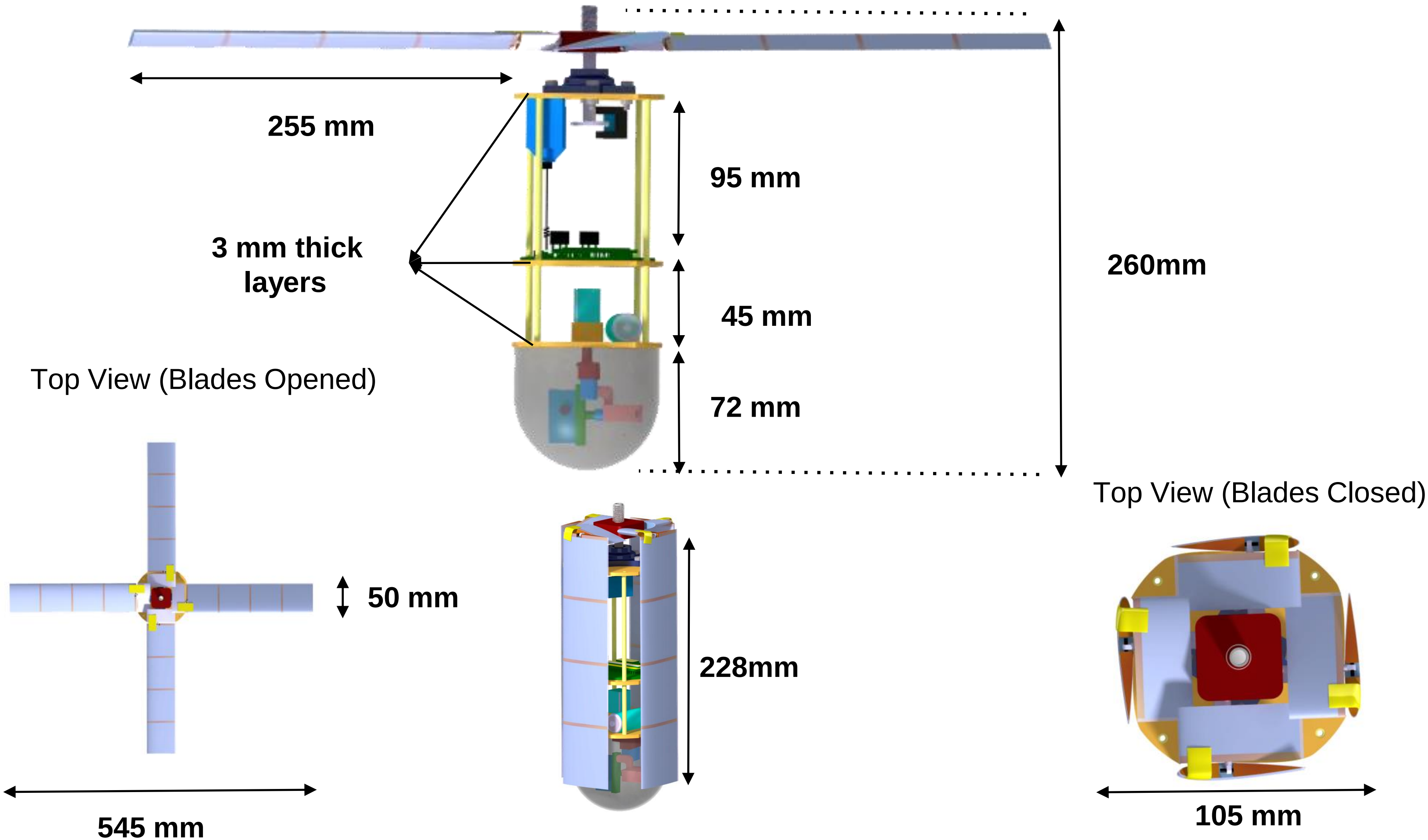


Camera Stabilizer Mechanism

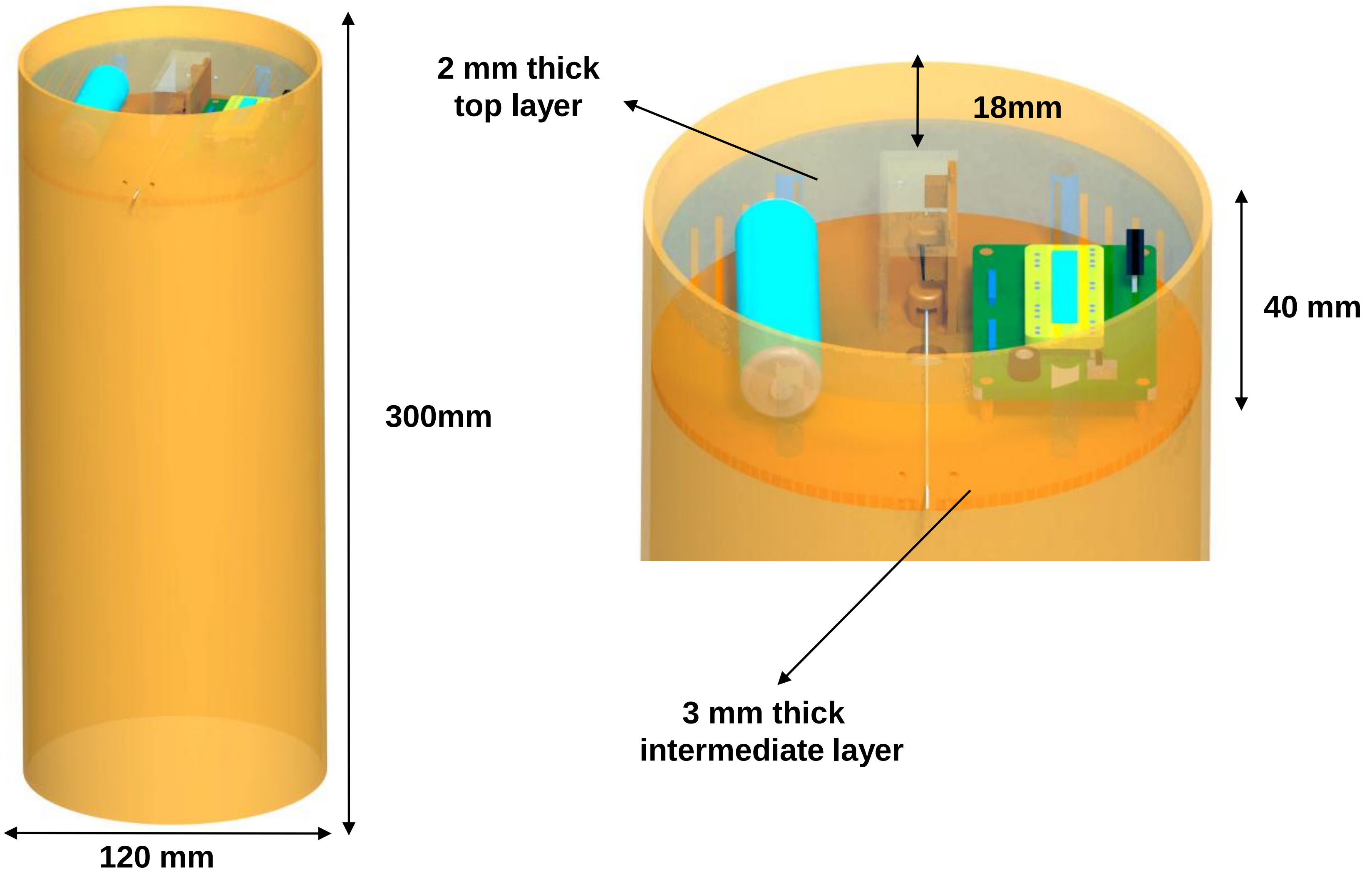


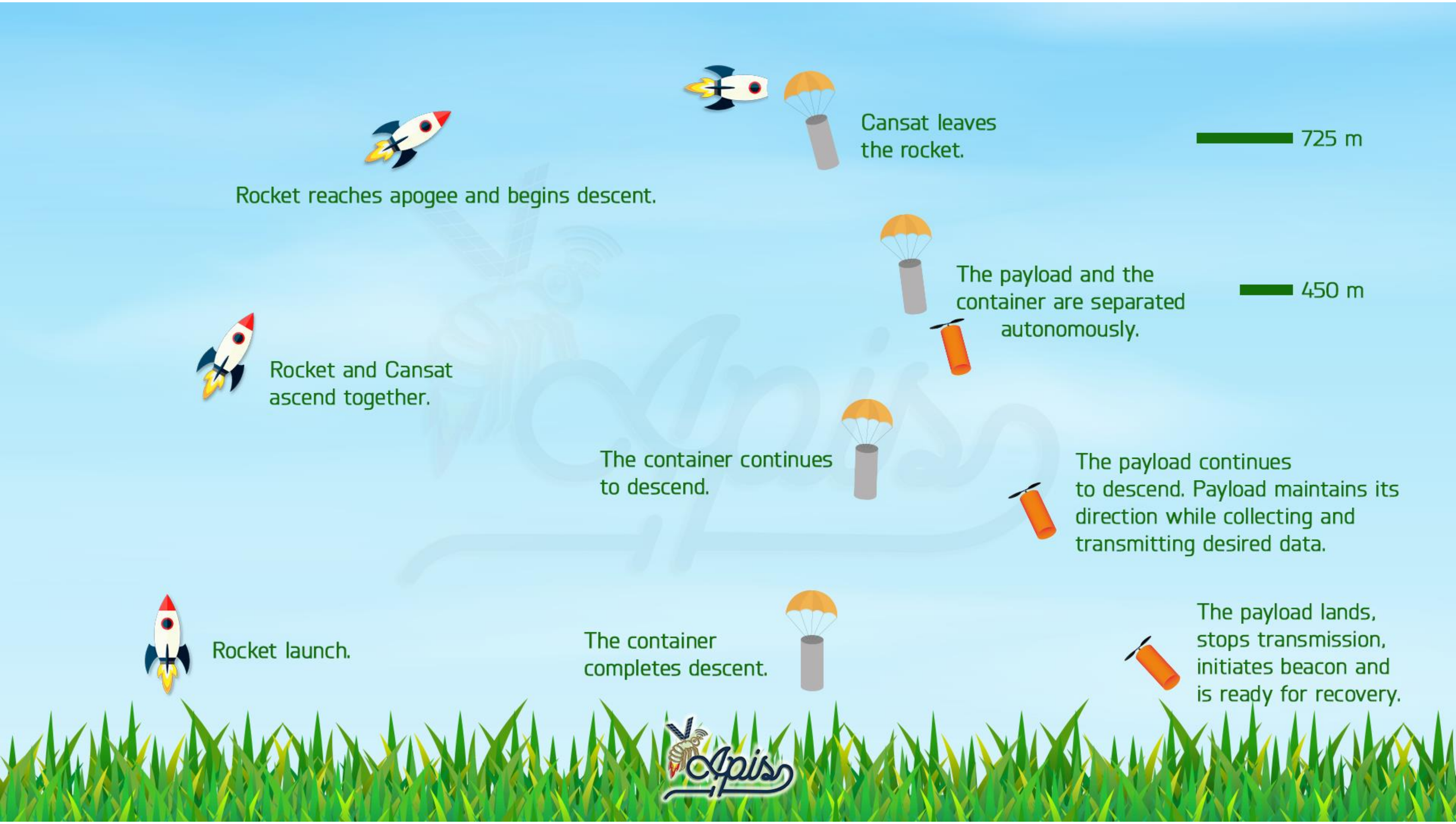


Physical Layout (6/7)



Physical Layout (7/7)




Cansat leaves
the rocket.
725 m
Rocket reaches apogee and begins descent.
The payload and the
container are separated
autonomously.
450 m
Rocket and Cansat
ascend together.
The container continues
to descend.
The payload continues
to descend. Payload maintains its
direction while collecting and
transmitting desired data.
Rocket launch.
The container
completes descent.
The payload lands,
stops transmission,
initiates beacon and
is ready for recovery.

System Concept of Operations (2/2)

01	Pre-Launch	• Competition area arrival. • Team briefing. • Last checks for integration. • Setting up Ground Control Station. • Last check of fully integrated CanSat. • Placement of CanSat into the rocket payload section.
02	Launch	• Ascent, separation and descent phases. • Telemetry data obtaining and .csv file creation via GCS software.
03	Post-Launch	• Recovery of Payload and Container. • Damage inspection of container and payload. • Analysis of sampled data. • Preparation of the PFR. • PFR presentation to jury.

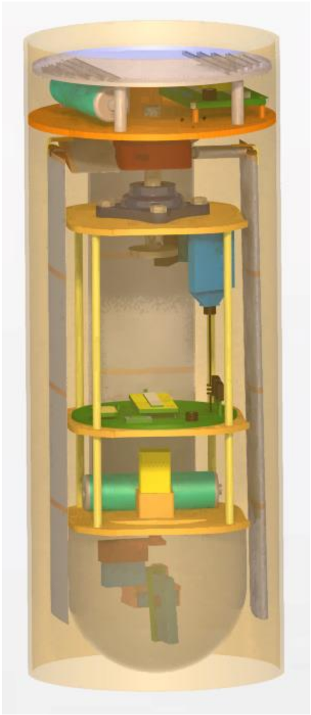
Launch Vehicle Compatibility (1/2)

★ Rocket payload section dimensions based on Mission Guide:
  - Height: 310 mm
  - Diameter: 125 mm

★ CanSat dimensions:
  - Height: 300 mm
  - Diameter: 120 mm

★ Payload dimensions after deployment:
  - Rotor Diameter: 545 mm
  - Structure Diameter: 102 mm
  - Height: 260 mm

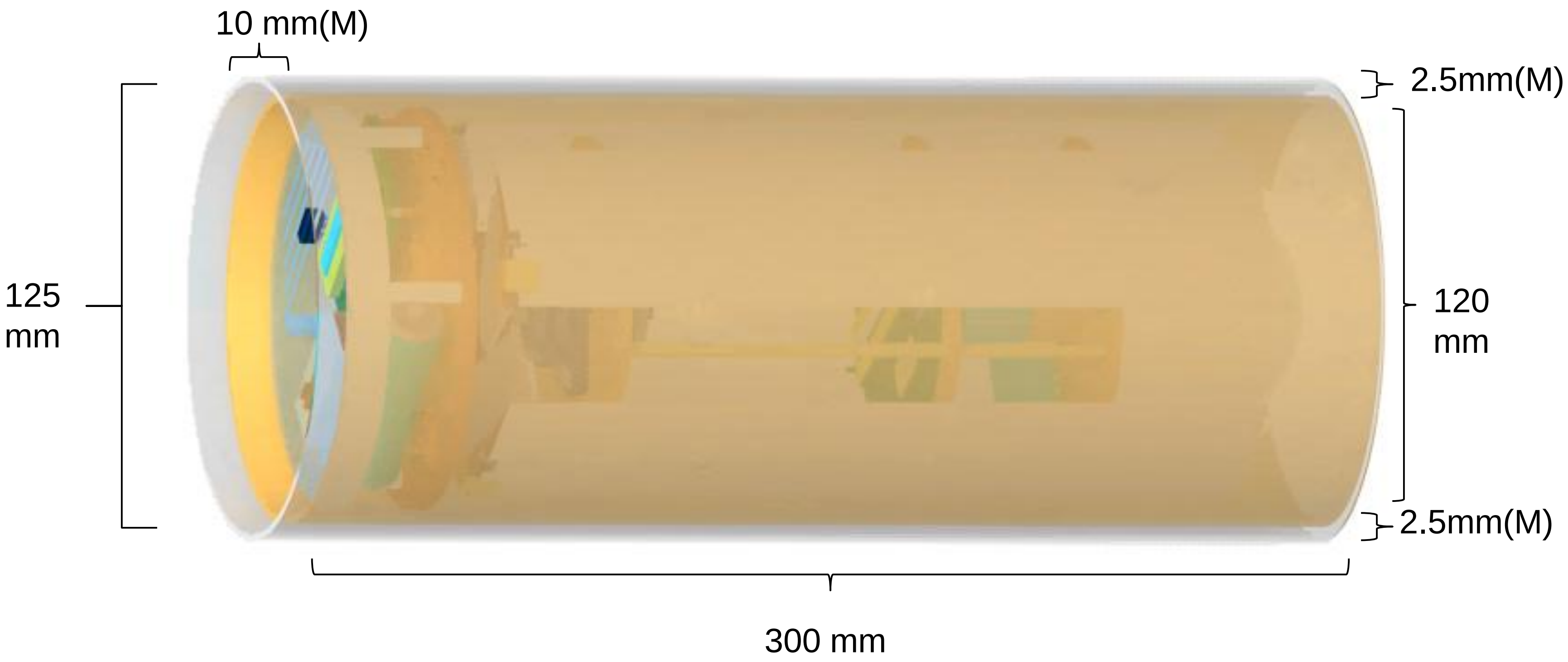
★ Parachute dimensions after separation:
  - Diameter: 132 mm
  - Spill Hole Diameter: 13 mm



➢ CanSat design has been selected to be thinning through rocket nose cone to reduce possibility of deployment failure.
➢ Margins left for secure deployment are examined in following slide.

Launch Vehicle Compatibility (2/2)

- **The rocket payload section dimensions at the outside of the container is illustrated by grey cylinder. Also, container is colored by orange.**



★ ‘M’ symbol represents **margins,** which are demonstrated on the above diagram. These dimensions will provide safety and smooth deployment from the rocket.

Sensor Subsystem Design

Altuğ ERTAN

Sensor Subsystem Overview

Sensor Type	Model	Purpose	CanSat Section
Air Pressure	BMP180	Measurement of altitude by using air pressure	Payload & Container
Air Temperature	BMP180	Measurement of air temperature	Payload
GPS	Adafruit Ultimate GPS	Determination of location	Payload
Power Voltage	Teensy 3.5’s Analog Pin	Measurement of payload battery voltage	Payload
Pitch and Roll	MPU 6050	Verification of stability	Payload
Auto-gyro Blade Spin Rate	FC-33	Measurement of RPM	Payload
Camera	Adafruit Mini Spy Camera	Recording video during descent	Payload
Magnetometer	HMC5883L	Measurement of angle with respect to magnetic north	Payload

Sensor Subsystem Requirements (1/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SS-1	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	CReq	BR-13	MS-12 EPS-1	Very High		√		
SS-2	All structures shall be built to survive 15 Gs of launch acceleration.	CReq	BR-14		Very High	√	√	√	
SS-3	All structures shall be built to survive 30 Gs of shock.	CReq	BR-15		Very High	√	√	√	
SS-4	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	CReq	BR-16	MS-10 DCS-6	Very High		√		√
SS-5	All mechanisms shall be capable of maintaining their configuration or states under all forces.	CReq	BR-17		Very High	√	√		√
SS-6	The science payload shall measure altitude using an air pressure sensor.	CReq	BR-20	CDH-1 FSW-1	Very High	√		√	
SS-7	The science payload shall provide position using GPS.	CReq	BR-21	CDH-2 FSW-2	Very High	√		√	

Sensor Subsystem Requirements (2/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SS-8	The science payload shall measure its battery voltage.	CReq	BR-22	CDH-3 FSW-3	Very High	√		√	
SS-9	The science payload shall measure outside temperature.	CReq	BR-23	CDH-13 FSW-4	Very High	√		√	
SS-10	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.	CReq	BR-24	CDH-5 FSW-5	Very High	√		√	
SS-11	The science payload shall measure pitch and roll.	CReq	BR-25	CDH-6 FSW-6	Very High	√		√	
SS-12	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.	CReq	BR-52	MS-9 DCS-7	Very High	√	√	√	
SS-13	Video shall be in color with a minimum resolution of 640x480 pixels and 30 fps.	Bonus Objective		FSW-15	High	√	√	√	

Sensor Subsystem Requirements (3/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SS-14	After the separation of container and payload at 450 meters, camera of the payload records a video during the descent and store the video to the SD Card.	Bonus Objective	SY-27	FSW-16	High	✓		✓	
SS-15	The camera shall point downward 45 degrees from nadir of the science payload.	Bonus Objective	SY-28	FSW-17	High	✓		✓	
SS-16	It shall point in one direction relative to the earth's magnetic field with a stability of +/- 10 degrees in all directions during descent.	Bonus Objective	SY-29	FSW-18	High	✓		✓	

Payload Air Pressure Sensor Trade & Selection

Model	Interfaces	Range	Accuracy	Supply Voltage	Current	Size	Mass	Cost
BMP180	I²C	300 hPa / 1100 hPa	±1 hPa	1.8 V / 3.6 V	5 µA	14 mm x 12 mm x 2 mm	0.9 g	$ 9.95
LPS25H	I²C, SPI	260 hPa / 1260 hPa	±1 hPa	1.7 V / 3.6 V	2 mA	10 mm x 20 mm x 3 mm	0.5 g	$ 7.95
BME280	I²C, SPI	300 hPa / 1100 hPa	±1 hPa	1.71 V / 3.6 V	3.6 µA	19 mm x 18 mm x 3 mm	1 g	$ 19.95

Selected Air Pressure Sensor: BMP180

- Considering 1 hPa, high measurement accuracy .
- Wide range for healthy measurement.
- Easy to access and useful library.
- Affordable cost.
- Draws low current on standard mode.
- Small sizes.
- According to our experiences in the past, BMP180 works stable.

Payload Air Temperature Sensor Trade & Selection

Model	Interfaces	Range	Accuracy	Supply Voltage	Current	Size	Mass	Cost
BMP180	I²C	-40 °C / 85 °C	±1 °C	1.8 V / 3.6 V	5 µA	14 mm x 12 mm x 2 mm	0.9 g	$ 9.95
DHT22	Digital	-40 °C / 80 °C	±0.5 °C	3.3 V / 6 V	2.5 mA	27 mm x 59 mm x 14 mm	2.4 g	$ 9.95
MPL311 5A2	I²C	-40 °C / 85 °C	±3 °C	1.95 V / 3.6 V	40 µA	18 mm x 19 mm x 2 mm	1.2 g	$ 9.95

Selected Air Temperature Sensor: BMP180

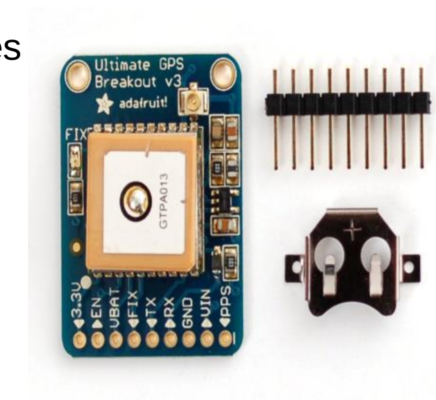
- Considering 1 °C, high measurement accuracy.
- Wide range for healthy measurement.
- Easy to access and useful library.
- Affordable cost.
- Lightweight.
- Draws low current on standard mode.
- Sensor also measure altitude and pressure.
- According to our experiences in the past, BMP180 works stable.

GPS Sensor Trade & Selection

Model	Interfaces	Accuracy	Supply Voltage	Current	Size	Mass	Cost
Adafruit Ultimate GPS	UART	±1.8 m	3.0 V / 5.5 V	20 mA	25 mm x 35 mm x 6.5 mm	8.5 g	$ 39.95
Ublox Neo GY-6MV2	UART, SPI I²C	±2.5 m	2.7 V / 3.6 V	47 mA	25 mm x 35 mm x 5 mm	10 g	$ 52.95
LS20031	UART	±3 m	3.0 V / 4.3 V	41 mA	30 mm x 30 mm x 7 mm	7 g	$ 69.95

Selected GPS Sensor: Adafruit Ultimate GPS

- Considering the maximum output voltage of the microprocessor being 3.3V, satisfies both 3.3V and 5V supply voltage pins.
- Considering its affordable cost, satisfies high position accuracy as 1.8 meter.
- Uses NMEA 0183 GGA protocol meets mission requirements.
- Draws low current.
- Antenna of Adafruit Ultimate GPS is onboard, so it is useful in terms of volume.
- According to our experiences in the past, Adafruit Ultimate GPS works stable.



Payload Power Voltage Sensor Trade & Selection

Model	Interfaces	Range	Error Rate	Cost
Teensy 3.5's Analog Input Pin	Analog	0 V / 5 V	% 0.03	Free
Max 471-B43 module	Analog	3 V / 25 V	% 0.1	$ 3.4
Phidgets Precision Voltage Sensor	Analog	-30 V / +30 V	% 0.5	$ 19

Selected Power Voltage Sensor: Teensy 3.5's Analog Input Pin

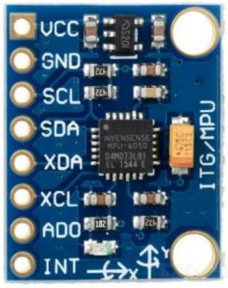
- Considering low error rate, meets high accuracy for healthy measurement.
- Power supply voltage value of the payload is between its measurement range limits.
- Located on our microcontroller, so there is no any external occupation of area on the circuit.
- Free of charge.
- Reduces the load on I²C.

Pitch and Roll Sensor Trade & Selection

Model	Interface	Zero Rate Level	Supply Voltage	Current	Size	Mass	Cost
MPU6050	I²C	±20 dps	2.3 V - 3.4 V	3.9 mA	20mm x 15mm x 3mm	1.8 g	$ 2.97
LSM6DS33	I²C, SPI	±10 dps	2.5 V - 5.5 V	2 mA	23mm x 13mm x 3mm	0.6 g	$ 11.95
MPU9250	I²C,SPI	±30 dps	2.4 V - 3.6 V	3.2 mA	25mm x 15mm x 3mm	2.2 g	$ 10

Selected Pitch and Roll Sensor: MPU6050.

- Cost effective.
- Appropriate current consumption.
- Easy to access and useful library.
- Appropriate supply voltage range.
- Even if LSM6DS33 offers better zero rate level considering the cost, MPU6050 is selected over LSM6DS33.



Auto-gyro Blade Spin Rate Sensor Trade & Selection (1/2)

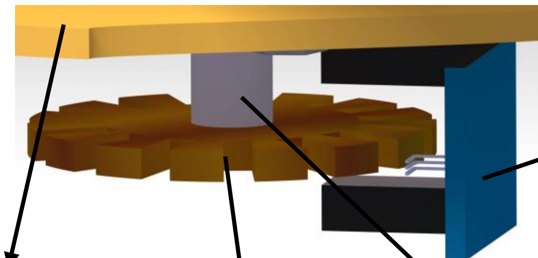
Model	Interfaces	Measurement Technique	Supply Voltage	Current	Size	Mass	Cost
FC-33 Sensor Module	Digital	Infrared Radiation	3.3 V – 5 V	15 mA	23 mm x 20 mm x 5 mm	3.2 g	$ 1.82
Sharp GP2Y0D810Z 0F Sensor Module	Digital	Infrared Radiation	2.7 V – 6.2 V	5 mA	21 mm x 9 mm x 10 mm	1.8 g	$ 7.49
KY-003 Sensor Module	Digital	Magnetic Field	3.3 V – 5 V	8 mA	18 mm x 15 mm x 3 mm	3.5 g	$ 2.79

Selected Auto-gyro Blade Spin Rate Sensor: FC-33 Sensor Module

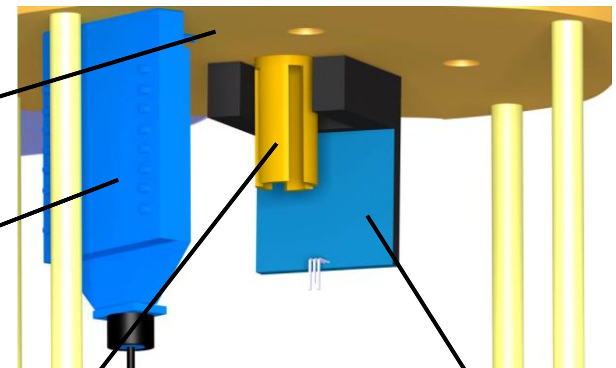
- Cost effective.
- Easy to program.
- Infrared radiation satisfies more accurate measurement compared to magnetic field.
- Location of IR LED and IR photodiode of FC-33 are opposite, so FC-33 meets requirements of selected RPM measurement design.
- KY-003 requires an external magnet for measuring RPM. Therefore, it might affect other sensors such as magnetometer and puts weight on payload.
- Location of IR LED and IR photodiode of Sharp GP2Y0D810 are side by side, so Sharp GPY20D810 increases difficulties of RPM measurement.

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

First Design: Perforated Plate



Second Design: Perforated Shaft



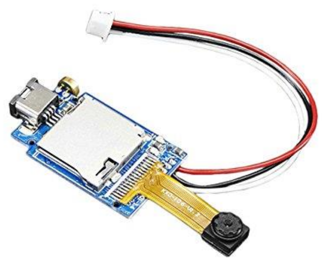
Selection	Rationale
Perforated Plate	• Easy to manufacture. • High durability when rotor blades spin • Satisfies healthier RPM value than perforated shaft owing to more hole number. • Perforated shaft may cause to lose in power and in stability.

Bonus Camera Trade & Selection

Model	Interfaces	Video Resolution	Frame Per Second	Supply Voltage	Current	Size	Cost
Adafruit Mini Spy Camera	Digital	640 x 480p	30 fps	3.7 V – 5.0 V	110 mA	28 mm x 17 mm x 4 mm	$ 12.50
OV7670	I²C and Digital	640 x 480p	30 fps	2.5 V - 3.0 V	180 mA	30 mm x 30 mm x 7 mm	$ 15.20
Quelima SQ11	Digital	1280 x 720p	30 fps	5 V	125 mA	23 mm x 23 mm x 23 mm	$ 30.25

Selected Camera: Adafruit Mini Spy Camera

- Affordable cost.
- Appropriate video resolution and fps values considering bonus mission requirements.
- Has a digital trigger pin, so the camera is enabled by digital signal easily, switch is not required.
- Includes SD card slot on its PCB, so any external module is not required.
- OV7670 has large dimensions and does not have SD card slot on its PCB.
- Quelima SQ11 starts to record by switch, so switch must be inactivated.



Container Air Pressure Sensor Trade & Selection

Model	Interfaces	Range	Accuracy	Supply Voltage	Current	Size	Mass	Cost
BMP180	I²C	300 hPa / 1100 hPa	±1 hPa	1.8 V / 3.6 V	5 µA	14 mm x 12 mm x 2 mm	0.9 g	$ 9.95
LPS25H	I²C, SPI	260 hPa / 1260 hPa	±1 hPa	1.7 V / 3.6 V	2 mA	10 mm x 20 mm x 3 mm	0.5 g	$ 7.95
BME280	I²C, SPI	300 hPa / 1100 hPa	±1 hPa	1.71 V / 3.6 V	3.6 µA	19 mm x 18 mm x 3 mm	1 g	$ 19.95

Selected Air Pressure Sensor: BMP180

- Considering 1 hPa, high measurement accuracy .
- Wide range for healthy measurement.
- Easy to access and useful library.
- Affordable cost.
- Draws low current on standard mode.
- Small sizes.
- According to our experiences in the past, BMP180 works stable.

Descent Control Design

İsmail ÖZCAN

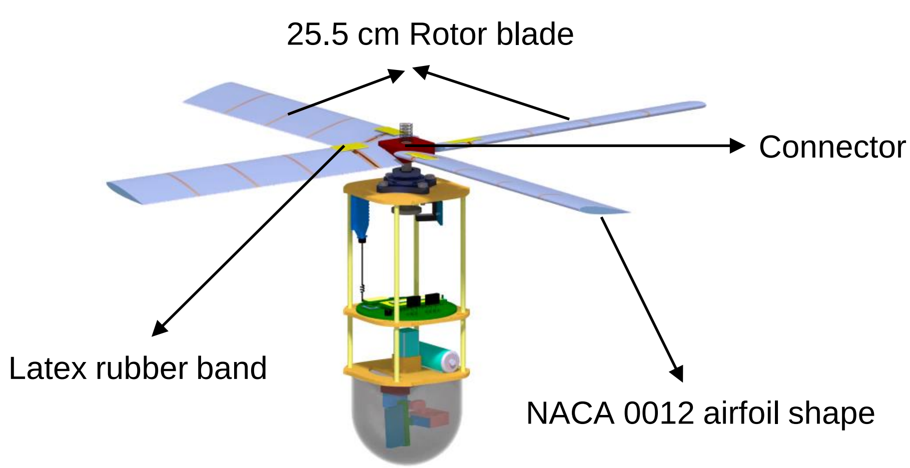
Descent Control Overview (1/3)

Rotor Blades (Payload Descent Control System) :

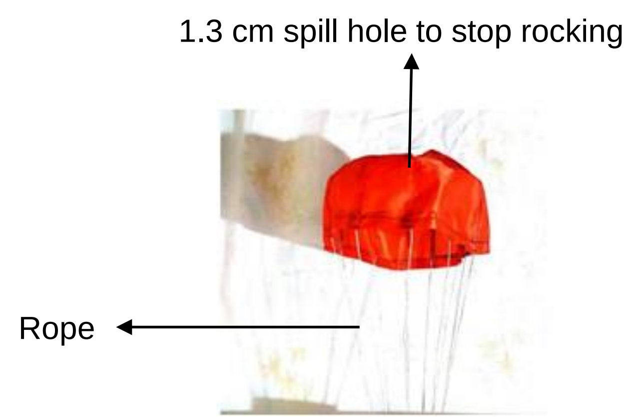
Rotor blades are chosen as 25.5 cm to be fit in container. They are covered by fiberglass which makes them rigid body. Rotor blades are held by connector part to carry payload. Rotor blades also have stowing mechanism to be fit in container. NACA 0012 airfoil selected for rotor blades because of high stall angle (between 15-20 degrees) and ease of fabrication.

Parachute (Container Descent Control System) :

Parachute has 13.2 cm diameter to reach 19.96 m/s velocity. It has been made from 30d Silicone Nylon 66 Cloth. It has 1.3 cm diameter spill hole to stabilize container during descent.

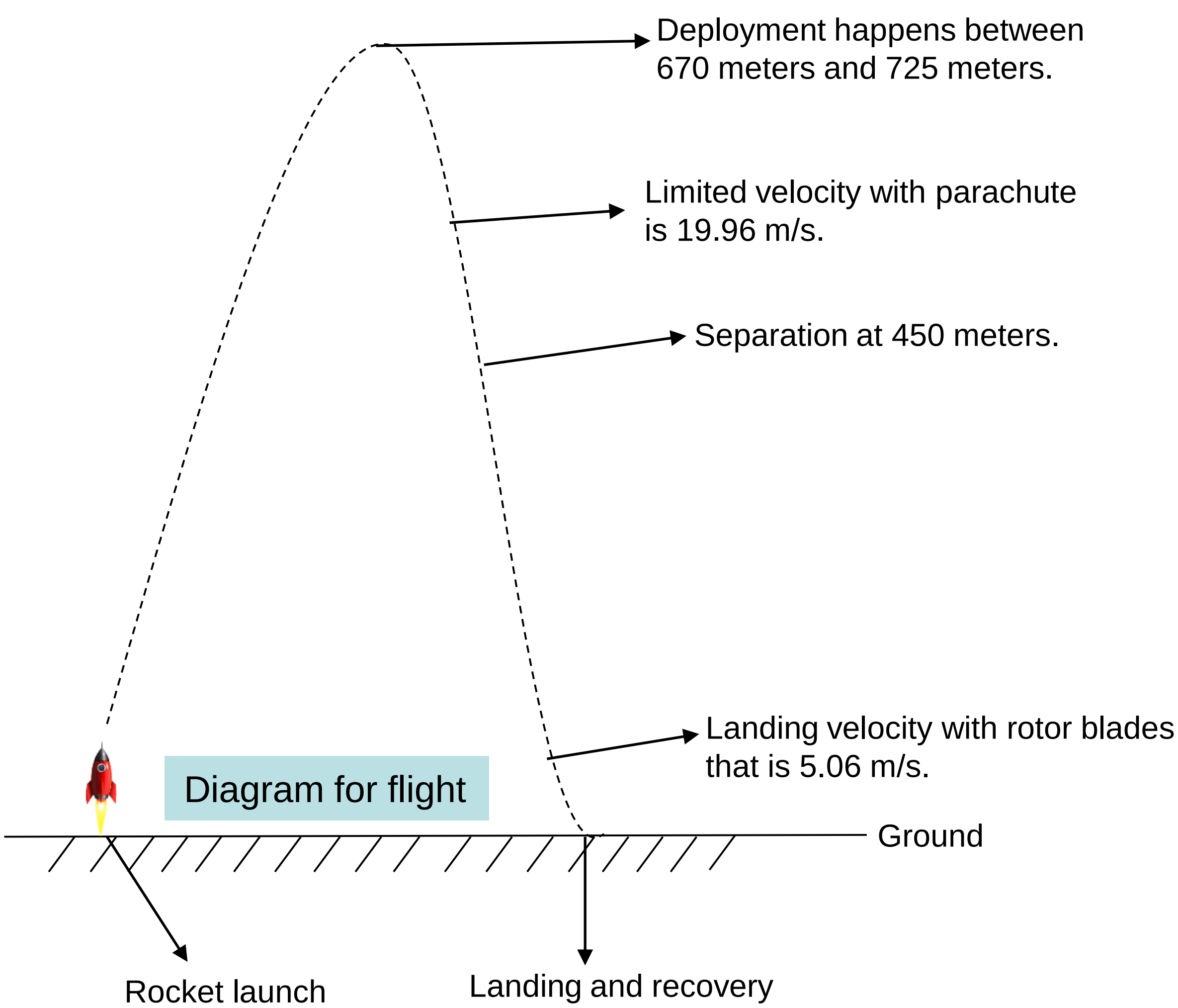


(Cylindrical Shaped Payload with Rotor blades)



(Parachute)

Descent Control Overview (2/3)



- Descent velocity for CanSat (container+payload) found as 19.96 m/s before the separation at 450 meters via the parachute.
- Payload starts descending with auto-gyro system from 450 meters to ground.
- Descent rate of payload is between 10-15 m/s.

Descent Control Overview (3/3)

Configuration Selected: Cylindrical Shaped Payload with Rotor blades

Components :

Component	Used Material
Shaft	Fiberglass pipe
Parachute connection with Container	Cotton line rope
Connector (Main shaft to the payload)	8 mm x 16 mm x 5 mm Bearing
Parachute fabric	30d Silicone Nylon 66 Cloth
Rotor blade skin	Fiberglass fabric +epoxy resin
Rotor blade body	Styrofoam and balsa wood

Descent Control Requirements

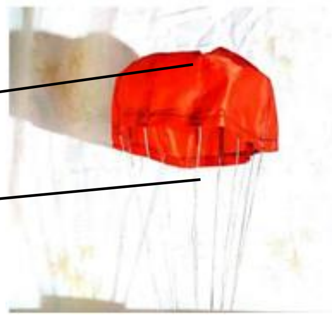
ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
DCS-1	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	Creq	BR-7	MS-7	Very High	✓	✓		✓
DCS-2	The science payload shall descend using an auto-gyro/ passive helicopter recovery descent control system.	Creq	BR-10	MS-9	Very High	✓	✓	✓	✓
DCS-3	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	Creq	BR-8	-	Very High	✓		✓	
DCS-4	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.	Creq	BR-11	-	Very High	✓		✓	
DCS-5	The container shall release the payload at 450 meters +/- 10 meters.	Creq	BR-9	MS-8	Very High	✓		✓	
DCS-6	All descent control device attachment components shall survive 30 Gs of shock.	Creq	BR-12	MS-10 SS-4	High	✓	✓	✓	
DCS-7	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.	Creq	BR-52	MS-9 SS-12	Very High	✓	✓	✓	

Pre Payload Deployment Descent Control Strategy

Parachute Configuration

Configuration Type 1: Dome Type

Spill hole



Rope

- Stability is easily ensured by a spill hole.
- High drag coefficient.
- Durable.
- Requires less space when stacked.
- Horizontal displacement is low.

Configuration Type 2: X Type

Rope

Fabric

- Easy to stack.
- Low drag coefficient.
- Easy to manufacture.
- Lightweight.

Selection	Rationale
Dome Type	• Occupies less space. • Less horizontal displacement. • More stable descent.

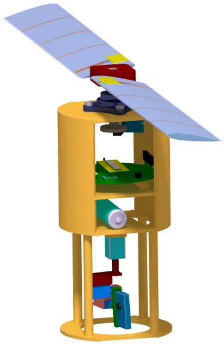
Post Payload Deployment Descent Control Strategy (1/2)

Rotor blade Configuration

Configuration Type 1: 4 rotor blades

- Produces sufficient lift for landing without fail.
- Drag coefficient for 10 degrees angle of attack is enough for autorotation.
- Difficult to stow.
- Descent is not interrupted if one of the rotor blades fails.

Configuration Type 2: 2 rotor blades



- The needed blade radius for safe landing is too long to easily fit in the container.
- Easy to manufacture.
- Easy to stow.
- If one of the rotor blades fails, descent is interrupted.

Selection	Rationale
4 Rotor Blades	• Produces sufficient lift for safe landing. • More proper in case of blade failure scenario.

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

Post Payload Deployment Descent Control Strategy (2/2)

Configuration Type 1: NACA 0012

- Hard and expensive production.
- Creates acceptable lift for safe landing.
- High stall angle.

Airfoil Configuration

Configuration Type 2: Flat Plate

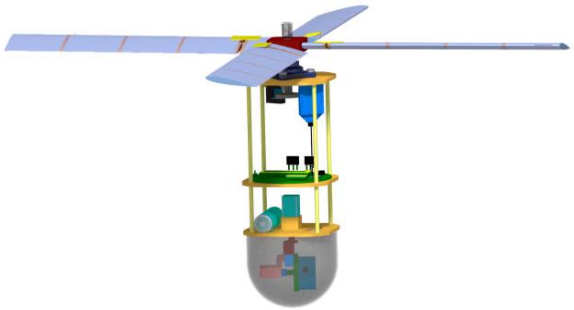
- Cheap and easy production.
- Gives sufficient lift at high angle of attack. May cause stall.

Selection	Rationale
NACA 0012	• Helps to produce sufficient lift for safe landing at low angle of attack values. • Enters stall late.

4 rotor blades provide more advantages compared to 2 rotor blades. Therefore, a rotor with 4 blades is selected. 4 blades are less susceptible to fail. Moreover, NACA 0012 airfoil shape is selected for rotor blades to obtain sufficient lift while autorotating.

Payload Descent Stability Control Strategy Selection and Trade (1/3)

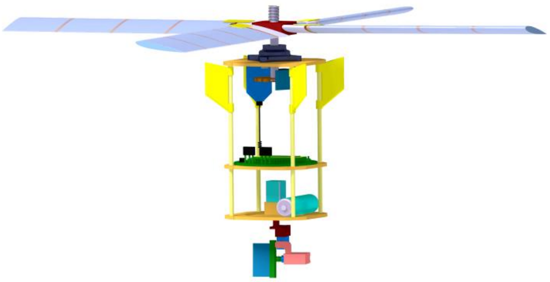
Configuration Type 1: Passive



- Pressure center, aerodynamic center, and mass center are placed on the same axis.
- Camera stabilizer protection mechanism ensures smooth airflow around blades.
- Camera stabilizer protection mechanism placed at the bottom of the payload. So the mass center is lowered down.

Tumbling controlling systems

Configuration Type 2: Active



- Fins are controlled by electronics, higher accuracy in stability obtained by feedback mechanism.
- Requiring stowing configuration for the fins.
- Requiring additional design concerns.

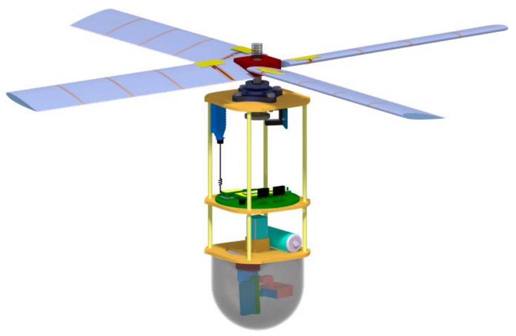
Selection	Rationale
Passive	• Smooth airflow around blades. • No need to use a complicated electronic mechanism. • Mass center positioned lower than configuration 2.

Payload Descent Stability Control Strategy Selection and Trade (2/3)

Camera stabilizer protection configuration directly affects on flow around the auto-gyro blades. So a design that did not distort the air flow was chosen. Proper air flow is required to maintain stability.

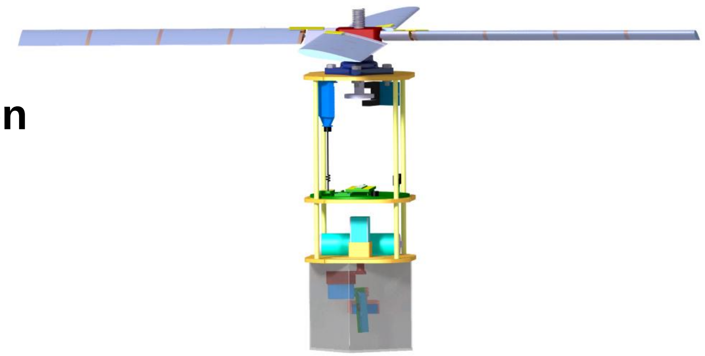
Gimbal Protection Configuration

Configuration Type 1: Half ellipsoid



- Durable.
- Less flow distortion.
- There are no edges to stuck anywhere.
- Integration is simple.

Configuration Type 2: Rectangular prism

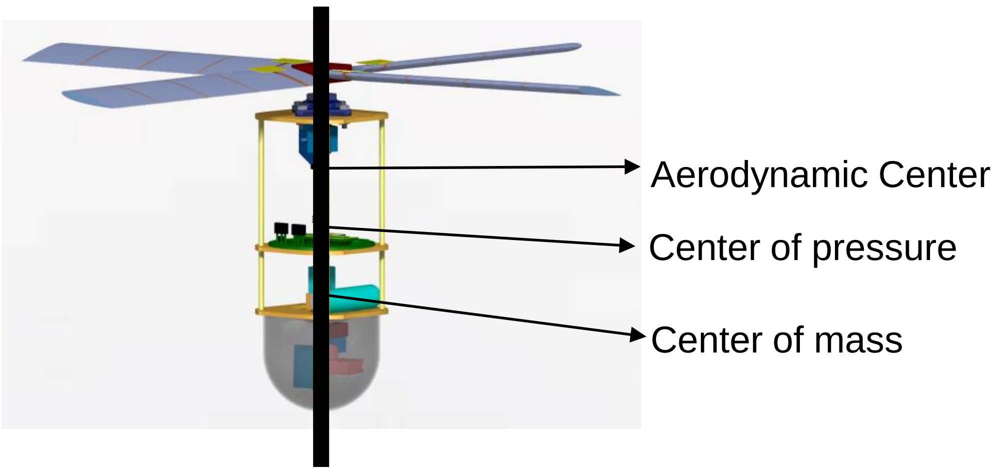


- Edges may result in stucking.
- High flow distortion.
- Lesser working area for gimbal mechanism.
- Produces extra drag.

Selection	Rationale
Half Ellipsoid	• Smooth airflow over auto-gyro blades. • Has advantages for rocking and tumbling. • Stucking issue is not concerned during separation.

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

Tumbling control system should be reliable for safe landing. Parachute stops tumbling of the CanSat (container+payload) due to reaching its limited velocity fastly and keeping its nadir direction easily. After separation, container maintains its nadir direction and is not exposed to tumbling. Payload keeps its nadir direction via passive controls. Rotor blades act like a parachute when they rotate enough. Payload's aerodynamic, pressure and mass centers of the payload are located on same vector which helps to stop tumbling. Nadir direction is also maintained because the center of mass will be positioned below pressure center and aerodynamic center. In order to have lower mass center, electronic components are also located below.



Passive nadir direction control

Descent Rate Estimates (1/6)

Descent for Container+Payload

$$V = \sqrt{\frac{2 \times m \times g}{A \times \rho \times C_d}} = \sqrt{\frac{8 \times (0.5\ kg) \times (9.81\ m/s^2)}{\pi \times (0.132\ m) \times (0.132\ m) \times (1.2\ kg/m^3) \times 1.5}} = 19.96\ m/s$$

V = Terminal velocity

m = mass (Payload+Container)

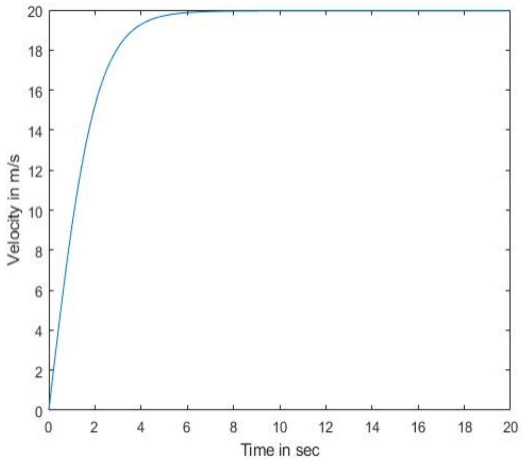
A = area (Circular area of parachute = π x R x R)

ρ = 1.2 kg/m^3 (air density for Texas)

g = 9.81 ^m/s^2 (acceleration of gravity)

C_d = drag coefficient (1.5 for Dome type)

After the separation from the rocket, first velocity of the payload+container is assumed to be zero at peak. After parachute opens at nearly 700 meters, terminal velocity for total mass is calculated as 19.96 m/s according to formula. Parachute has 13.2 cm diameter.



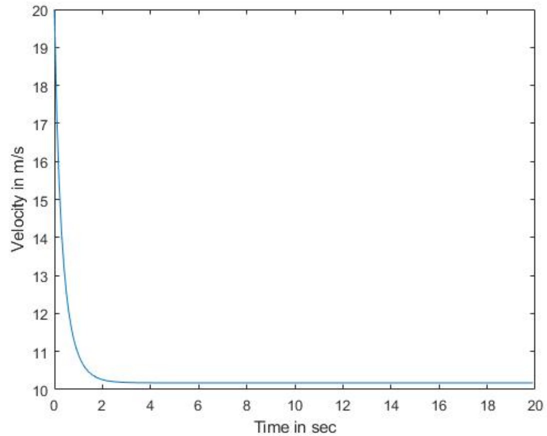
Container+payload vertical velocity graph for after deployment from the rocket

Descent for Container

$$V = \sqrt{\frac{2 \times m \times g}{A \times \rho \times C_d}} = \sqrt{\frac{2 \times (0.13\ kg) \times (9.81\ m/s^2)}{(0.013625\ m^2) \times (1.2\ kg/m^3) \times 1.5}} = 10.176\ m/s$$

V = Terminal velocity	ρ = 1.2 kg/m^3 (air density for Texas)
m = mass (Container only)	g = 9.81 m/s^2 (acceleration of gravity)
A = area (Circular area of parachute)	C_d = drag coefficient (1.5 for Dome type)

After the payload is released at 450 meters, first velocity of Container is less than 20 m/s because of spring reaction force. Parachute starts to decelerate Container to **10.176 m/s** according to given formula.



Container vertical velocity graph

Descent Rate Estimates (3/6)

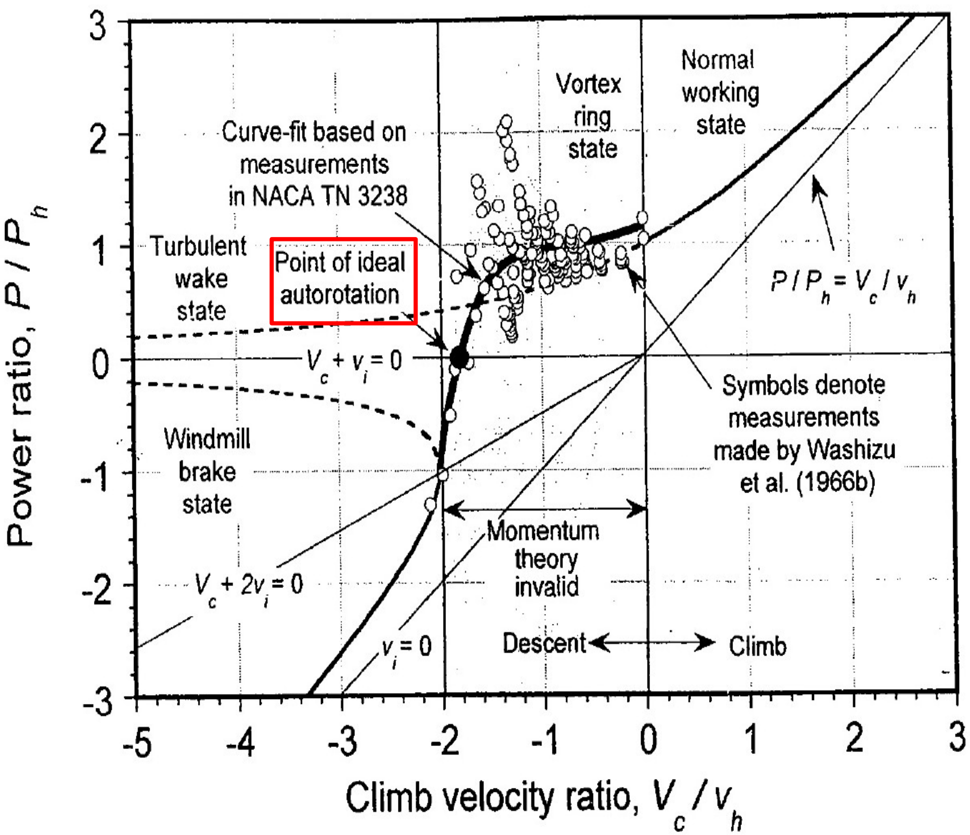
Descent for Payload (1/3)

In autorotation condition, no power is needed. For an ideal autorotation Vc /Vh ratio should be between -1.85 and -1.9. This value is read from the graph. So drag coefficient found between 1.10 and 1.16 from the formula is given below. Vc means climb velocity, Vh means induced velocity at hover.

$$-1.85 \leq \frac{V_c}{V_h} \leq -1.90$$

$$C_d = \frac{4}{(\frac{V_c}{V_h})^2}$$

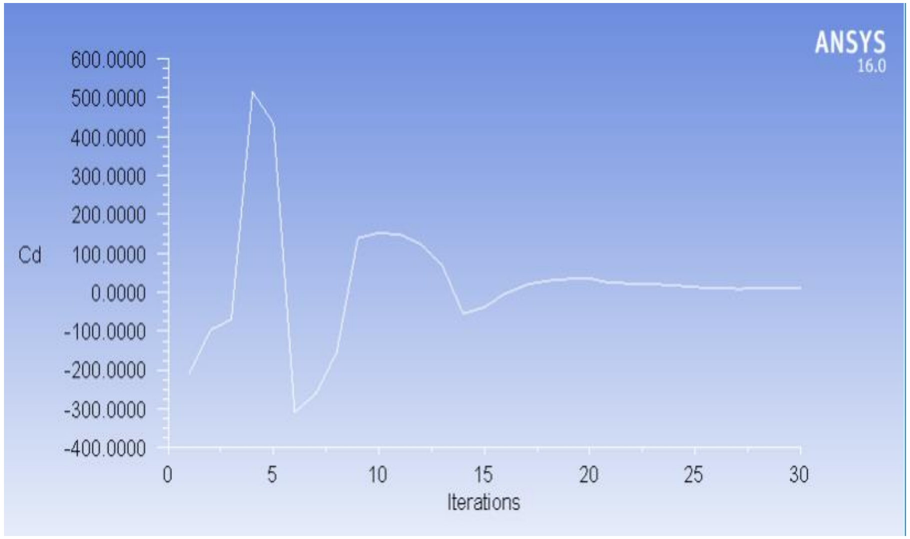
$$1.10 \leq C_d \leq 1.16$$



Taken from (Principles of Helicopter Aerodynamics – J.GORDON LEISHMAN)

Descent for Payload (2/3)

- ➔ The numerical solution method is used in the process of the auto-gyro blades design. To achieve needed drag coefficient, blades are analyzed for different angle of attack values.
- ➔ Air comes from bottom side of the auto-gyro blades during the descent. Thus, air acts as if it contacts with a flat plate. Flat plate's drag coefficient is 1.28. To decrease this drag coefficient, angle of attack of the auto-gyro blades increased and tested for each degree. After several iterations, the desired drift coefficient was obtained at 10 degrees of attack angle.
- ➔ Drag coefficient for 10 degrees angle of attack is approximately 1.16, according to ANSYS 16.0. Fluent analysis and it is desirable for starting auto-rotation at nearly 20 m/s velocity.



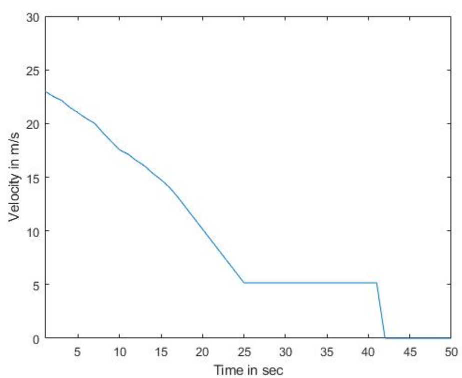
Iteration Number	Drag Coefficient
23	4.61214e+00
24	4.72753e+00
25	3.44343e+00
26	1.35525e+00
27	1.44389e+00
28	1.25526e+00
29	1.17447e+00
30	1.15896e+00

Descent for Payload (3/3)

The length of the auto-gyro blades was chosen to be 25.5 cm in order to use the area effectively and to avoid any inconvenience in folding.

$$V = \sqrt{\frac{2 \times m \times g}{A \times \rho \times C_d}} = \sqrt{\frac{2 \times (0.3715\ kg) \times (9.81\ m/s^2)}{\pi \times (0.255\ m) \times (0.255\ m) \times (1.2\ kg/m^3) \times (1.16)}} = 5.06\ m/s$$

V = Terminal velocity	ρ = 1.2 kg/m^3 (air density for Texas)
m = mass (Payload only)	g = 9.81 ^m/s^2 (acceleration of gravity)
A = area (Rotor disk area)	C_d = drag coefficient (1.16 for Auto-gyro)

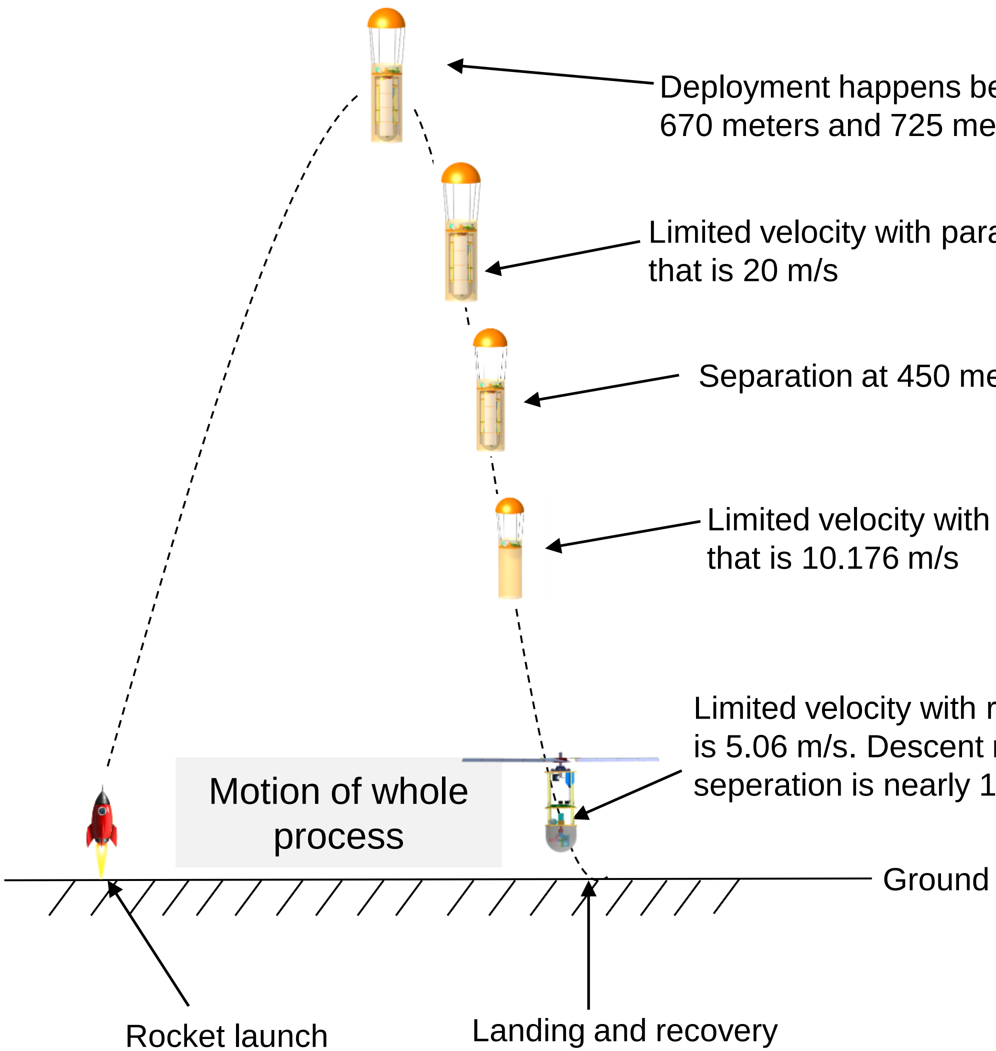


Possible vertical velocity graph for payload

Our initial velocity is bigger than 20 m/s because of spring force on payload. Descent rate of payload after separation is between 10 m/s - 15 m/s because *autorotation does not start immediately*. Descent rate of payload was found as nearly **11 m/s** referring to vertical velocity graph. Velocity graph is plotted on MATLAB.

$$\text{Descent Rate} = \frac{Total\ Height}{Total\ Time}$$

Descent Rate Estimates (6/6)

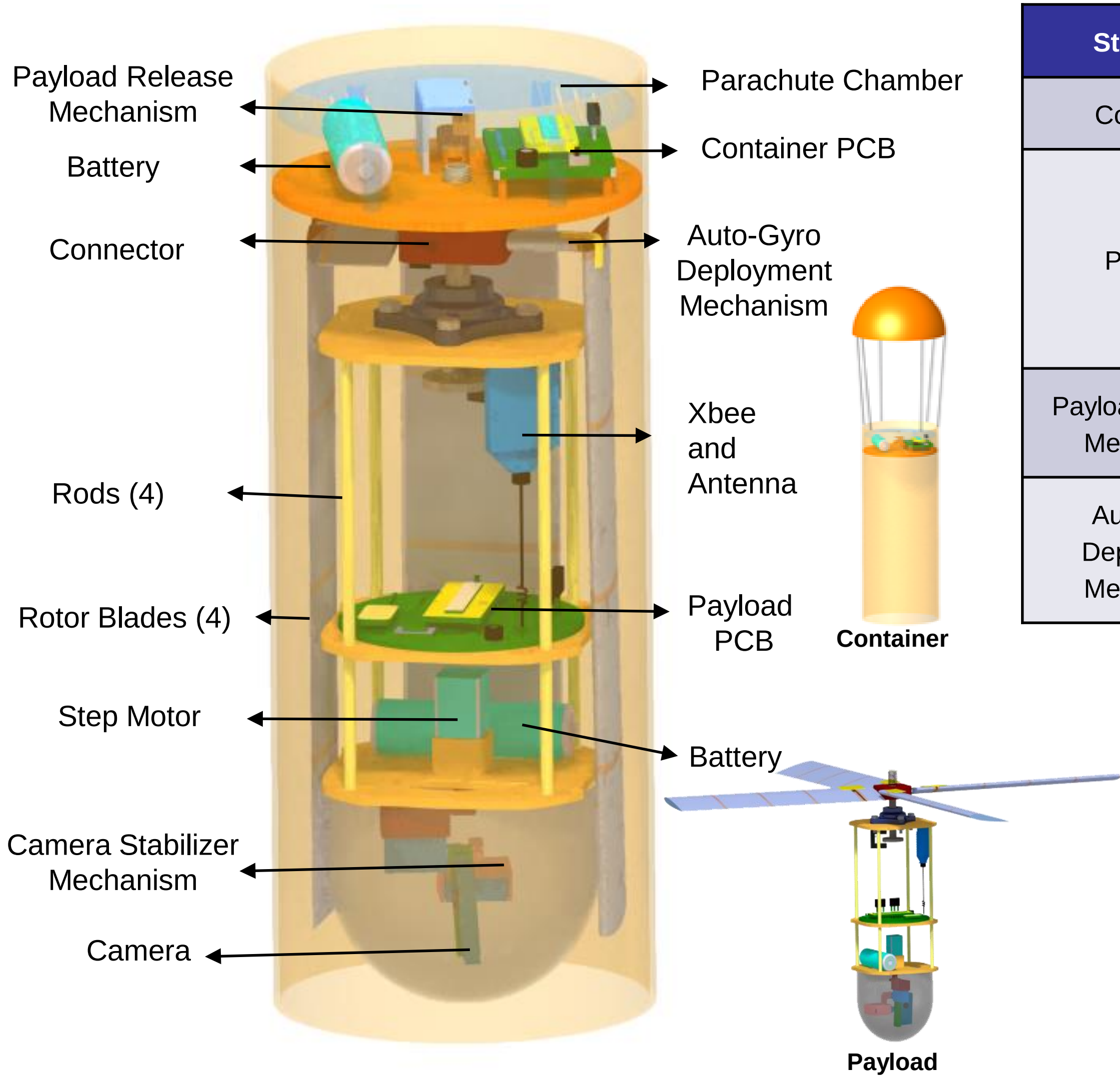


- The descent velocity for container+payload is 19.96 m/s before the separation.
- After separation, container descent velocity decreased to limited velocity 10.176 m/s via parachute.
- After separation, payload velocity increased to nearly 25 m/s due to spring force. Landing velocity decreased to 5.06 m/s via auto-gyro blade rotation. Descent rate is nearly **11 m/s**.

Mechanical Subsystem Design

Muhammed KARA

Mechanical Subsystem Overview



Structure	Material Selection
Container	Fiberglass
Payload	Plywood for Layers, Fiberglass Rods, 3D Printed ABS for Rotor Blade Connector, Styrofoam, Fiberglass Resin and Balsa Wood for production of Rotor Blades, Plexiglas for Camera Cover
Payload Release Mechanism	Nichrome Wire, Fishing Line, Spring
Auto-Gyro Deployment Mechanism	Hinge, Latex

Interface Definitions

- There is a top plate on the container for separating parachute from electronic components in the container.
- Interior plates in the payload to set mechanical and electronic components apart from each other.
- Payload Release Mechanism keeps Payload and Container during flight until 450m.

Mechanical Sub-System Requirements (1/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
MS-1	Total mass of the CanSat (science payload and container) shall be 500 grams +/- 10 grams.	CReq	BR-1		Very High	√		√	
MS-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.	CReq	BR-2		Very High	√	√	√	
MS-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.	CReq	BR-3		Very High		√	√	
MS-4	The container shall be a fluorescent color; pink, red or orange.	CReq	BR-4		Very High		√		
MS-5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	CReq	BR-5		Very High	√			√
MS-6	The rocket airframe shall not be used as part of the CanSat operations.	CReq	BR-6		Very High	√			√
MS-7	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	CReq	BR-7	DCS-1	Very High	√	√		√

Mechanical Sub-System Requirements (2/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
MS-8	The container shall release the payload at 450 meters +/- 10 meters.	Creq	BR-9	DCS-5	Very High	✓		✓	
MS-9	The science payload shall descend using an auto-gyro/ passive helicopter recovery descent control system. This system shall not be motorized.	Creq	BR-10 BR-52	DCS-2 DCS-7 SS-12	Very High	✓	✓	✓	
MS-10	All descent control device attachment components and structures shall survive 30 Gs of shock and 15 Gs acceleration.	Creq	BR-12 BR-14 BR-15 BR-16	SS-4 DCS-6	Very High	✓	✓	✓	
MS-11	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Creq	BR-17	SS-1	Very High	✓	✓		✓
MS-12	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Creq	BR-13	EPS-1	High		✓		
MS-13	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.	Creq	BR-19		Very High		✓		✓

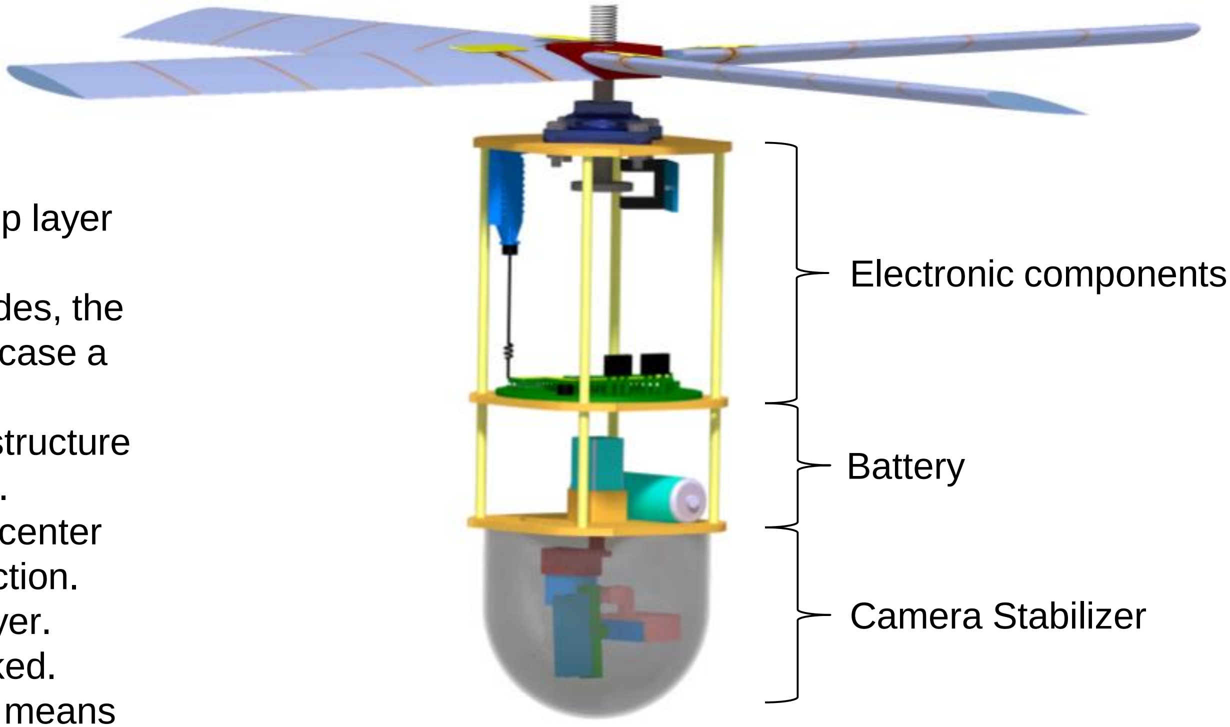
DESIGN 1 (Selected)

<u>Advantages</u>:

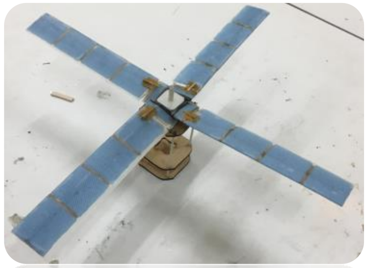
- Access to inner parts is easier.
- Auto-gyro system is attached to top layer by the fixing element.
- Since there are four auto-gyro blades, the system is more reliable to work in case a blade problem occurs.
- There is a transparent plexiglass structure protecting the camera mechanism.
- The electronics are placed on the center of payload to provide a high protection.
- Battery is placed on the bottom layer.
- Camera view angle is not be blocked.
- The center of mass at the bottom, means better stability.
- In case of a collision, the structure continues to maintain its shape.

<u>Disadvantages</u>:

- Design is more sophisticated.
- Assemby is harder because of containing many parts.



Actual Prototype



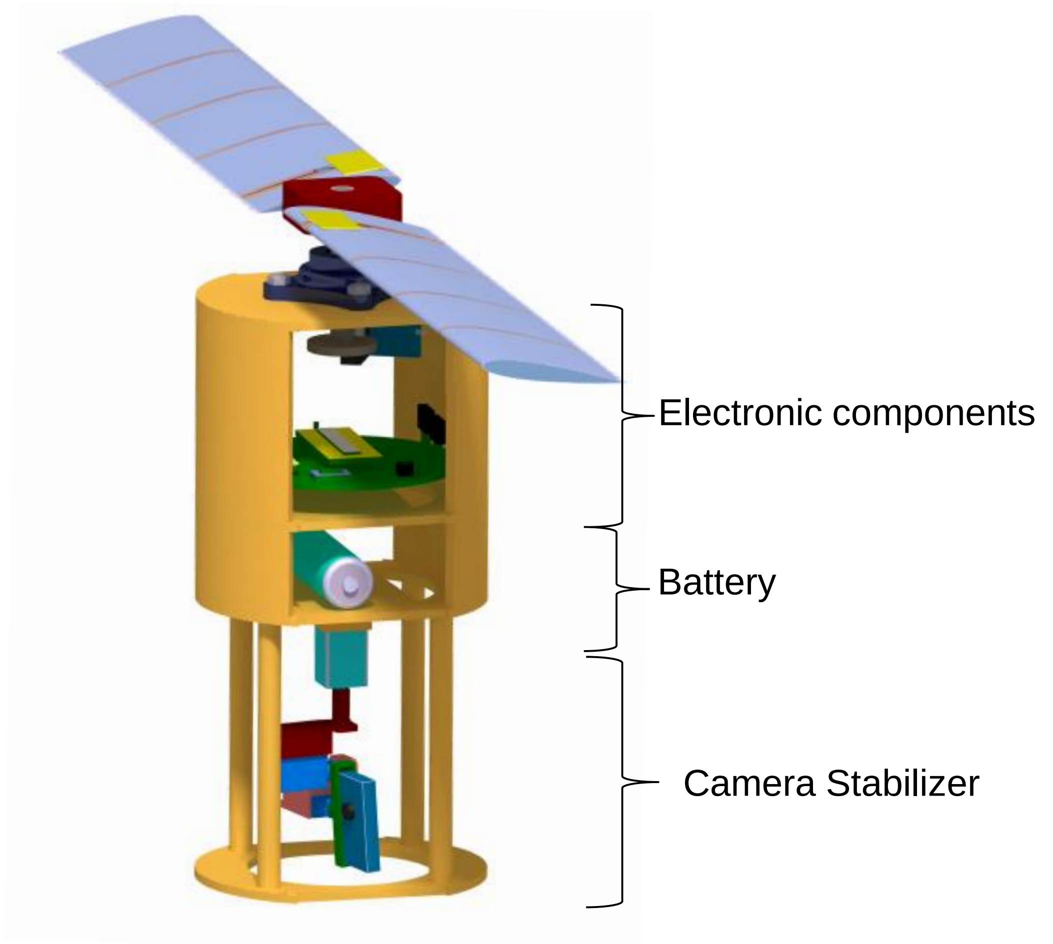
DESIGN 2

Advantages:

- 3D Printing method is mostly used, because it is easy and cost-effective.
- The battery is placed on the middle layer of the payload.
- Auto-gyro System will be placed on top of the payload.
- The electronics are placed on the upside layer of the payload to provide high protection.

Disadvantages:

- Because the camera stabilizer system is not covered by a protective shield, It can easily be damaged.
- Production methods are limited due to large parts.
- Heavier than design 1.
- The needed blade radius for safe landing is too long to easily fit in the container.



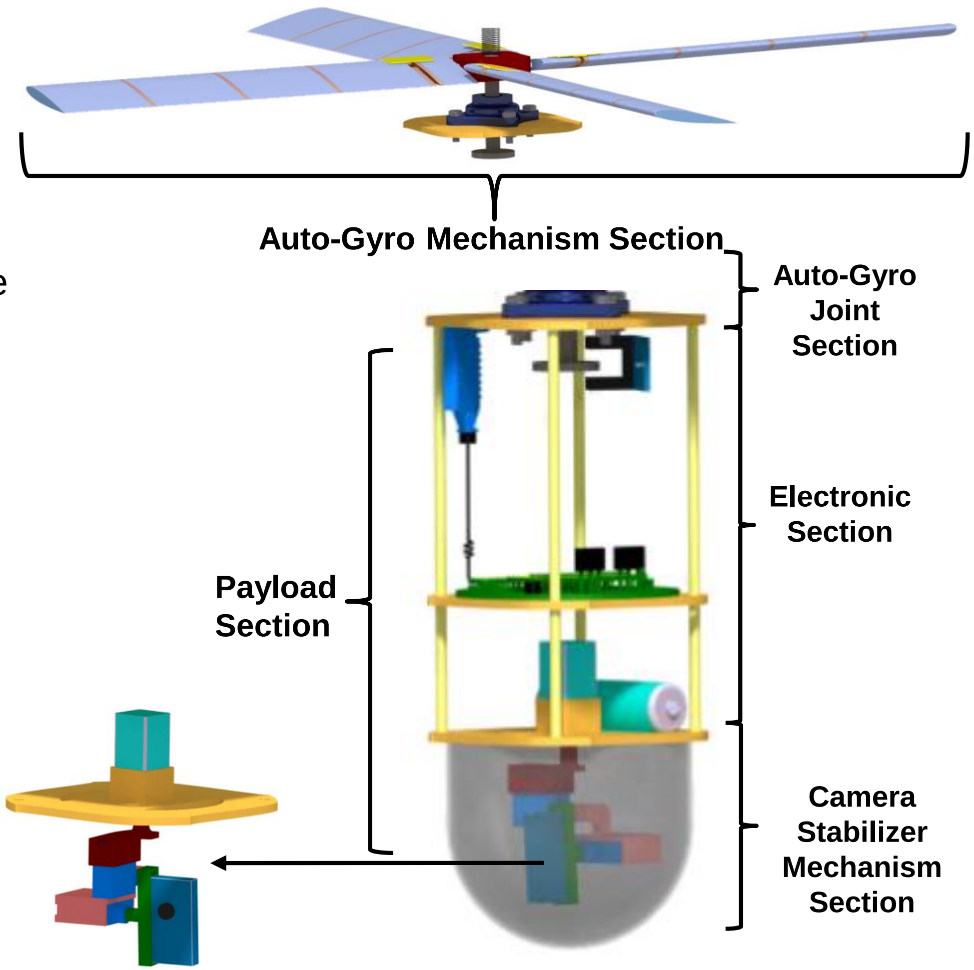
Payload Mechanical Layout of Components Trade & Selection (3/10)

	Design 1	Design 2
Durability	High	Medium
Mass	Low	High
Cost	Medium	Low
Strength	High	High
Stability	High	Low
Aerodynamically Design	High	Low

Selected Design	Rationales
Design 1	▪ Lighter. ▪ Better component protection. ▪ Highly strengthened by using composites. ▪ High stability during descent.

Payload Structure

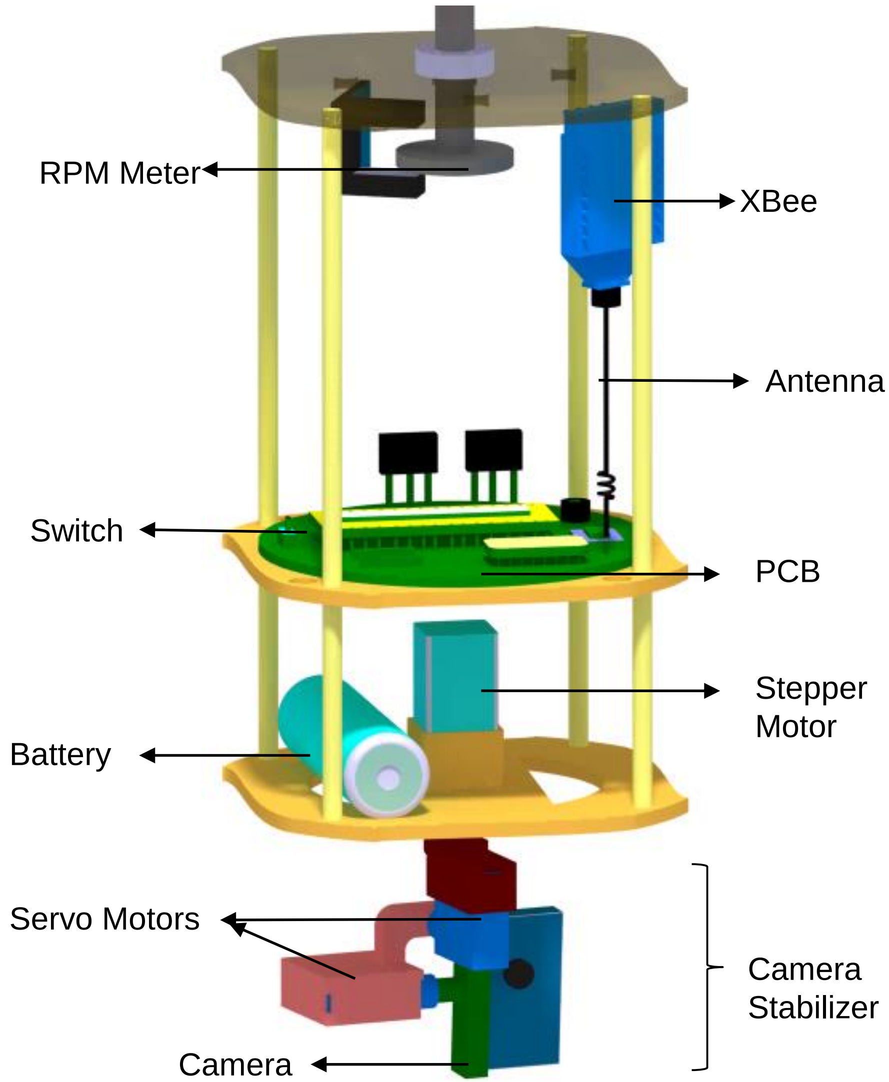
- It is decided that the all system will occupy as little volume as possible.
- Joint sections of the payload are designed to perform high burst strength against impacts.
- To protect the camera stabilizer from any damage, a transparent plexiglass structure will be used.
- The center of mass is positioned below the both pressure and aerodynamic center to prevent tumbling.
- After deployment, rotor blades maintain their positions by latexes (bendable plastic).
- Latexes and hinges will be securely integrated from the fixed ends.
- Easy access to electronic components.
- Purpose is to make a production according to the requirements and design the individual parts to perform related tasks with suitable materials.



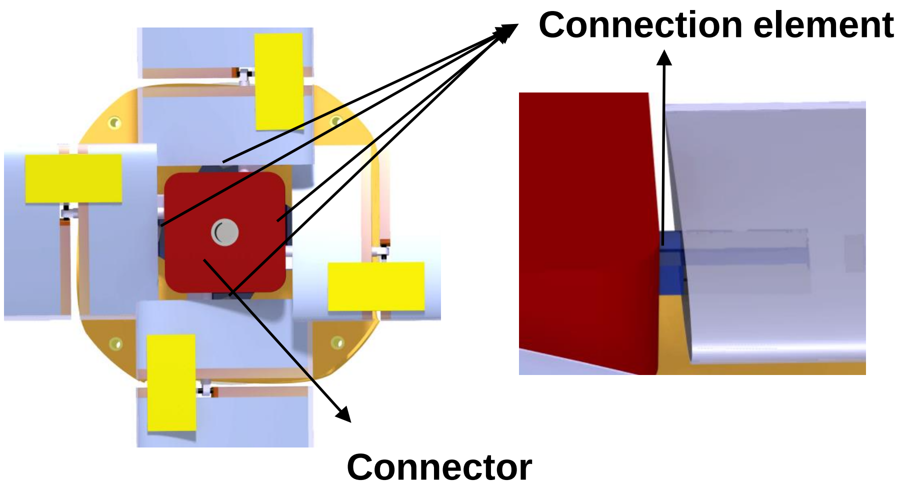
Payload Mechanical Layout of Components Trade & Selection (5/10)

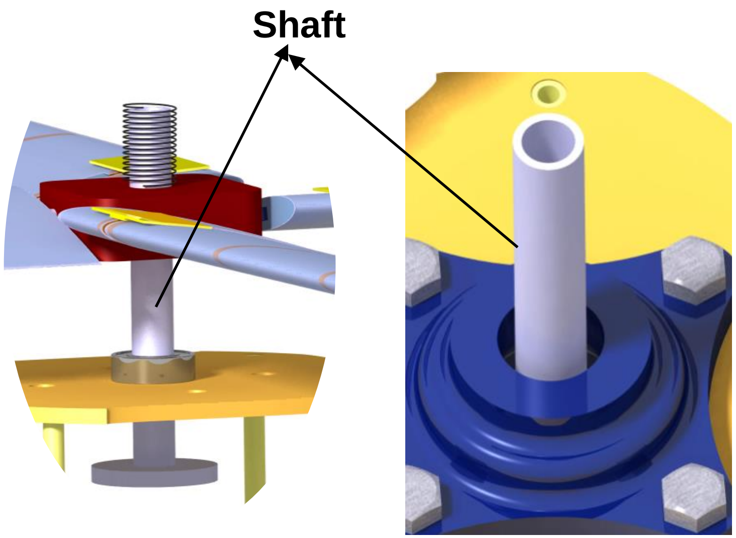
Electronic Components

- The PCB is placed in the middle of payload and fixed to the payload plate.
- The battery is placed on the lower layer.
- Camera Stabilizer Mechanism is located at the bottom of payload.
- There are 2 servo motors and a stepper motor to provide 3-axis motion to the Camera Stabilizer.
- The camera is properly positioned to perform the bonus mission.
- XBee with antenna is attached to one of the rods.
- RPM meter is placed on the ceiling of the payload.



Auto-Gyro Attachment Points

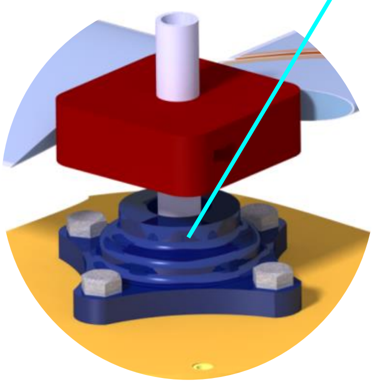


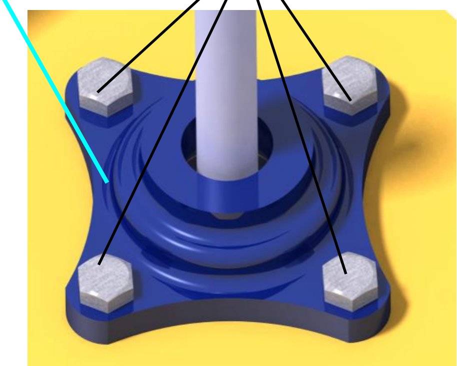


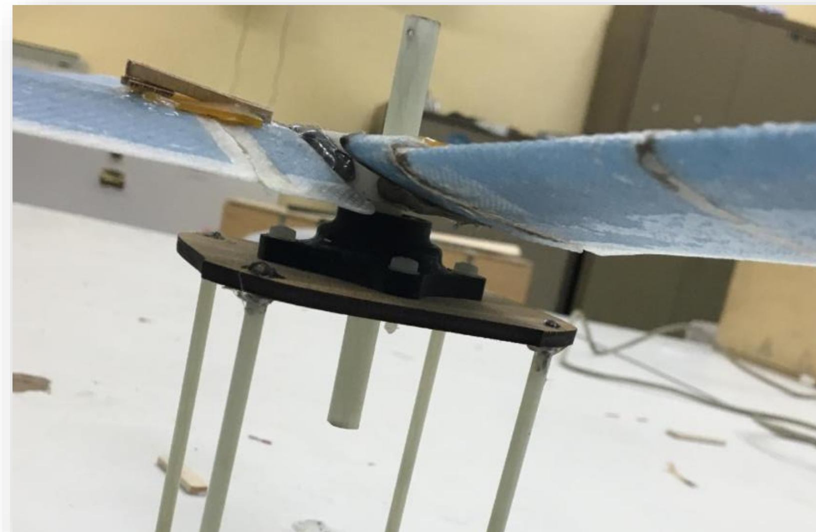
- Connector keeps 4 blades together by connection element with appropriate angle of attack.
- A shaft, which is mounted to a bearing and getting through to payload from connector, holds system together.

Auto-Gyro Attachment Points

Fixing Element **Bolts**

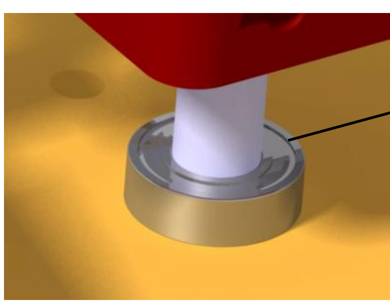






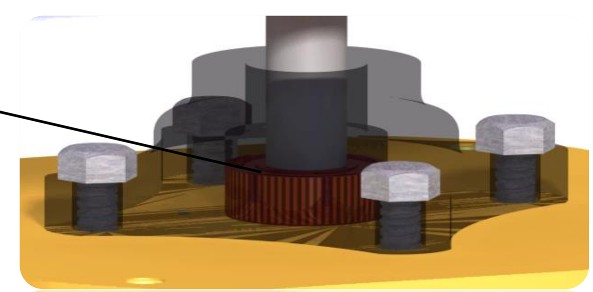
All Attachment Points

- A fixing element is used for the integration of bearing and it is mounted by 4 bolts.

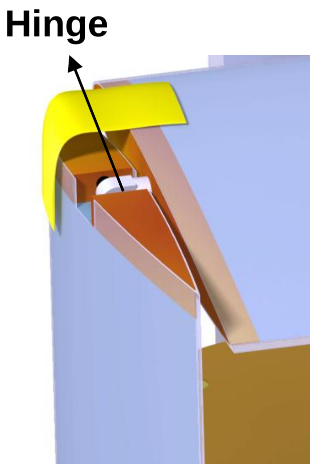


Bearing

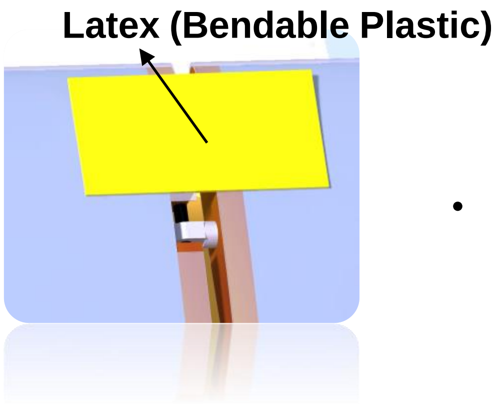
- The effect of shaft moment created by the autogyro is minimized by connecting the shaft to the bearing.



Major Mechanical Parts

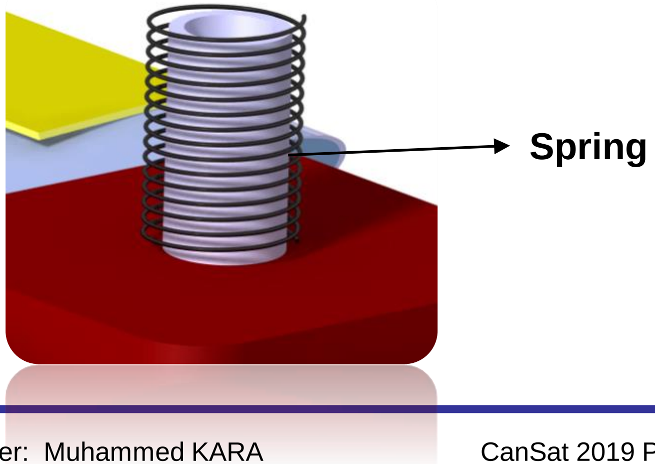


Folded Blade



Open Blade

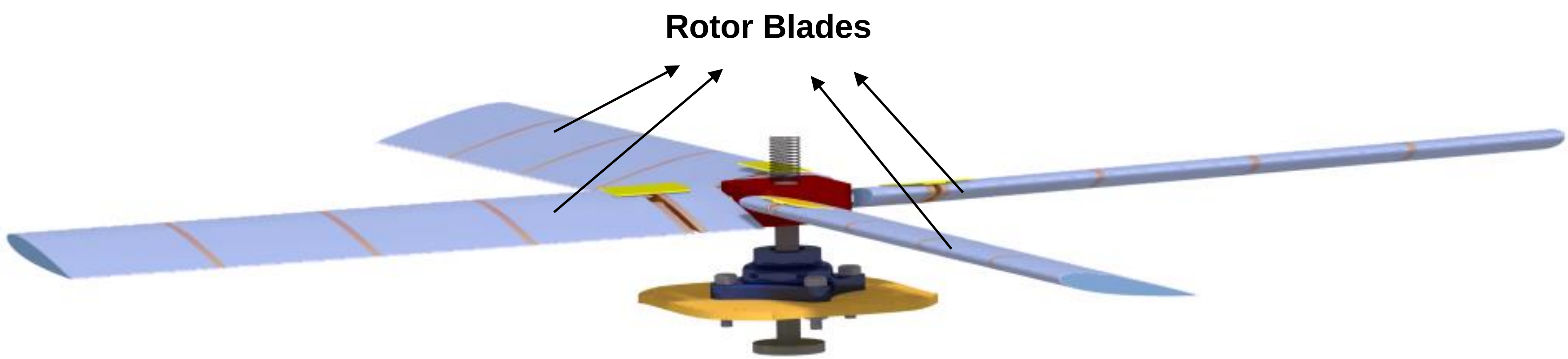
- Hinges and latexes are used for deployment of Auto-gyro Mechanism.

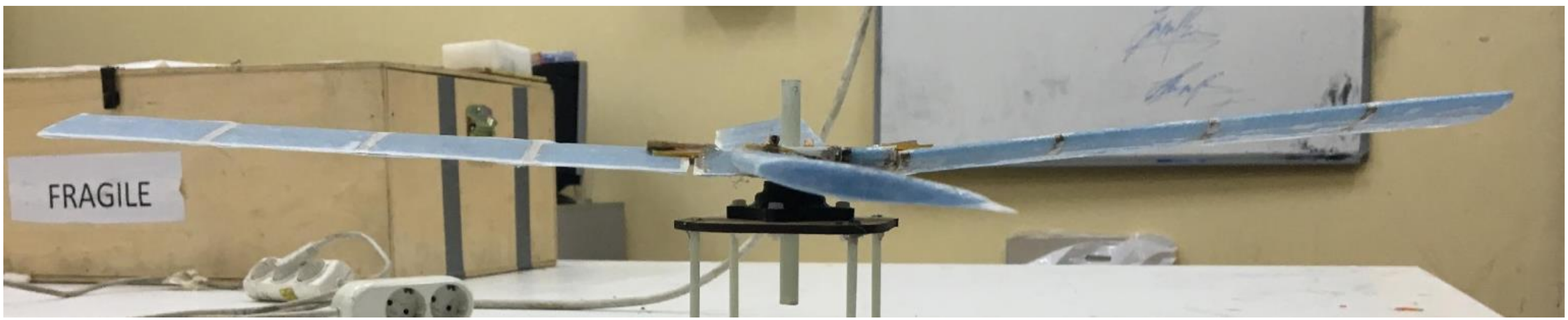


- There is a spring, coincident with an axis of the shaft, on the payload to push the payload downwards.

Payload Mechanical Layout of Components Trade & Selection (9/10)

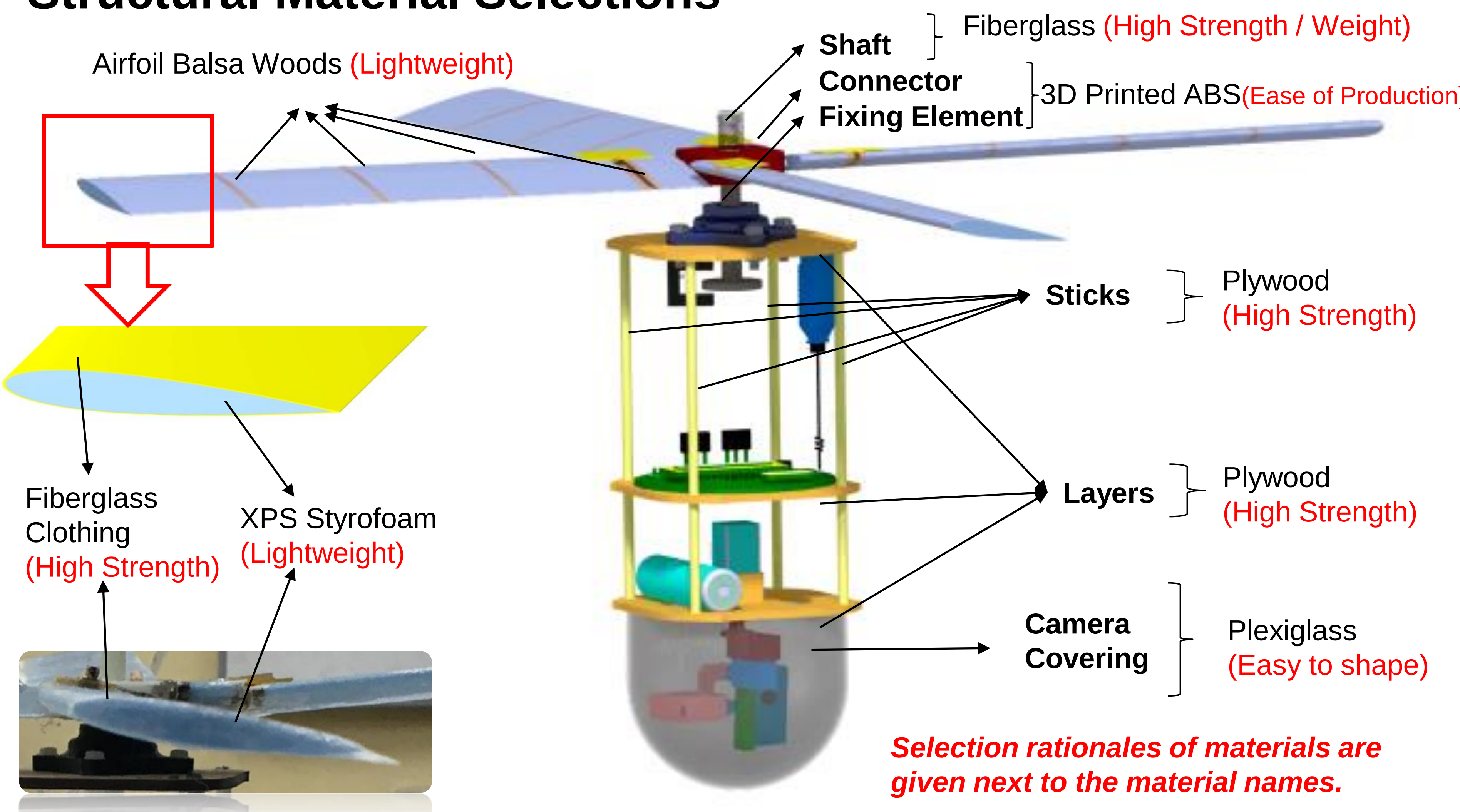
Major Mechanical Parts





- Auto-gyro mechanism exists on the payload to provide required lift and drag. (BR-10)

Structural Material Selections

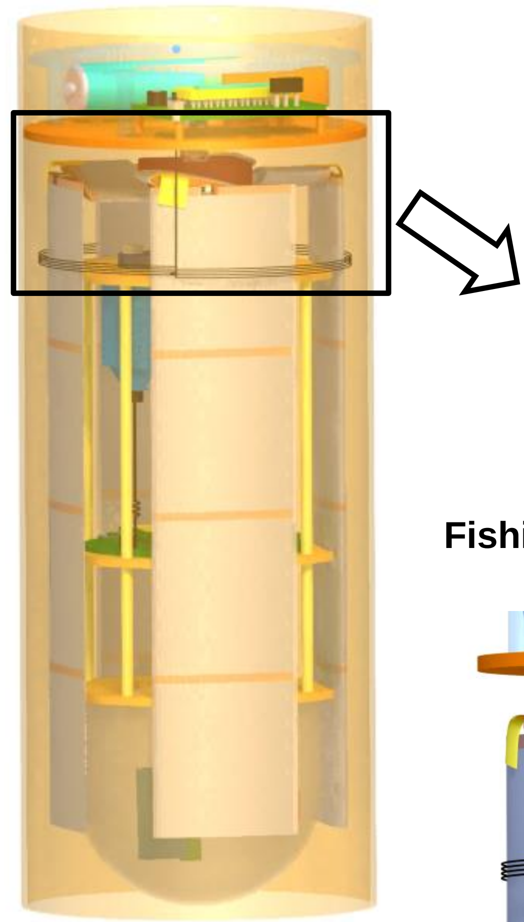


Selection rationales of materials are given next to the material names.

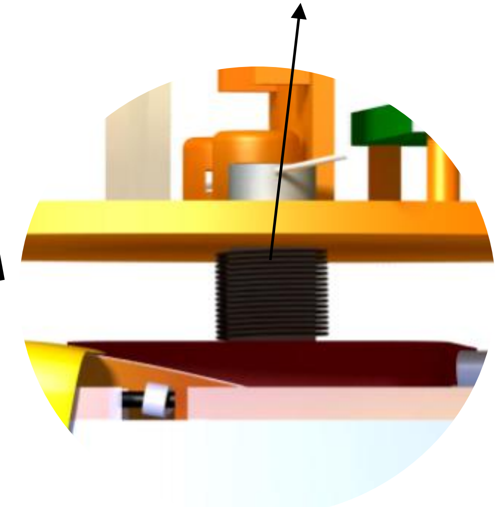
Payload Pre Deployment Configuration Trade & Selection (1/3)

Strategy 1: Fishing Line

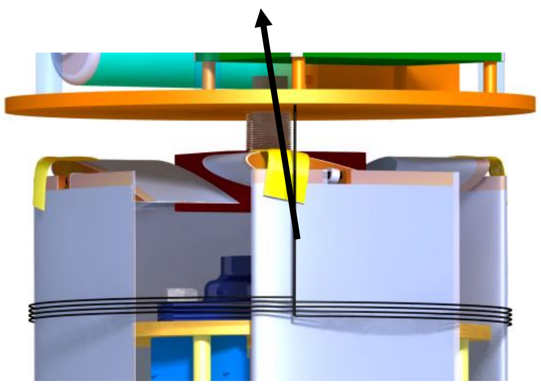
- Blades are folded by hand force and kept folded by fishing line 2 cm away from initial position using hinges and latexes.
- Since blades have angle of attack, they can not be folded properly. However, by using a hinge with 2 axis, this problem is solved.
- A fishing line which is only used for stowing, attached to container intermediate layer to hold rotor blades folded.
- Spring applies force to payload while payload is releasing. As a result, payload leaves fishing line and container.
- Latexes force to revert blades to deployed position and blades are opened after payload is released from container.
- System is reliable.



Compressed Spring

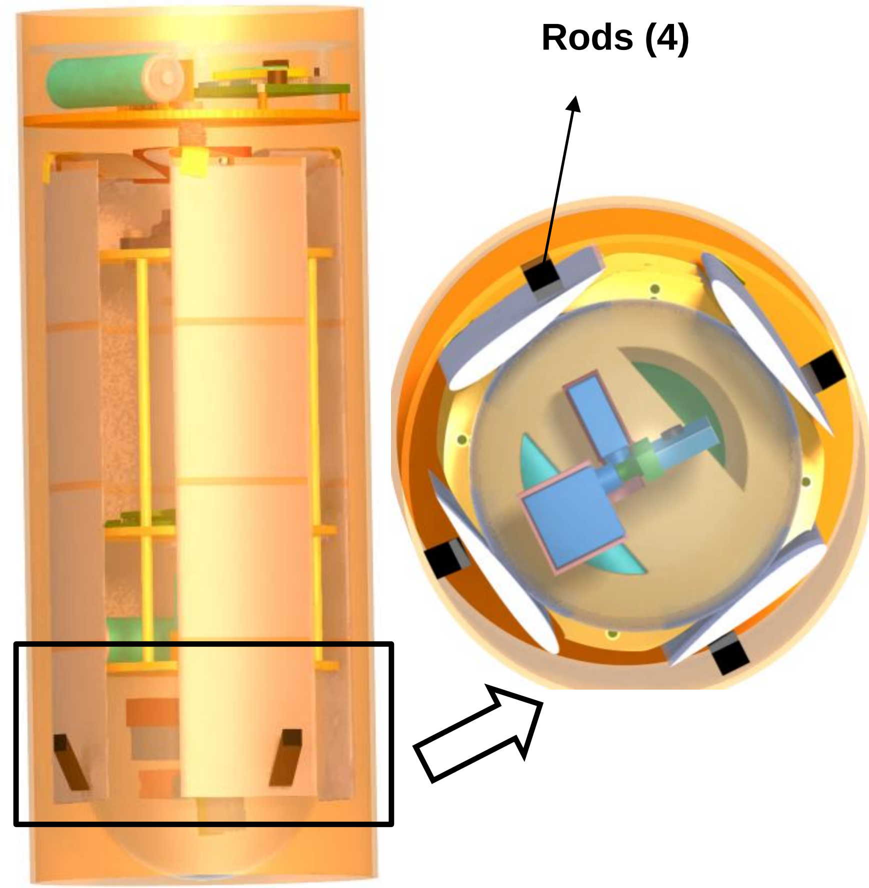


Fishing Line Connected to Layer



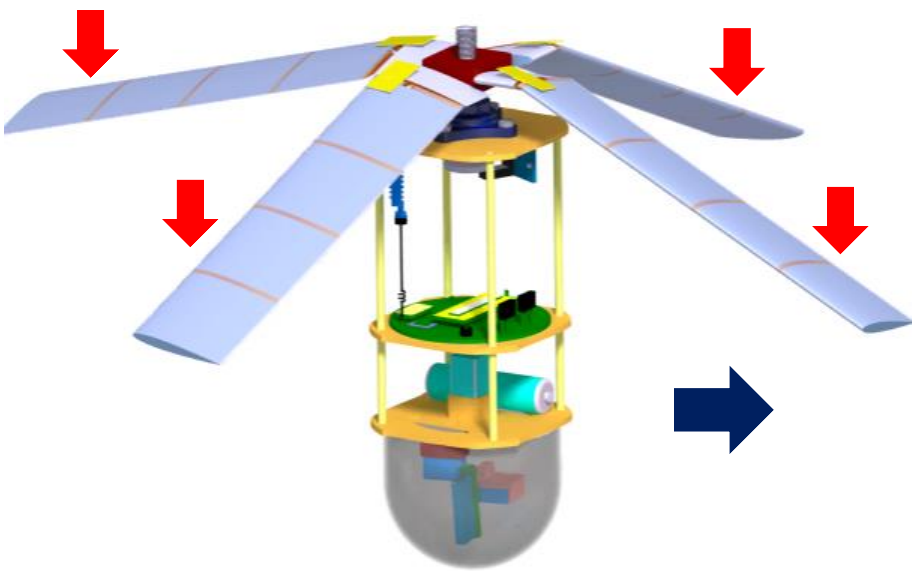
Strategy 2: Rods

- Rotor blades are folded by hand force and kept folded by rods.
- Blades are held together by rods.
- After separation occurs, rods do not apply force to blades and blades will be ready to open.
- Keeping system together by the rods increase pressure on container walls. This may cause Cansat to stuck in the rocket.
- This system requires extra mass.
- Rods may fail during the deployment and blades may open earlier, so this causes fails.

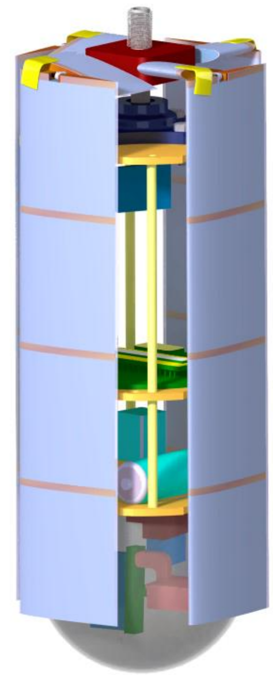


Selected Strategy	Rationale
Strategy 1	▪ Requires low mass. ▪ It is easy to realize. ▪ Rods can be broken because of impact force occurred while deploying from the rocket. ▪ Configuration with fishing line is more reliable against stuck.

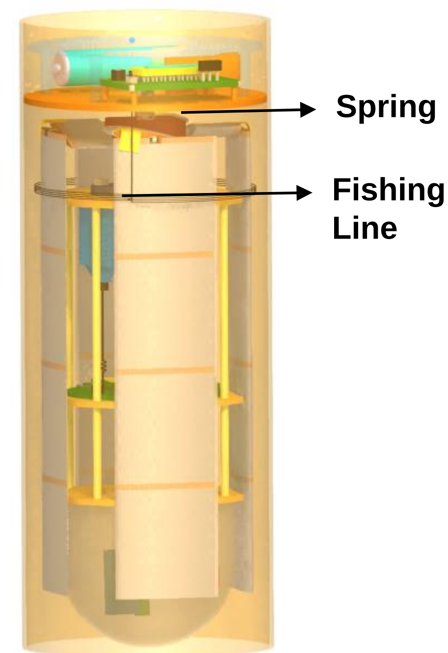
Payload Pre Deployment Configuration Trade & Selection (3/3)



- Folded by hand force.



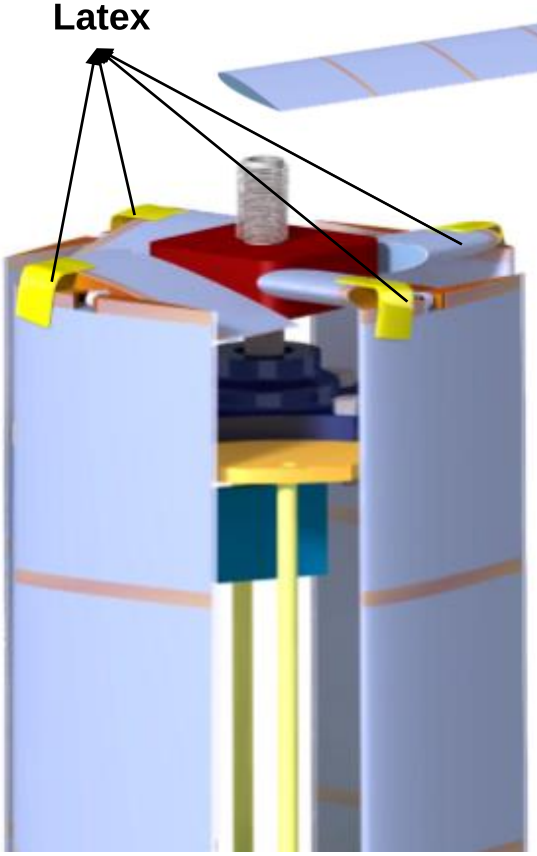
- After folding, integration is carried out.

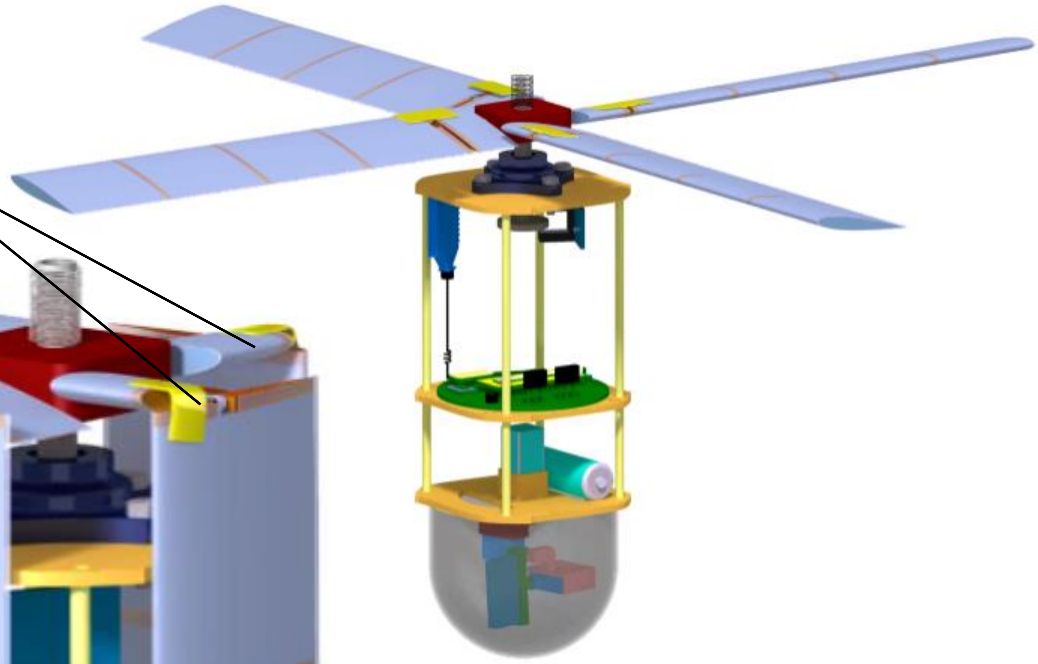


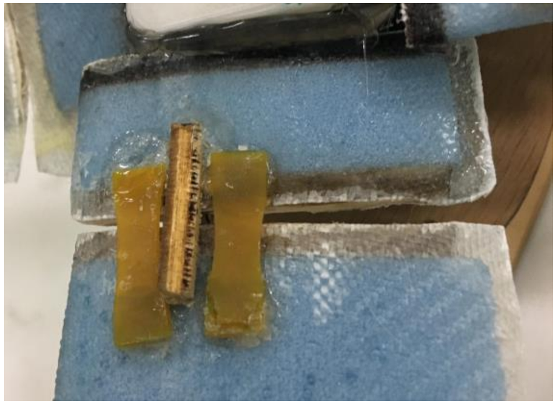
- Stowed in container. Fishing line in the release mechanism keeps payload and container together. Other fishing line is wrapped around the folded blades. A compressed spring eases the deployment.

Configuration 1: Latex

- Rotor blades are held by latexes.
- Container keeps blades closed.
- Latexes produce a torque around the hinge axis to make blades position same with initial position.
- After releasing, deployment carries out.
- More reliable.
- Easy to manufacture.



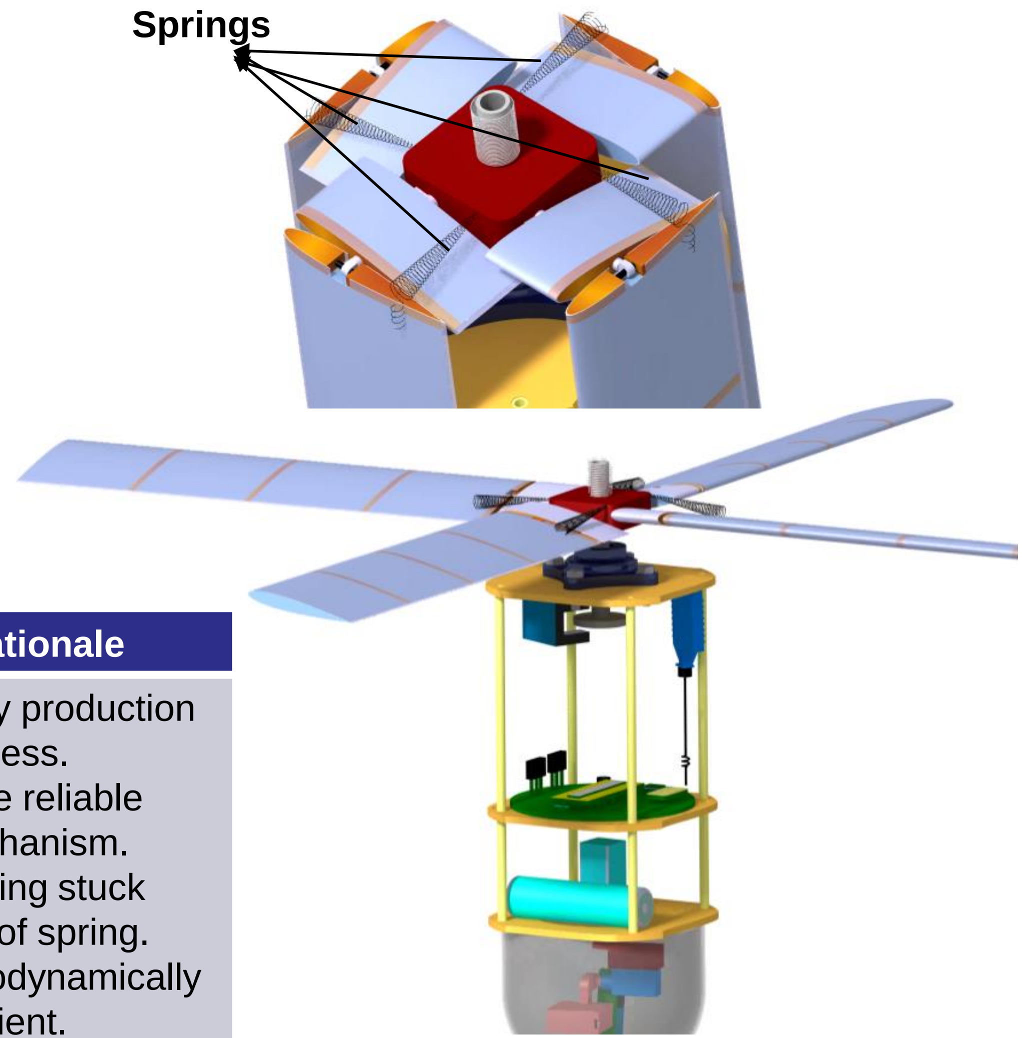




Payload Deployment Configuration Trade & Selection (2/4)

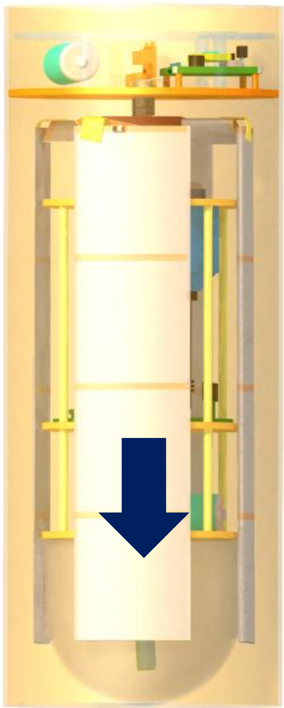
Configuration 2: Spring

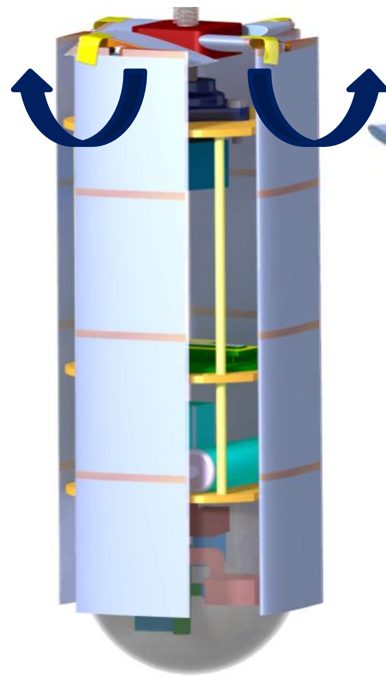
- Blades are kept closed by spring.
- Springs provide to blades turn and open.
- When payload exit from container, mechanism starts to work.
- Springs can cause vibrations during flight.
- Low endurance against instant force caused by unfolding.
- Springs can be stucked.

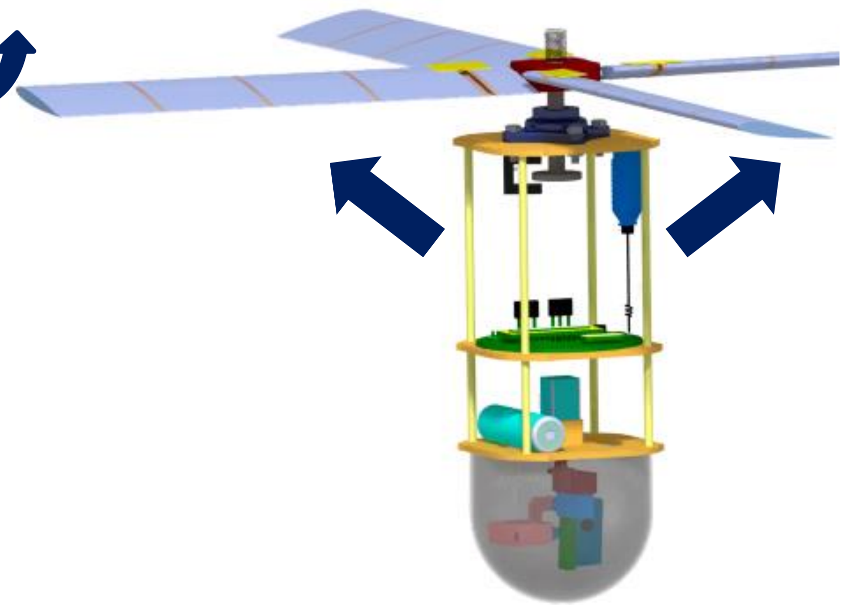


Configuration Selection	Rationale
Configuration 1	▪ Easy production process. ▪ More reliable mechanism. ▪ Getting stuck risk of spring. ▪ Aerodynamically efficient.

Payload Deployment Configuration Trade & Selection (3/4)



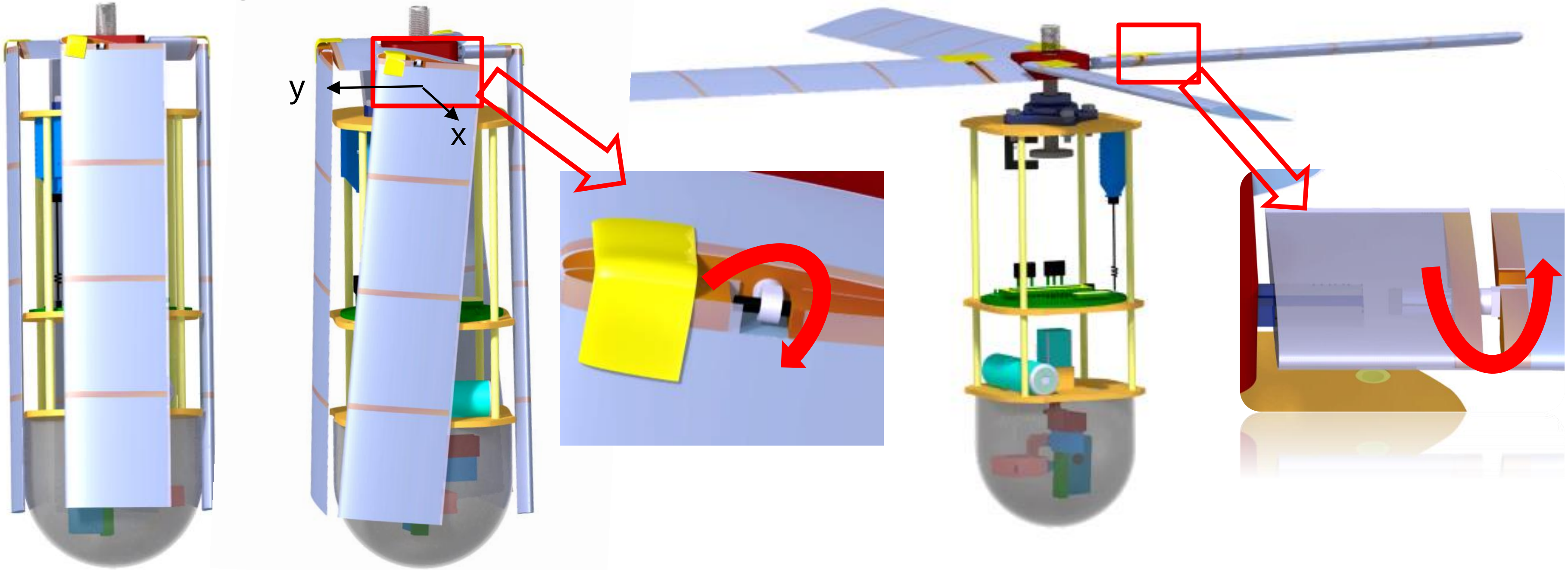




- There are latexes, pulling blades to open, on folded and not folded parts of blades.
- When payload is released, mechanism starts to work applying tensile force.
- After exit from container, blades are deployed.

Payload Deployment Configuration Trade & Selection (4/4)

How Does Hinge Works in 2 Axis:



A

- Configuration of payload looks like figure A, just after payload separates from container.

B

- After deployment, folded part of blade is positioned like figure B because of the angle of attack. Hinge turns around x axis for a few degrees.

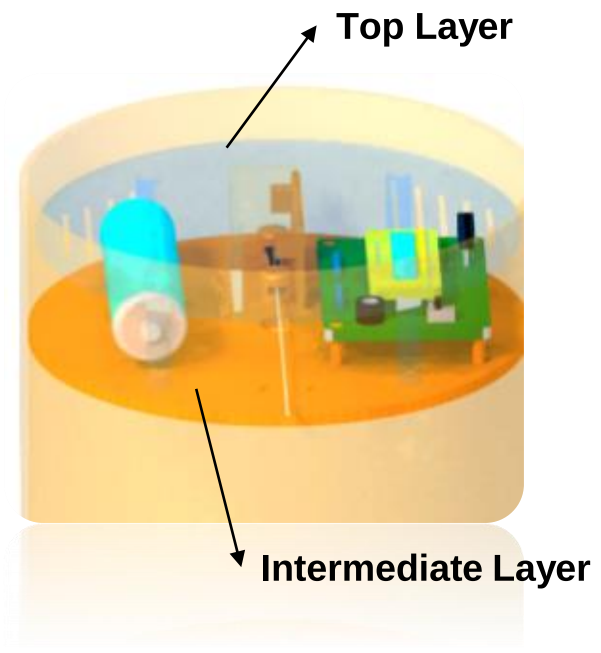
C

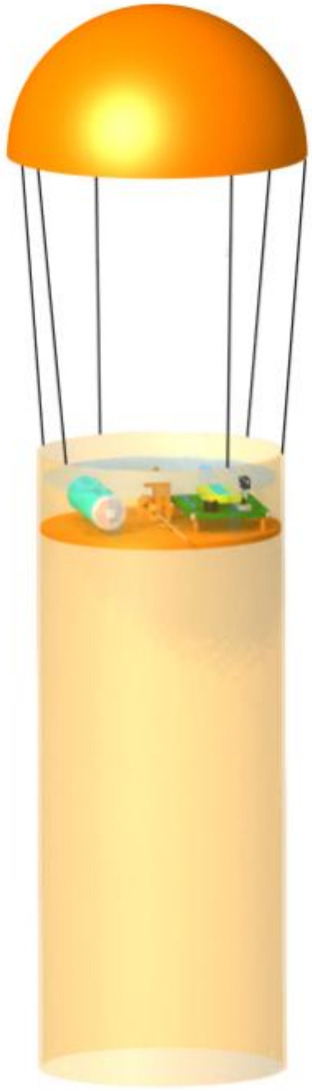
- Just after turning around x axis, blades get their right positions for descending by rotating around y axis. (Figure C)

Container Mechanical Layout of Components Trade & Selection (1/5)

Design 1

- Cylindrical shape prevents payload to stuck inside the rocket.
- Bottom of container is designed to be as big volume as possible.
- There is a top layer separating parachute from electronic parts.
- An intermediate layer separates payload volume from container electronics.
- There are electronics and payload release mechanism between 2 layers to prevent separation faults.
- There is a nichrome wire, the most important element of separation, in release mechanism.
- There are holes on the container to allow passage of fishing line, which keeps payload and container together.
- Margins are considered to prevent deployment failures.
- It can be produced by fiberglass as a single part which has high strength.
- Having less parts than design 2, provides higher durability.

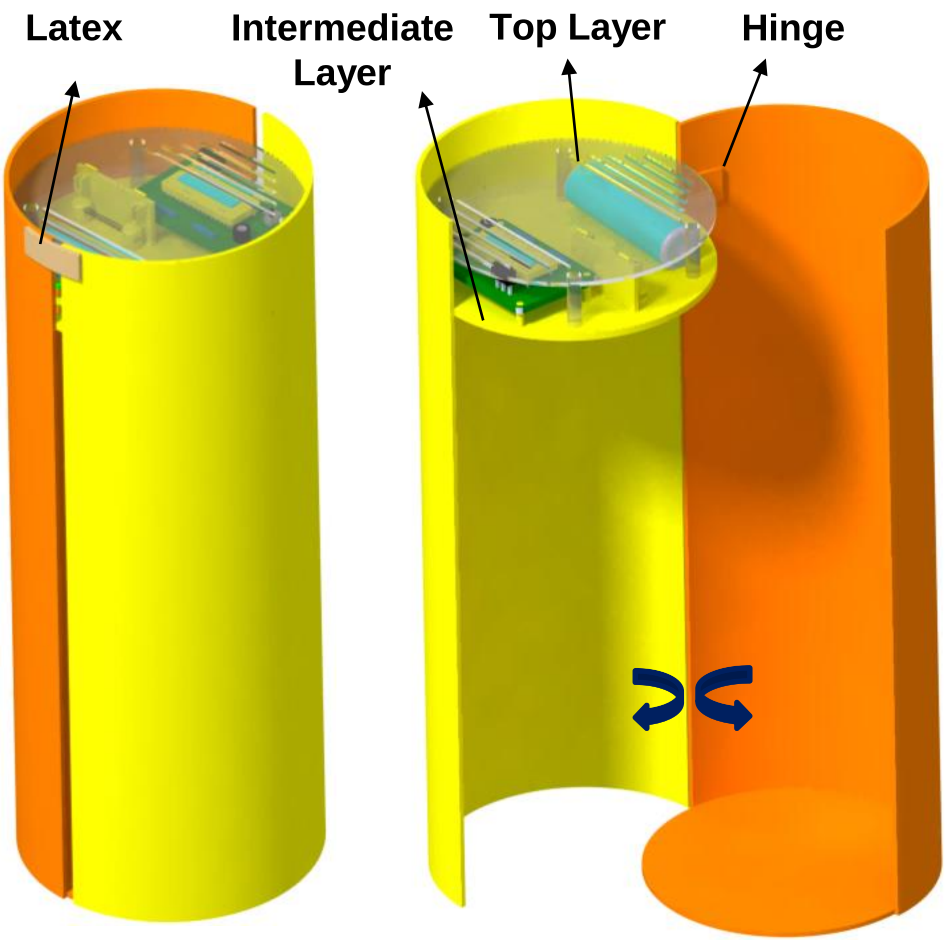




Container Mechanical Layout of Components Trade & Selection (2/5)

Design 2

- Container has also cylindrical shape to prevent possible stucks.
- Required volume for stowed payload is allocated.
- Electronics and 2 layers are at the same place with configuration 1. But another layer is at the bottom of container to keep payload closed in container.
- Bottom of container is designed to be opening 2 parts which are integrated each other by a hinge.
- These parts can be linked each other by rope or fishing line.
- Thanks to opening parts, it has easy access to payload.
- After releasing the payload, container can lose its stability because of non-aerodynamic shape. (The case of container with open lids)
- When lids are opening, blades also deploy. So, they might be stucked each other.
- It is difficult to manufacture because of not being a single part. (which also means high cost).



Container Mechanical Layout of Components Trade & Selection (3/5)

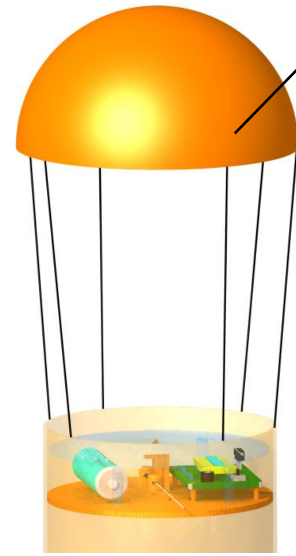
	Design 1	Design 2
Durability	High	Low
Weight	Medium	High
Cost	Low	Medium
Strength	High	Medium
Stability	High	Low
Aerodynamically Design	High	Low

Selected Design	Rationales
Design 1	▪ Easy to manufacture. ▪ Better durability. ▪ More efficient aerodynamically. ▪ Less cost. ▪ More reliable.

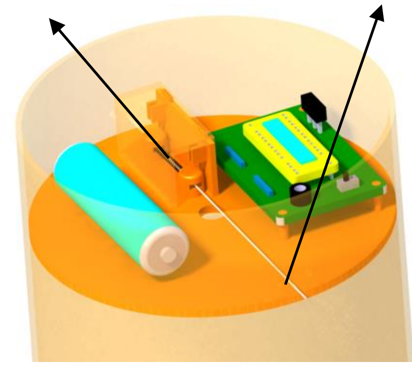
Container Mechanical Layout of Components Trade & Selection (4/5)

Major Mechanical Parts

- Container structure is used to keep payload closed inside itself and container descends together with payload until 450m.



- Parachute mechanism provides passive descent. When CanSat is deployed, parachute opens freely to limit container’s velocity.



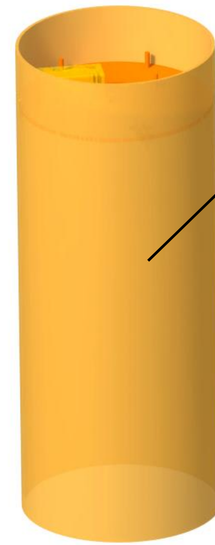
- Nichrome wire mechanism is used to separate the payload from container by melting the fishing line, via heat, which keeps system together till release.

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

Structural Material Selections

Top Layer — Balsa Wood

Intermediate Layer — Plywood

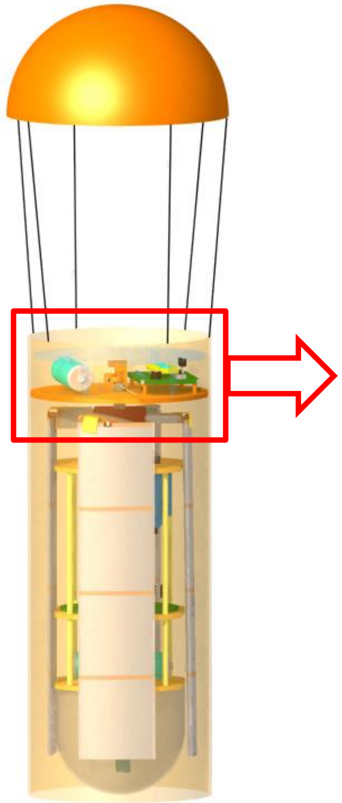


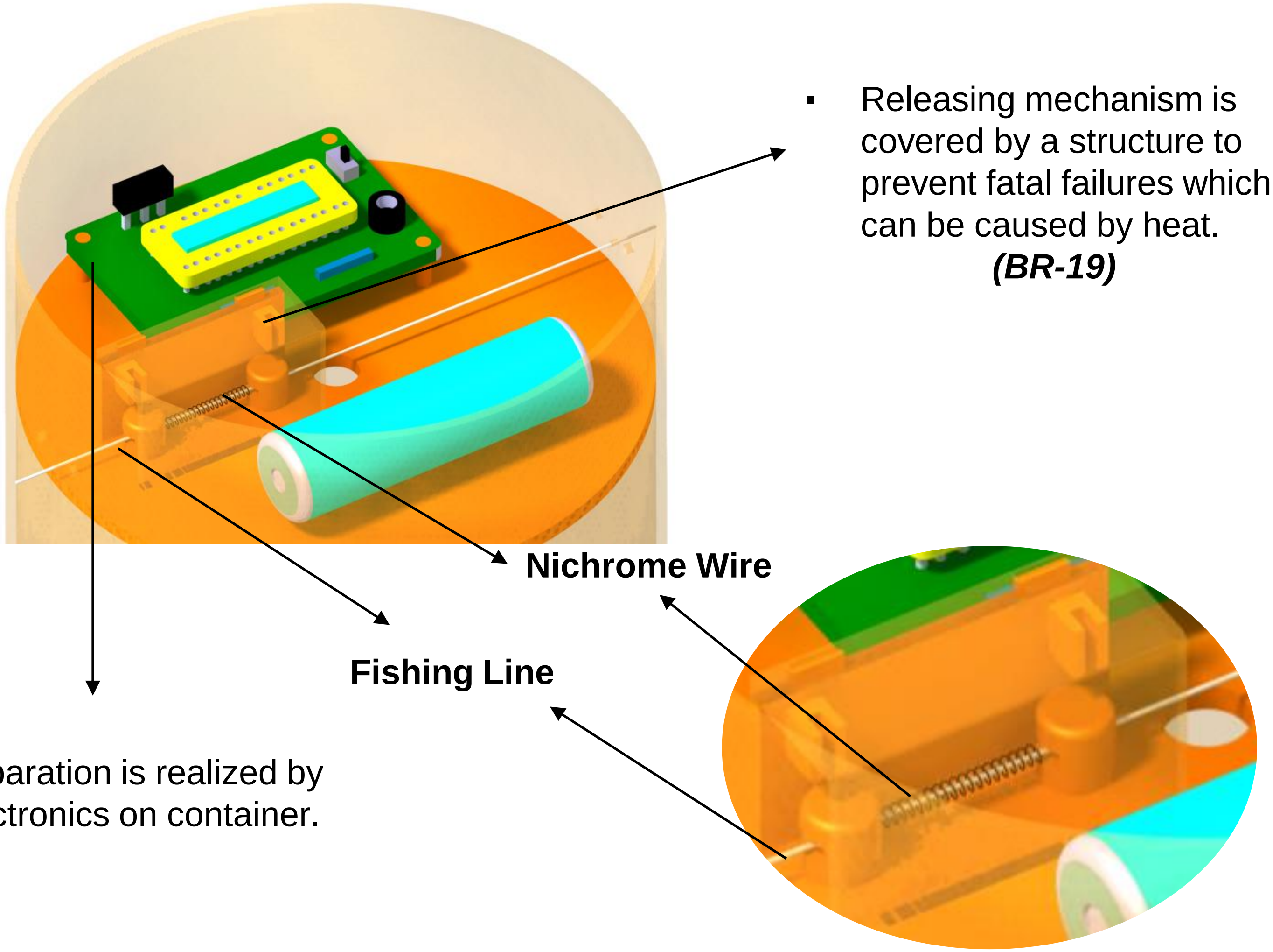
Container Main Body — Fiberglass

Material Selection Rationales

Fiberglass is selected for container body because of its high strength/weight ratio.
Plywood is used because of its high strength.
Balsa is used because of its lightweight.

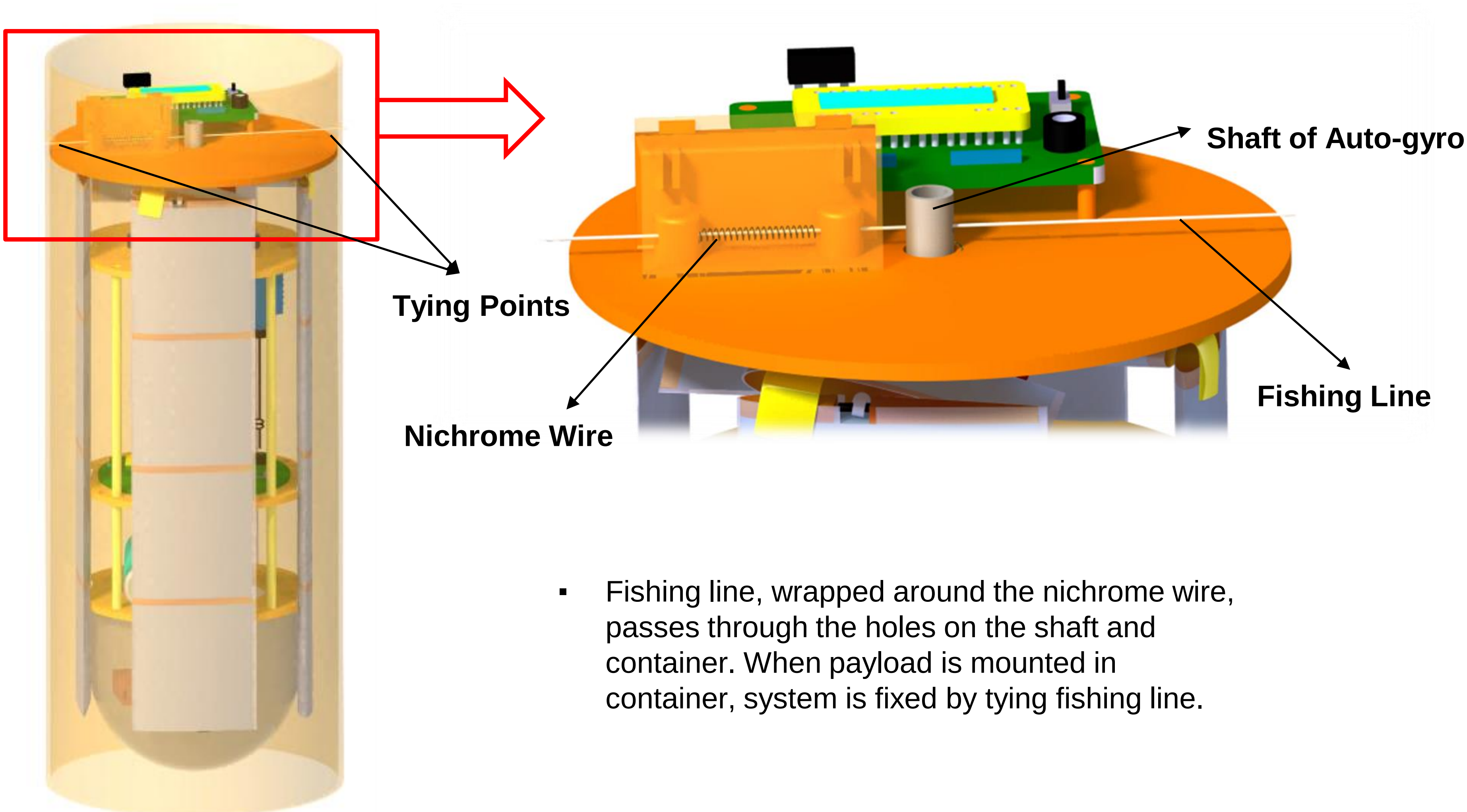
Payload Release Mechanism (1/3)





- Releasing mechanism is covered by a structure to prevent fatal failures which can be caused by heat. ***(BR-19)***

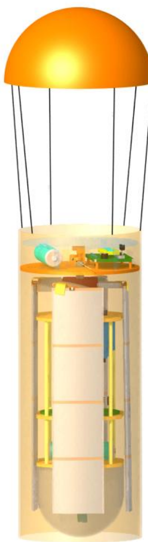
- Separation is realized by electronics on container.



- Fishing line, wrapped around the nichrome wire, passes through the holes on the shaft and container. When payload is mounted in container, system is fixed by tying fishing line.

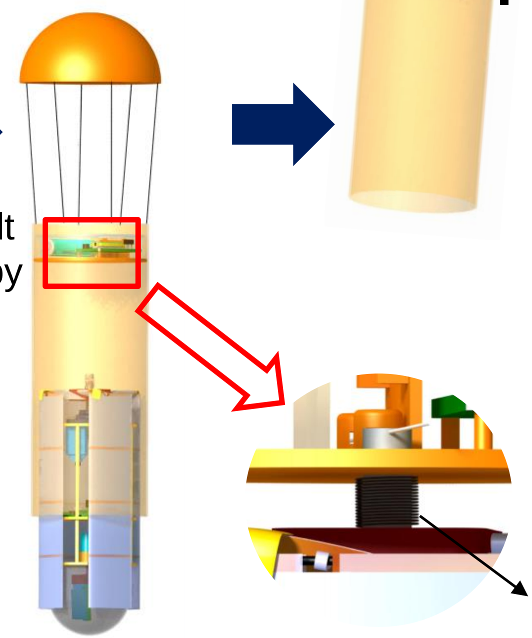
Payload Release Mechanism (3/3)

1

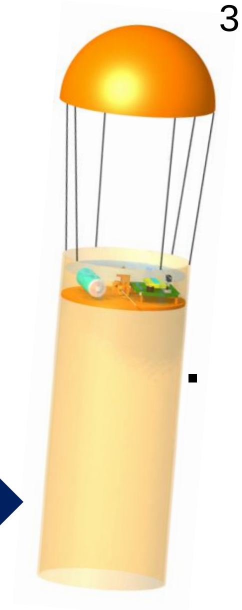


- The fishing line is melt with heat generated by nichrome wire for autonomous separation at 450 meters.

2

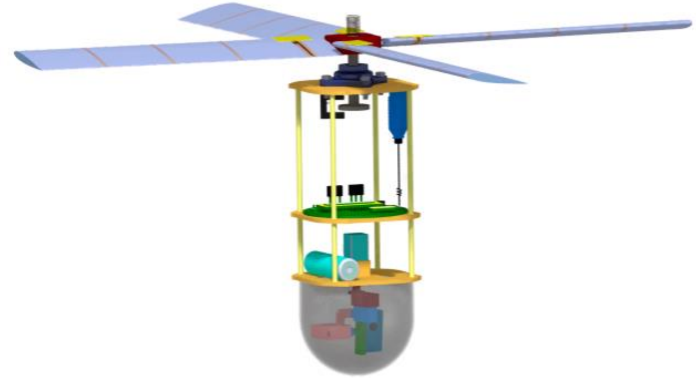


3



- Container continues to descend passively.

4

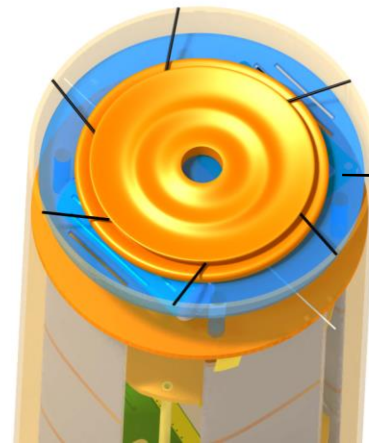


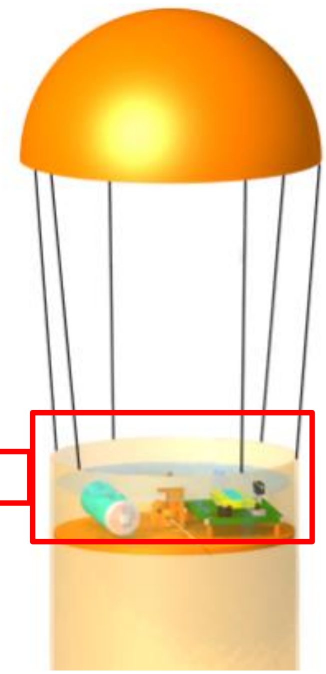
- Payload starts to descend with auto-gyro mechanism.

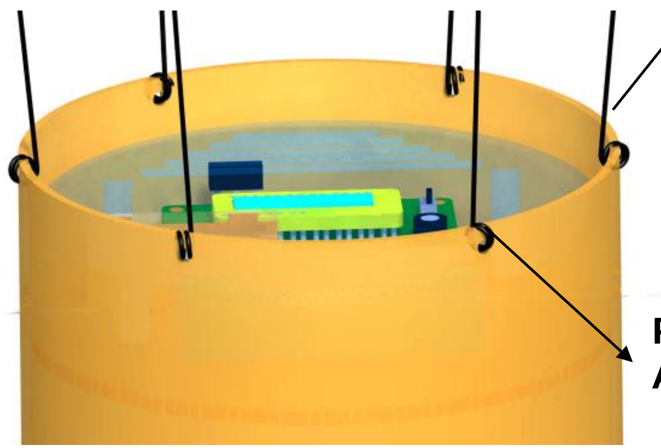
- The payload is released and separation carries out.
- The spring facilitates separation by releasing spring potential energy.

Container Parachute Release Mechanism (1/2)

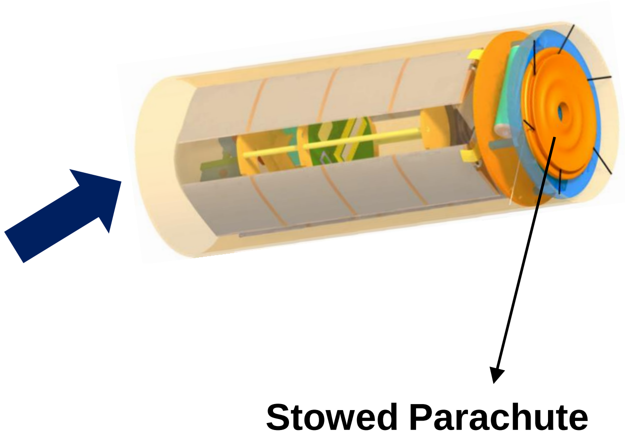
- A passive landing control system which is parachute will be assembled to container.
- Parachute ropes attached to the container's holes will be knotted.
- The parachute is located on the top of the container and stowed freely.
- When CanSat deploys from rocket, stowed parachute is freed to open.
- The parachute moves directly upward and opens immediately due to air filling inside of the parachute.

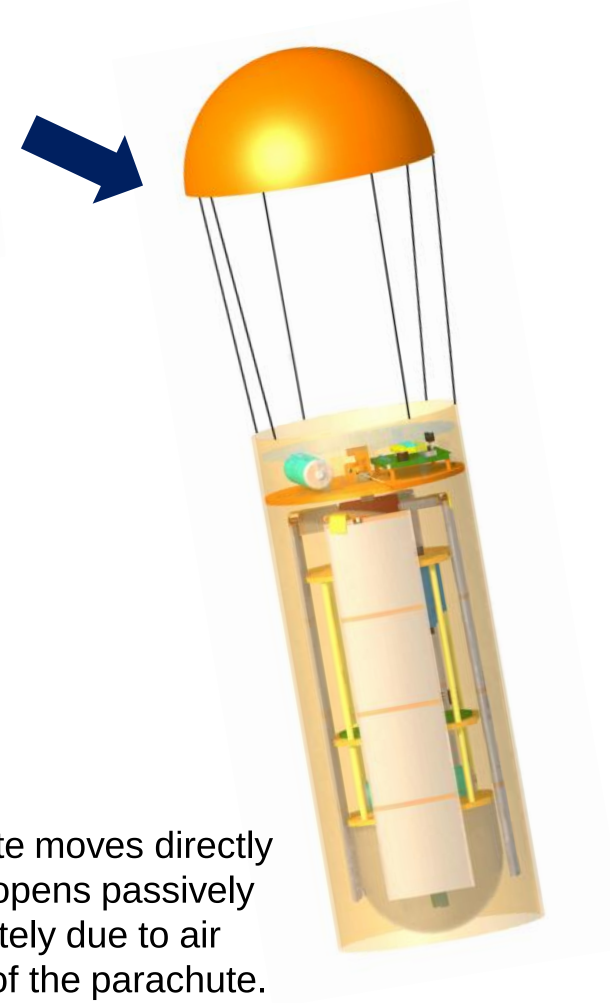






Container Parachute Release Mechanism (2/2)





- The parachute moves directly upward and opens passively and immediately due to air filling inside of the parachute.

Mounting methods

- PCB is to have fit in payload with a diameter of 80 mm.
- PCB is to be mounted with silicone on the layer.
- A plexiglass structure is planned to cover the Camera Stabilizer Mechanism from environment.
- A stepper motor and 2 servo motors are integrated with each other modularly.
- Pin connections are mounted by silicone.
- Stepper motor holder with 16 mm x 16 mm dimensions are designed for stepper motor.
- Rods are glued by epoxy to plywood layers.

Enclosures

- Nichrome wire is enclosed by a 3D printed ABS structure.
- To access to PCB easily, only 3 sides of the payload will be enclosed by duct-tape. Just before the launch, non covered parts will be enclosed.
- Electronic components in the payload are enclosed with duct-tape that will be the cover.

Electronics Structural Integrity (2/2)

Securing Electrical Connections

- Depending on the connection components, proper methods for securing will be used.
- Electrical connection methods are:
  - ➢ Soldering
  - ➢ Specific adhesives for electronics
  - ➢ Electric tape
  - ➢ Polyolefin Tubing
  - ➢ Silicone

Descent Control Attachments

- Auto-gyro mechanism will be attached to payload by the shaft, connector, and fixing element.
- Folded parts of rotor blades are connected to not folded parts of rotor blades by hinges and latexes.
- Blades are attached to connector by connection parts.
- Shaft is glued to connector and bearing.
- Bearing is attached to payload by fixing element which is bolted to layer.
- Parachute will be attached to container by cotton line ropes.
- Parachute connections will be secured by knots and epoxy to holes on the top layer of container.

Mass Budget (1/3)

Payload	Mass(g)	Data Type	Margins (g)
Structure of Payload	55.5	M	-
Servo x2	12	D	-
Stepper Motor	27	D	-
Rotor Blades x4	60	M	-
Auto-Gyro Connection Parts	7	M	-
Shaft and Connector	10	M	-
Spring	6	M	-
Plexiglass Covering Structure	20.3	M	-
Camera Stabilizer Connection Parts	5	M	-
PCB	30	E	6
Battery	68.2	D	-
Bearing	17	M	-
Camera	5	D	-
Electronic Sensors	25	D	-
XBee and XBee Module	5	D	-
Antenna	14	E	2.8
Adhesives	4.5	E	0.9

Total Mass of Payload (g)
371.5 ± (9.7) g

Error margin for estimated data is selected as %20.

Acronyms:
E: Estimated
D: Data Sheet
M: Measured

Mass Budget (2/3)

Container	Mass(g)	Data Type	Margins (g)
Structure of Container	62	M	-
Parachute and Ropes	10	M	-
Layer Balsa	5	E	1
Layer Plywood	12.5	E	2,5
Fishing Line	1	E	0,2
Nichrome Wire	1	E	0,2
PCB + Sensors	20	E	4
Battery	18.5	D	-

Total Mass of Container (g)
130 ± (7.9) g

Error margin for estimated data is selected as %20.

Acronyms:
E: Estimated
D: Data Sheet
M: Measured

Mass Budget (3/3)

Total Mass of CanSat (g)
501.5 g

- **Total Mass Margin of CanSat= $|500 - 501.5| = 1.5$ g**

Correction Methods

Two containers which have different wall thicknesses will be manufactured before the flight to USA.

In case total mass measured at launch site is different than expected, following processes are to be done.

If mass of CanSat <490g, container with thicker wall(140 g) is to be used.

If mass of CanSat >510g, container with thinner wall(118 g) is to be used.

Communication and Data Handling (CDH) Subsystem Design

Elif ACAR

Payload CDH Overview

Teensy 3.5: *A processor* is used to obtain and process data from the sensors. *The real time clock* data is obtained by **Teensy 3.5 Oscillator**.

TL-ANT2405CL: *An antenna* is used to strengthen the transmitted signals from payload to the ground station.

Sandisk Ultra 16GB: *A memory card* is used to record data from the sensors that are obtained by the processor.

XBee PRO S2C: *A transceiver* is used to transmit and receive data between the payload and the ground station.

Payload CDH Requirements (1/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
CDH-1	The science payload shall measure altitude using an air pressure sensor.	CReq	BR - 20	SS-6 FSW-1	Very High	✓		✓	
CDH-2	The science payload shall provide position using GPS.	CReq	BR - 21	SS-7 FSW-2	Very High	✓		✓	
CDH-3	The science payload shall measure its battery voltage.	CReq	BR - 22	SS-8 FSW-3	Very High	✓		✓	
CDH-4	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.	CReq	BR - 42	FSW-13	Very High	✓		✓	✓
CDH-5	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.	CReq	BR - 24	SS-10 FSW-5	Very High	✓		✓	
CDH-6	The science payload shall measure pitch and roll.	CReq	BR - 25	SS-11 FSW-6	Very High	✓		✓	
CDH-7	The science payload shall transmit all sensor data in the telemetry.	CReq	BR - 26	FSW-7	Very High	✓		✓	

Payload CDH Requirements (2/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
CDH-8	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.	CReq	BR - 28	FSW-8	Very High	✓		✓	
CDH-9	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.	CReq	BR - 30	FSW-9	Very High	✓		✓	
CDH-10	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	CReq	BR - 31		Very High		✓		
CDH-11	XBEE radios shall have their NETID/PANID set to their team number.	CReq	BR - 32		Very High	✓	✓	✓	
CDH-12	XBEE radios shall not use broadcast mode.	CReq	BR - 33		Very High	✓	✓	✓	
CDH-13	The science payload shall measure outside temperature.	CReq	BR - 23	SS-9 FSW-4	Very High	✓		✓	

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

Model	Processor Speed	Supply Voltage	I/O Pins [Number]	Interfaces [Number]	Memory	Dimensions	Boot Time	Price
Teensy 3.5	120 MHz	3.6 V - 6 V	Analog In[25] PWM [20] Digital[14]	I^2C [3] SPI [3] UART [6]	Flash - 512 KB SRAM - 256 KB EEPROM - 4KB	62.3 mm x 18.0 mm x 4.2 mm	3 s	$ 24.95
Arduino Nano	16 MHz	7 V - 12 V	Analog In[8] PWM [6] Digital[62]	I^2C [1] SPI [1] UART [1]	Flash - 32 KB SRAM - 2 KB EEPROM - 1 KB	43.18 mm × 18.54 mm x 6.1 mm	4.84 s	$ 22
ESP32	160 MHz (Dual Core)	2.7 V - 3.6 V	Analog In[18] PWM [16] Digital[32]	I^2C [2] SPI [3] UART [3]	Flash - 16 MB SRAM - 512 KB ROM - 448 KB	50.2 mm x 25.5 mm x 4.1 mm	2.85 s	$ 13.8

Selected Processor: Teensy 3.5

- High processor speed which is sufficient for managing sensor data.
- High flash memory to keep flight software.
- Number of interface connections satisfy our requirements.
- Arduino Nano offers one hardware UART interface, so it cannot satisfy required sensor connections and has insufficient flash memory to keep flight software.
- ESP32 satisfies our requirements, but area of the circuit is limited. Therefore, we selected Teensy 3.5 having on board SD Card slot.
- According to our experiences in the past, Teensy 3.5 is suitable.

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

- **The properties of Teensy 3.5 are given below:**

Operating Voltage (Logic Level)	3.3 V	**Analog Input**	25
Supply Voltage (Limits)	3.6 V - 6 V	**I^2C**	3
Number of I/O Pins	62	**SPI**	3
PWM	20	**UART**	6
Flash Memory	512 KB	**Price**	$ 24.95
Dimensions	62.3 mm x 18.0 mm x 4.2 mm	**Mass**	4.8 g
Processor Speed	120 Mhz	**Boot Time**	3 s

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

Model	Memory	Interface	Data Transfer Rate	Price
SanDisk Ultra 16GB SD Card	16 GB	SPI	80 MB/s	$ 7
Samsung 16 GB Micro SD Card	16 GB	SPI	48 MB/s	$ 7.52
Lexar 4 GB Micro SDHC Card	4 GB	SPI	9 MB/s	$ 7.99

Selected Memory: SanDisk Ultra 16 GB SD Card

- Affordable price.
- High data transfer rate.
- Samsung and SanDisk have the same memory but Samsung offers low data transfer rate.
- Lexar is a SDHC card, so it is incompatible with SD Card modules because of its dimensions.

Payload Real-Time Clock

Model	Voltage	Current	Accuracy	Reset Tolerance	Price	Hardware/ Software
Teensy 3.5 Oscillator	1.7 V - 3.6 V	500 nA	±500 ppm	In reset condition software reads the last data from the EEPROM	Free	Software
DS-1302	3.3 V	20 µA	±42 ppm	In reset condition external clock continues keeping time	$ 4.5	Hardware
DS-3231	3.3 V	200 µA	±40 ppm	In reset condition external clock continues keeping time	$ 2	Hardware

Selected RTC : Teensy 3.5 Oscillator

- Draws convenient current.
- Free of charge since it’s onboard.
- Easy to program.
- Does not add external weight and does not occupy external area since it is integrated on the Teensy 3.5.
- Offers high accuracy compared to other trades.

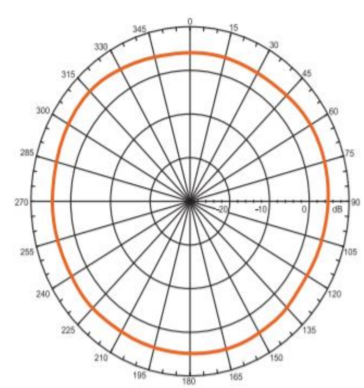
Payload Antenna Trade & Selection

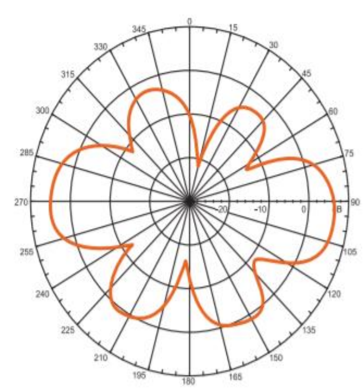
Model	Connection Type	Frequency	Direction	Gain	Beam Width Horizontal /Vertical	Price
TL-ANT2405CL	RP-SMA	2.4 GHz	Omni-directional	5 dBi	360° / 32°	$ 5
TL-ANT2408CL	RP-SMA	2.4 GHz	Omni-directional	8 dBi	360° / 15°	$ 10
Delock 12434	RP-SMA	2.4 GHz	Directional	10 dBi	90° / 60°	$ 37

Selected Antenna: TL-ANT2405CL

- Satisfies payload requirements.
- Provides sufficient gain and vertical beam width.
- TL-ANT2408CL has low vertical beam width.
- Delock 12434 is directional which is unsuitable for payload transmission as a result of very low horizontal beam width and doesn't satisfy payload requirements.
- According to our experiences in the past TL-ANT2405CL is suitable for desired communication.

Radiation Patterns of TL-ANT2405CL:

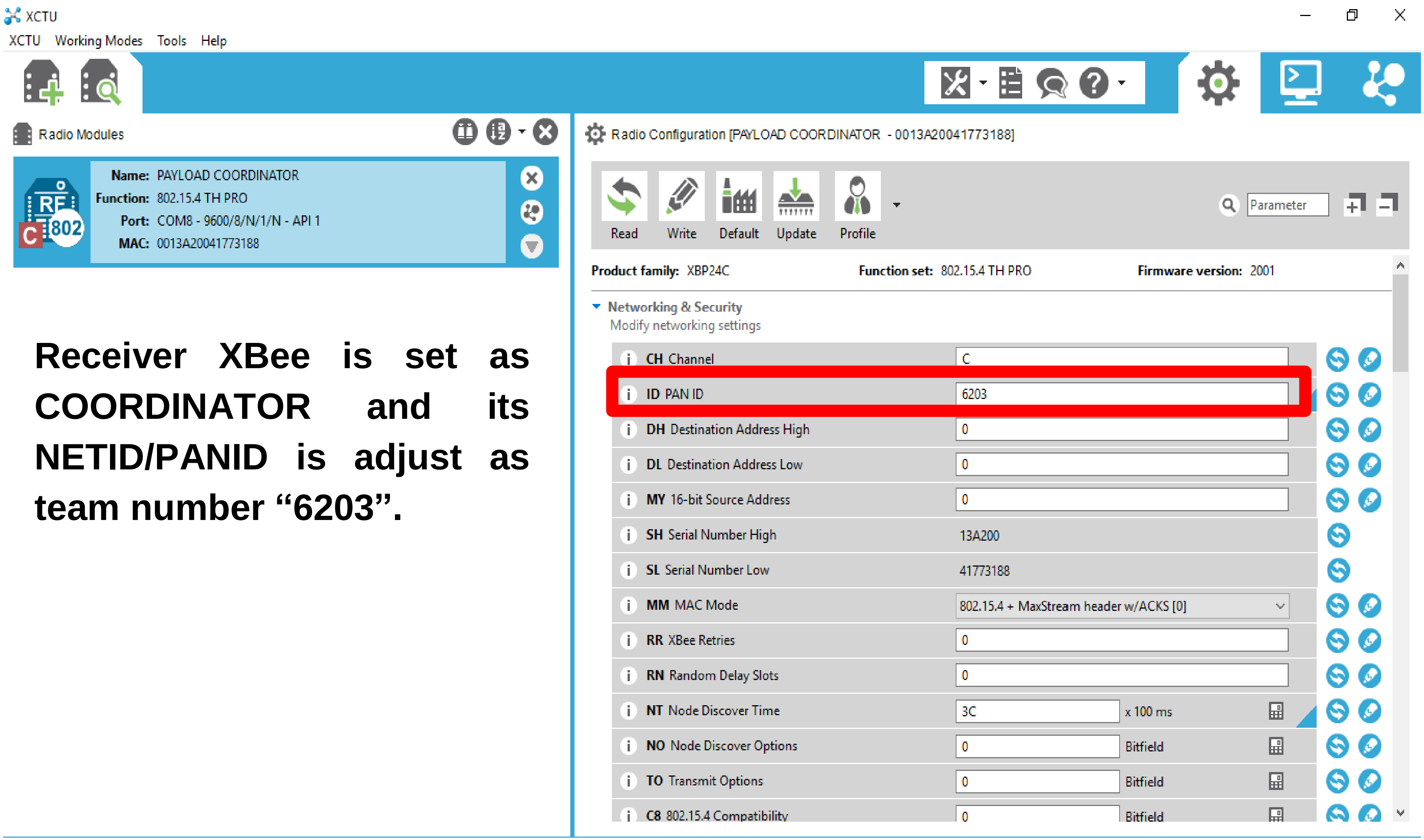




Payload Radio Configuration (1/2)

- **XBee Radio Model selection:** XBee Pro S2C has been selected and used as a transmitter for the payload and a receiver for the ground station.
- By using X-CTU software, NETID/PANID numbers of XBees are set as our given team number which is 6203 and both of the XBees are adjusted to communication with each other. *(BR-32)*
- **Transmission control:** The XBee in the payload is set as Endpoint while the XBee at the ground station is set as Coordinator. In the launchpad the Coordinator sends calibration command to the Endpoint for calibrating telemetry data. In all of the mission phases the Endpoint transmits the telemetry data to the Coordinator and the Coordinator receives the telemetry data from the Endpoint. *After landing, the flight software stops to transmit sensor data to Endpoint. As a result, telemetry transmission to Coordinator will be stopped.*
- **Data rate:** The XBee inside the payload is set to transmit the data to the ground station at 1Hz transmission rate.
- Both XBees communicate in unicast mode, **NOT** in broadcast mode.

Payload Radio Configuration (2/2)



- **Receiver XBee is set as COORDINATOR and its NETID/PANID is adjust as team number "6203".**

Payload Telemetry Format (1/3)

Data Format	Sample Data	Description
<TEAM ID>	6203	Team identification number.
<MISSION TIME>	15	Time in seconds since initial power up.
<PACKET COUNT>	15	The count of the transmitted telemetry packets.
<ALTITUDE>	45.2	The altitude in meters relative to ground level. The resolution is 0.1 meters.
<PRESSURE>	10540	The atmospheric pressure in units of pascals. The resolution is 1 pascal.
<TEMP>	32.5	The temperature in degree Celsius. The resolution is 0.1 *C.
<VOLTAGE>	4.24	The voltage of the Cansat power bus. The resolution is 0.01 Volts.
<GPS TIME>	12:25:11	The time generated by the GPS receiver. Time is reported in UTC and have a resolution of seconds.
<GPS LATITUDE>	29.5142	The latitude generated by the GPS receiver. The resolution must be in decimal degrees of 0.0001.

Payload Telemetry Format (2/3)

Data Format	Sample Data	Description
<GPS LONGITUDE>	42.1589	The longitude generated by the GPS receiver. The resolution must be in decimal degrees of 0.0001.
<GPS ALTITUDE>	195.2	The sea level altitude generated by the GPS receiver. The resolution must be in decimal degrees of 0.1 meters.
<GPS SATS>	4	The number of satellites tracked by the GPS receiver. This must be an integer number.
<PITCH>	2	The tilt angle in the pitch axis. The resolution is 1 degree.
<ROLL>	1	The tilt angle in the roll axis. The resolution is 1 degree.
<BLADE SPIN RATE>	18	The rate the auto-gyro blades spin relative to the science payload. The units are in revolutions per minute (rpm). The resolution is 1 rpm.
<SOFTWARE STATE>	ASCENT	The operating state of the Cansat.
<BONUS DIRECTION>	257	The direction of the camera relative to the Earth's magnetic north. The resolution is in degrees.

Payload Telemetry Format (3/3)

Data rate of Packets:

- The data is transmitted with 1 Hz to the ground station.
- Burst transmission is used to transmit telemetry packets.

Data 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>

Example Telemetry Packet :

6203,15,14,45.2,10540.7,32.5,4.24,12:25:11,29.5142,42.1589,195.2,4,2,1,18,3,257

Example telemetry matches with competition guide requirements.

The telemetry on the ground station will be saved as **Flight_APISARGE_6203.csv**

Bonus Mission:

There will be a bonus direction data of the camera. This data shows the direction of the camera relative to Earth’s magnetic north.

Container CDH Overview

Microprocessor: Teensy 3.2

Used to control the release mechanism and process the sensor data.

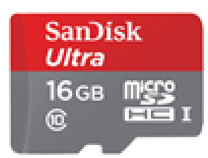
Mosfet: IRL 540

N channel mosfet is used to activate the release mechanism.

Pressure Sensor: BMP 180

Used to measure the altitude of the container.

Storage Device: SanDisk Ultra 16 GB SD Card



SD Card is used to store altitude data of the container.

Container CDH Requirements

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
CCDH-1	The container shall measure altitude using an air pressure sensor.	Additional	-	-	Very High	√		√	
CCDH-2	The container processor shall store altitude data into a memory card.	Additional	-	-	Very High	√		√	
CCDH-3	The container shall release the payload at 450 meters +/- 10 meters.	CReq	BR-9	DCS-5 MS-8	Very High	√		√	
CCDH-4	All structures shall be built to survive 15 Gs of launch acceleration.	CReq	BR-14	SS-2 MS-10	Very High	√	√	√	
CCDH-5	All structures shall be built to survive 30 Gs of shock	CReq	BR-15	SS-3 MS-10 DCS-6	Very High	√	√	√	

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

Model	Processor Speed	Supply Voltage	I/O Pins [Number]	Interface [Number]	Memory	Dimensions	Boot Time	Price
Teensy 3.2	72 MHz	3.6 V - 5 V	Digital [34] Analog In[14]	UART [3] I2C [2] SPI [1]	EEPROM - 2 KB Flash - 256 KB SRAM - 64 KB	32 mm x 18 mm x 4.2 mm	3 s	$ 19.8
Arduino Nano	16 MHz	5 V	Digital [14] Analog In[6] Analog Out[2]	UART [2] I2C [1] SPI [1]	EEPROM - 1 KB Flash - 32 KB SRAM - 2KB	18 mm x 45 mm x 6.1 mm	4.84 s	$ 2.5
Arduino Pro Mini328	8 MHz	3.3 V	Digital[14] Analog In[4] Analog Out[4]	UART [1] I2C [1] SPI [1]	EEPROM - 1 KB Flash - 32 KB SRAM - 2 KB	33mm x 18 mm x 2 mm	6.6 s	$ 9.95

Selected Processor : Teensy 3.2

- Sufficient program and appropriate memory area.
- Has higher processor speed than other processors.
- Easy to program.
- Has acceptable dimensions for the circuit of the container.
- Relatively less boot time than other compared processors.

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

- **The properties of Teensy 3.2 are given below:**

Operating Voltage (Logic Level)	3.3 V	**Analog Input**	14
Supply Voltage (Limits)	3.6 V - 5 V	**I²C**	2
Number of I/O Pins	48	**SPI**	1
PWM	12	**UART**	3
Flash Memory	256 KB	**Price**	$ 19.8
Dimensions	32 mm x18 mm x 4.2 mm	**Mass**	7 g
Processor speed	72 MHz	**Boot Time**	3 s

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

Model	Memory	Interface	Data Transfer Rate	Type	Price
SanDisk Ultra 16 GB SD Card	16 GB	SPI	80 MB/s	Flash	$ 7
EM 783	32 KB	I^2C	20.8 MB/s	Flash	$ 3
SanDisk Ultra SDHC	32 GB	SPI	48 MB/s	Flash	$ 15

Selected Memory: SanDisk Ultra 16 GB SD Card

- Affordable cost.
- Significantly more memory than EM 783.
- High data transfer rate.
- SPI interface is more stable than I^2C interface.
- Easy pluggable and removable structure.
- SanDisk Ultra SDHC has lower data transfer rate .

Electrical Power Subsystem (EPS) Design

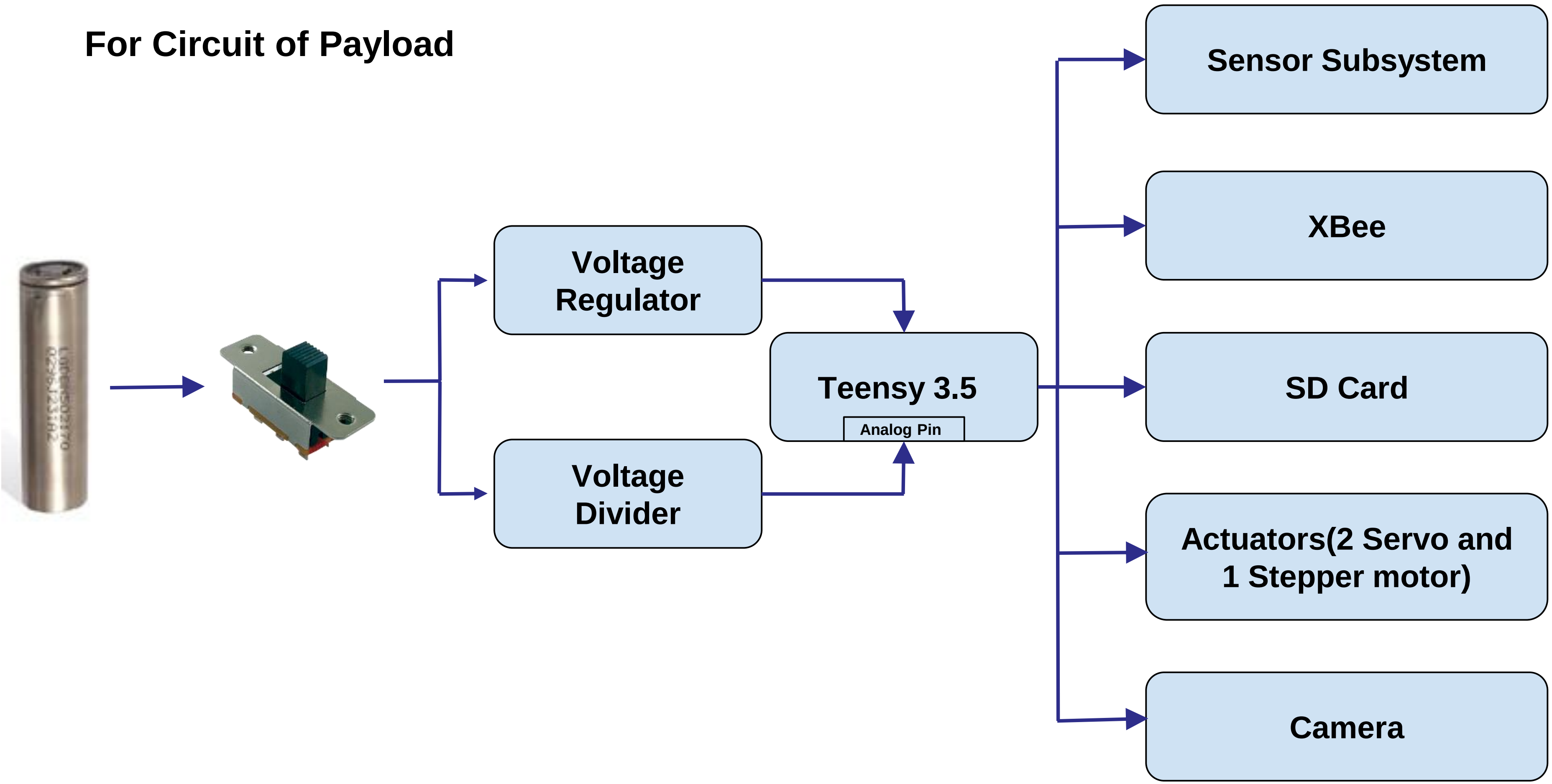
Buse COP

EPS Overview (1/3)

Component	Purpose of the Component
Battery	Supplies power to the circuit.
Switch	Provides a connection between the battery and the electronic system, and allows power on or off for the circuit.
Voltage Regulator	Adjusts the appropriate voltage level that the sensors and processor need by increasing and decreasing the voltage.
Voltage Divider	Helps to measure the voltage level of the CanSat power bus on an analog pin of Teensy 3.5 by dividing the voltage.
Buzzer	Helps the recovery team by making a sound after landing.
Mosfet	Enables current flowing through nichrome wire to melt fishing line for separation.

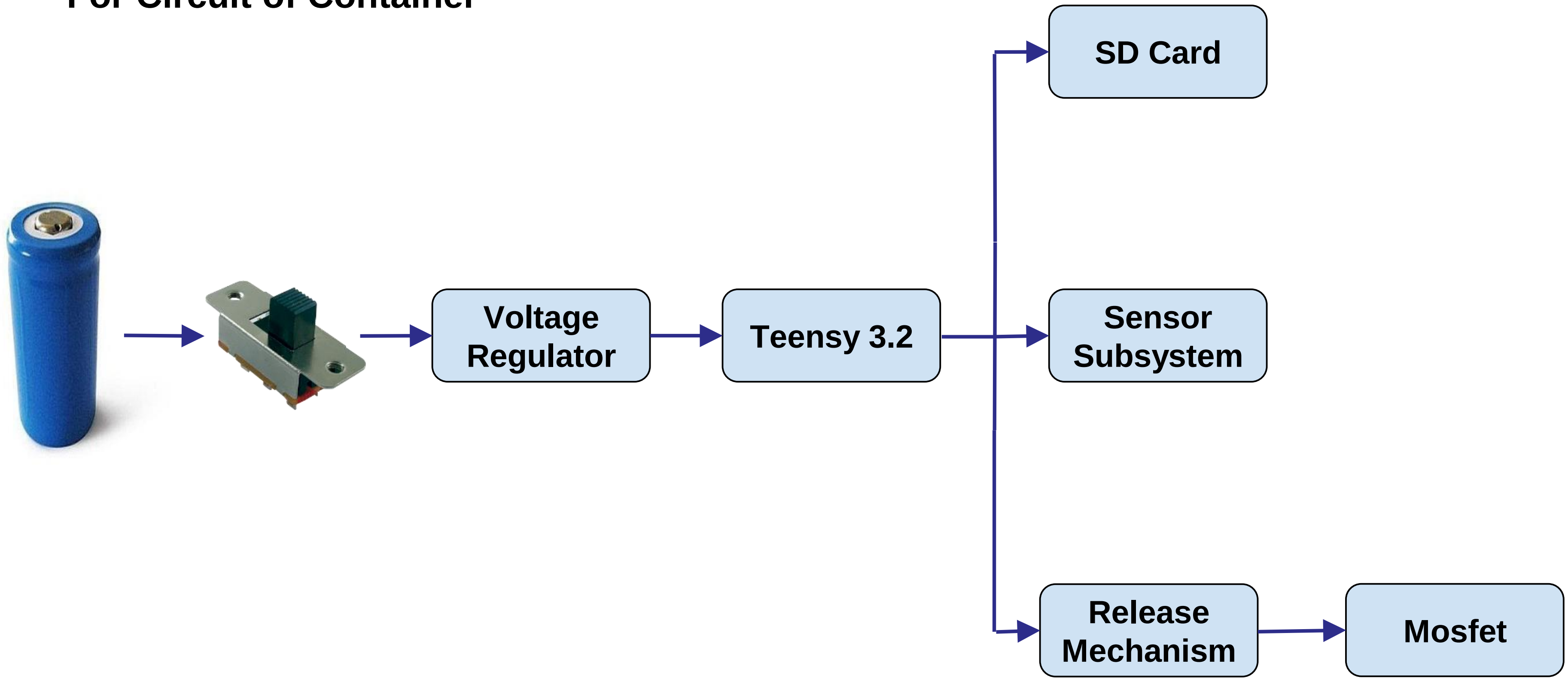
EPS Overview (2/3)

For Circuit of Payload



EPS Overview (3/3)

For Circuit of Container



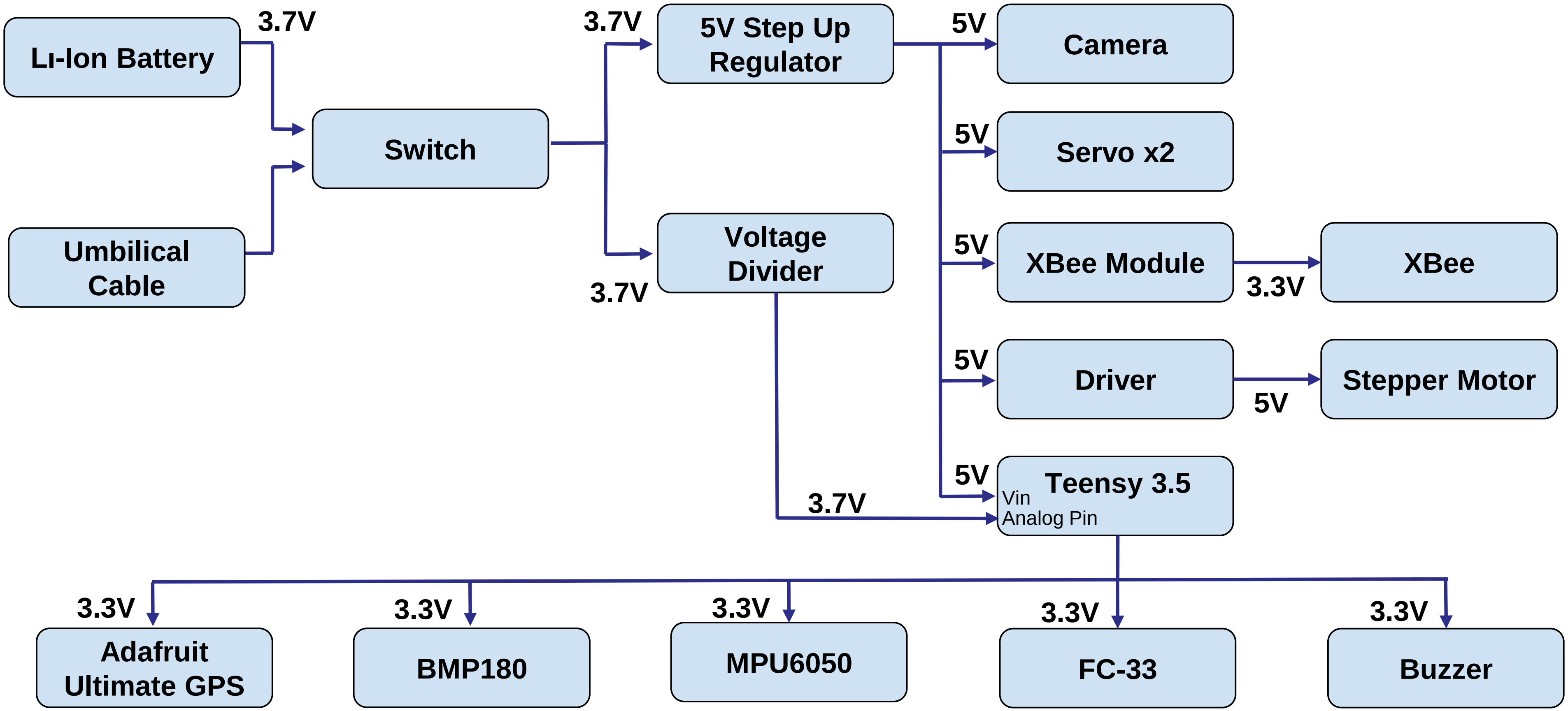
EPS Requirements (1/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
EPS-1	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	CReq	BR-13	SS-1 MS-12	Very High		✓		
EPS-2	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	CReq	BR-45	-	Very High		✓		✓
EPS-3	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.	CReq	BR-46	-	High		✓		✓
EPS-4	An audio beacon is required for the payload. It may be powered after landing or operate continuously.	CReq	BR-47	FSW-14	High		✓		✓
EPS-5	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	CReq	BR-55	-	Very High	✓		✓	

EPS Requirements (2/2)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
EPS-6	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.	CReq	BR-49	-	Very High		✓		
EPS-7	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.	CReq	BR-50	-	Very High		✓		✓
EPS-8	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	CReq	BR-51	-	Very High		✓		✓

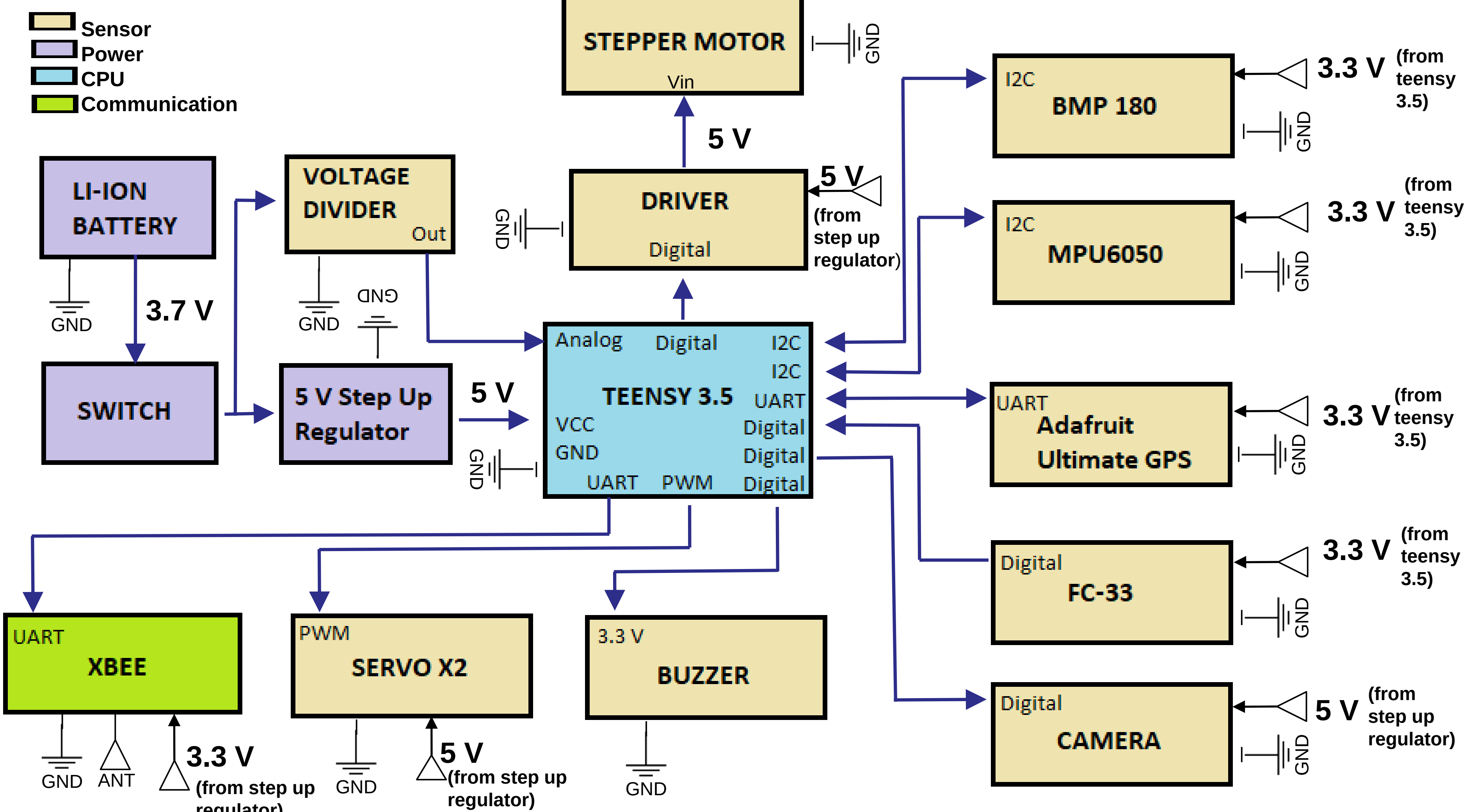
Payload Electrical Block Diagram (1/2)



- The power will be controlled by a switch which is not required to disassemble since it will be placed in an easily accessible place from the exterior.
- Teensy 3.5 will activate the buzzer for half a second during its setup to verify that power is on.
- The umbilical power source is formed by the umbilical cables connected to the battery for use in testing and safety inspection.

Payload Electrical Block Diagram (2/2)

DIAGRAM OF INTERFACES



Payload Power Trade & Selection

Model	Type	Quantity	Configuration	Voltage	Capacity	Continuous Discharge Current	Energy	Diameter	Mass	Price
LG M50 21700	Li-Ion	1	Series	3.7 V	5000 mAh	7.3 A	18.2 Wh	21.1 mm	68.2 g	$ 9
AWT 26650	Li-Ion	1	Series	3.7 V	4500 mAh	45 A	16.65 Wh	32.2 mm	90 g	$9.75
GREPOW D	Ni-MH	1	Series	1.2 V	5000 mAh	30 A	6 Wh	26 mm	110 g	$ 13.5

Selected Battery: LG M50 21700

- Lightweight compared to other trades.
- Cheapest.
- High charge capacity meets 2 hours operation with system.
- Continuous discharge current is appropriate to actuate all electronic components simultaneously.
- Short diameter compared to other trades.

Payload Power Budget (1/3)

Component	Voltage (V)	Current (mA)	Power (W)	Power Consumption (Wh) (W x 1h)	Duty Cycle (%)	Source
Teensy 3.5	5	45	0.225	0.225	100	Datasheet
Adafruit Ultimate GPS	3.3	20	0.066	0.066	100	Datasheet
BMP180	3.3	0.005	0.0000165	0.0000165	100	Datasheet
2 x Servo	5	2 x 300	2 x 1.5	2 x 1.5	45	Datasheet/ Estimate
Adafruit Mini Spy Camera	5	110	0.55	0.55	45	Datasheet
Stepper Motor	5	600	3	3	45	Datasheet
Driver	5	4	0.02	0.02	45	Datasheet/ Estimate
MPU6050	3.3	3.9	0.01287	0.01287	100	Datasheet

Payload Power Budget (2/3)

Component	Voltage (V)	Current (mA)	Power (W)	Power Consumption (Wh) (W x 1h)	Duty Cycle (%)	Source
XBee Pro S2C (Transmit)	3.3	120	0.396	0.396	100	Datasheet
FC-33	3.3	15	0.0495	0.0495	45	Datasheet/ Estimate
Buzzer	3.3	25	0.0825	0.0825	10	Datasheet

Total Current	Total Current Consumed (for two hours)	Total Power	Total Power Consumed (for two hours)
1542.905 mA	1542.905 mA x 2 h = **3085.81 mAh**	7.402 W	7.402 W x 2 h = **14.804 Wh**

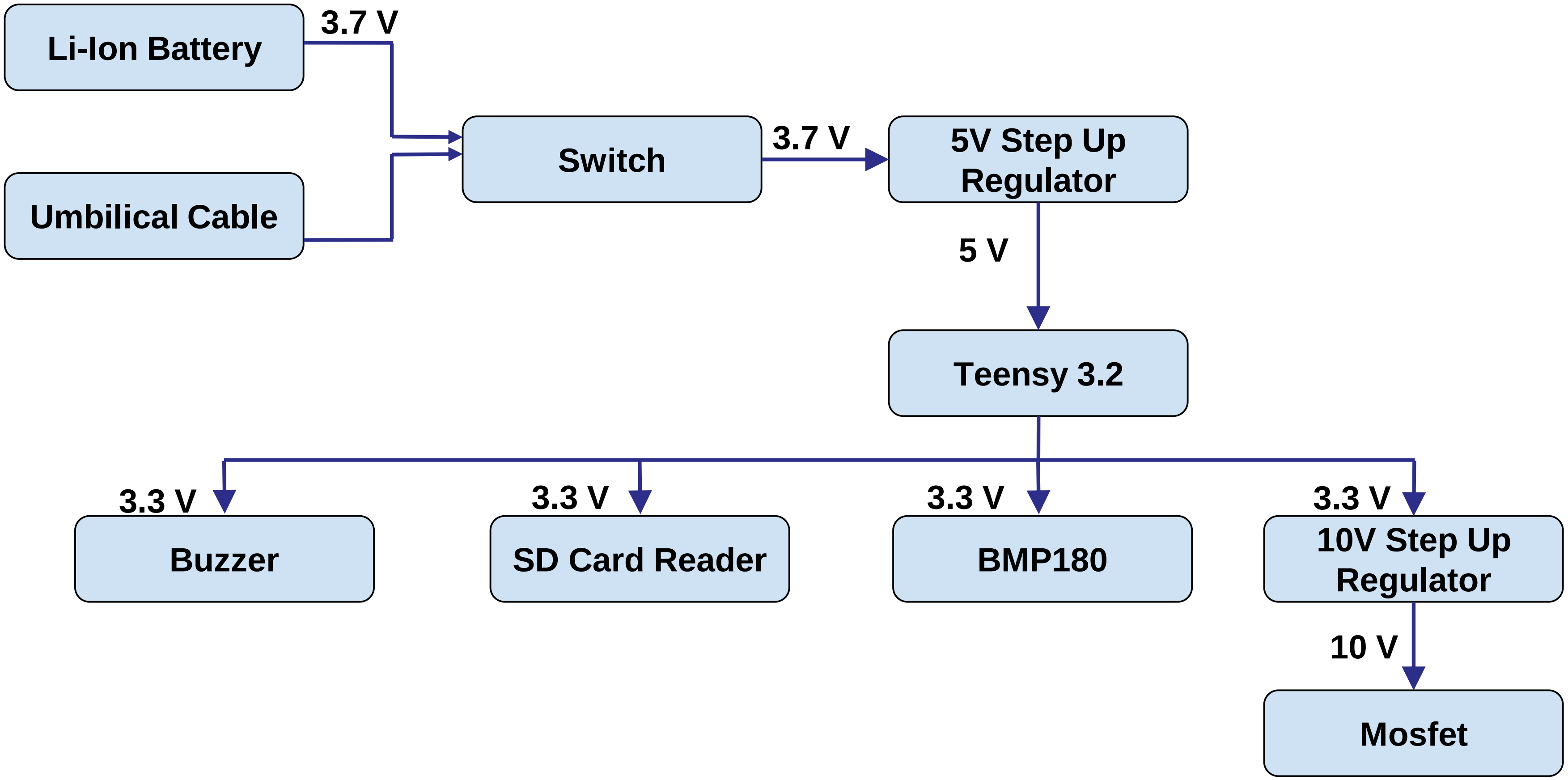
Payload Power Budget (3/3)

Available Total Current Capacity (for two hours)	Available Total Power Capacity (for two hours)
5000 mAh	18.2 Wh

Margin of Current Consumption (for two hours)	Margin of Power Consumption (for two hours)
1914.19 mAh	**3.396 Wh**

- **Selected battery is capable of supplying power to the payload for at least two hours.**
- **Single LG M50 21700 battery will be used as a power source.**

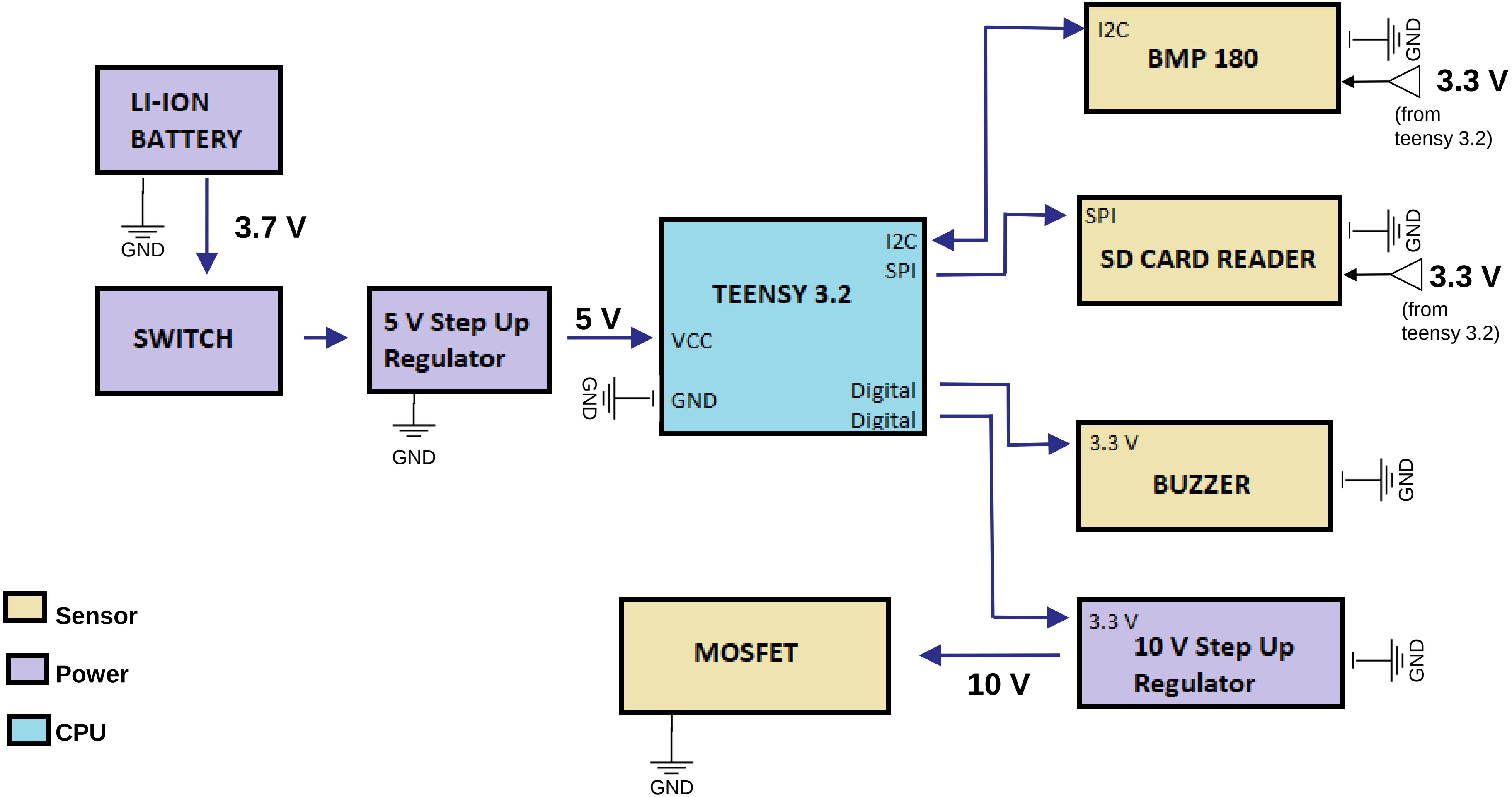
Container Electrical Block Diagram (1/2)



- **The power will be controlled by a switch which is not required to disassemble since it will be placed in an easily accessible place from the exterior.**
- **Teensy 3.2 will activate the buzzer for half a second during its setup to verify that power is on.**
- **The umbilical power source is formed by the umbilical cables connected to the battery for use in testing and safety inspection.**

Container Electrical Block Diagram (2/2)

DIAGRAM OF INTERFACES



Container Power Trade & Selection

Model	Type	Quantity	Configuration	Voltage	Capacity	Continuous Discharge Current	Energy	Diameter	Mass	Price
LG 18650	Li-Ion	1	Series	3.7V	2500 mAh	20 A	9,25 Wh	18.25 mm	48 g	$ 4.85
OEM 16340	Li-Ion	1	Series	3.7V	1400 mAh	1.4 A	5,18 Wh	16 mm	18,5 g	$ 4
GP-110AFH	Ni-MH	1	Series	1.2V	1100 mAh	0.6 A	1,32 Wh	28.5 mm	21 g	$ 4.15

Selected Battery: OEM 16340

- Lightweight compared to other trades.
- Cost effective.
- Enough charge capacity for 2 hours operation with system.
- Continuous discharge current is appropriate to activate release mechanism.
- Short diameter compared to other trades.

Container Power Budget (1/2)

Component	Voltage (V)	Current (mA)	Power (W)	Power Consumption (Wh) (W x 1h)	Duty Cycle (%)	Source
Teensy 3.2	5	45	0.225	0.225	100	Datasheet
BMP180	3.3	0.005	0.0000165	0.0000165	100	Datasheet
Mosfet (IRL540)	10	150	1.5	1.5	5	Estimate
SD Card Reader	3.3	150	0.495	0.495	100	Datasheet/ Estimate
Buzzer	3.3	25	0.0825	0.0825	100	Datasheet

Total Current	Total Current Consumed (for two hours)	Total Power	Total Power Consumed (for two hours)
370.005 mA	370.005 mA x 2 h = **740.01 mAh**	2.30255 W	2.30255 W x 2 h = **4.6051 Wh**

Container Power Budget (2/2)

Available Total Current Capacity (for two hours)	Available Total Power Capacity (for two hours)
1400 mAh	5.18 Wh

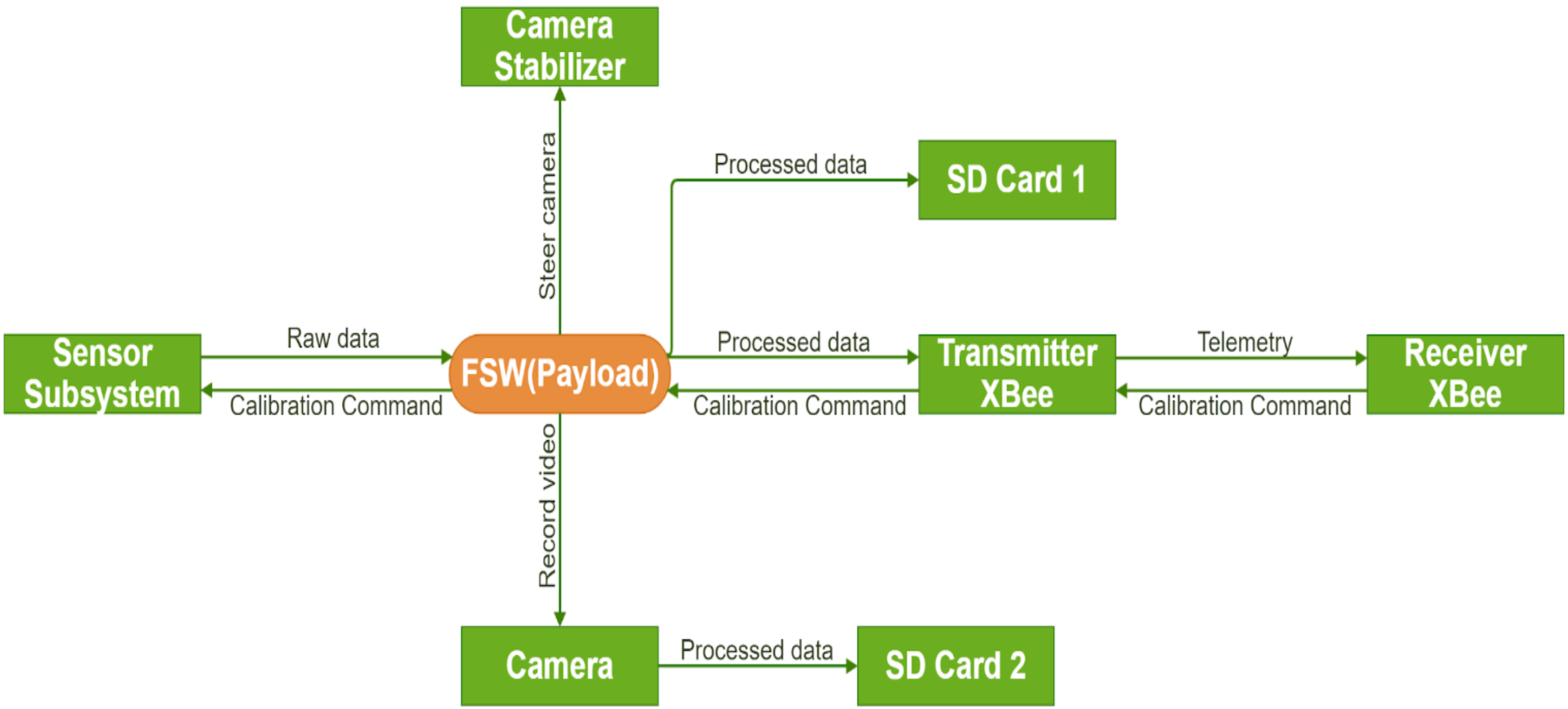
Margin of Current Consumption (for two hours)	Margin of Power Consumption (for two hours)
659.99 mAh	**0.5749 Wh**

- **Selected battery is capable of providing power to the container for at least two hours.**
- **Single OEM 16340 battery will be used as power source.**

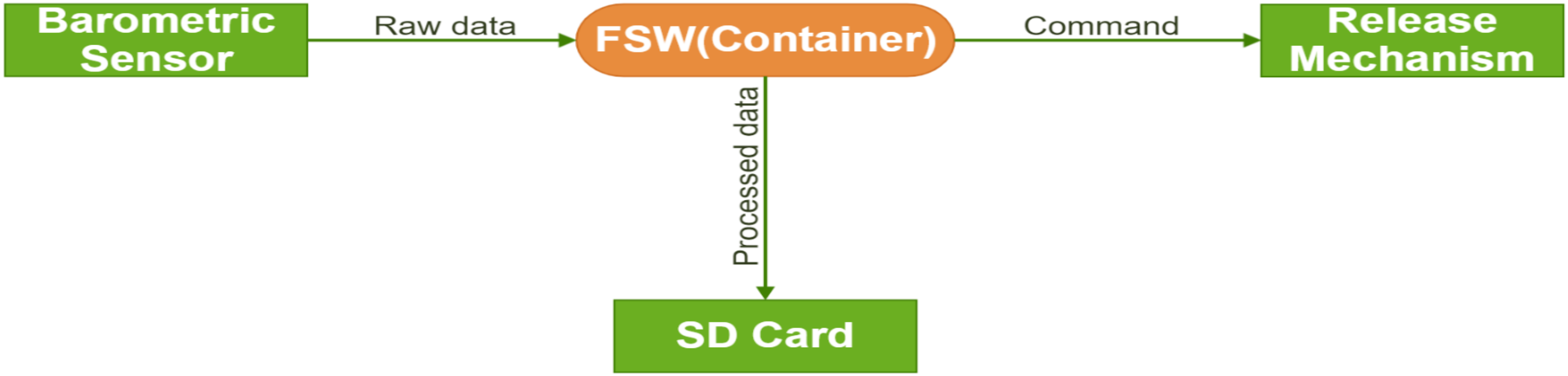
Flight Software (FSW) Design

Altuğ ERTAN

FSW Overview (1/3)



FSW Overview (2/3)



FSW Overview (3/3)

- **Programming Language:**
  - ➢ C/C++
- **Development Environment:**
  - ➢ Arduino IDE
- **Summary of FSW (Payload) Tasks:**
  - ➢ To obtain raw data from payload sensors and convert them to processed data expressed in engineering units.
  - ➢ To command to transmitter XBee for sending telemetry data to receiver XBee at 1 Hz
  - ➢ To command to camera for recording descent of the payload.
  - ➢ To save processed data and video to SD card.
  - ➢ To steer servo and stepper motors which control camera stabilizer according to magnetic north and nadir.
- **Summary of FSW (Container) Tasks:**
  - ➢ Reading altitude value from barometer sensor during flight and carrying out separation of the payload at 450 meters.

FSW Requirements (1/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
FSW-1	The science payload shall measure altitude using an air pressure sensor.	CReq	BR-20	SS-6 CDH-1	Very High	✓		✓	
FSW-2	The science payload shall provide position using GPS.	CReq	BR-21	SS-7 CDH-2	Very High	✓		✓	
FSW-3	The science payload shall measure its battery voltage.	CReq	BR-22	SS-8 CDH-3	Very High	✓		✓	
FSW-4	The science payload shall measure outside temperature.	CReq	BR-23	SS-9 CDH-13	Very High	✓		✓	
FSW-5	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.	CReq	BR-24	SS-10 CDH-5	Very High	✓		✓	
FSW-6	The science payload shall measure pitch and roll.	CReq	BR-25	SS-11 CDH-6	Very High	✓		✓	

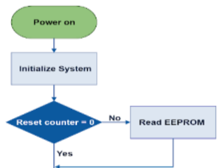
FSW Requirements (2/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
FSW-7	The probe shall transmit all sensor data in the telemetry	CReq	BR-26		Very High	√		√	
FSW-8	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.	CReq	BR-28		Very High	√		√	
FSW-9	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.	CReq	BR-30	CDH-9	Very High	√		√	
FSW-10	All telemetry shall be displayed in real time during descent.	CReq	BR-36	GCS-3	Very High	√	√	√	
FSW-11	All telemetry shall be displayed in engineering units (meters, meters/sec,Celsius, etc.)	CReq	BR-37	GCS-4	Very High	√	√	√	
FSW-12	The GPS receiver must use the NMEA 0183 GGA message format.	CReq	BR-53		Very High	√	√	√	

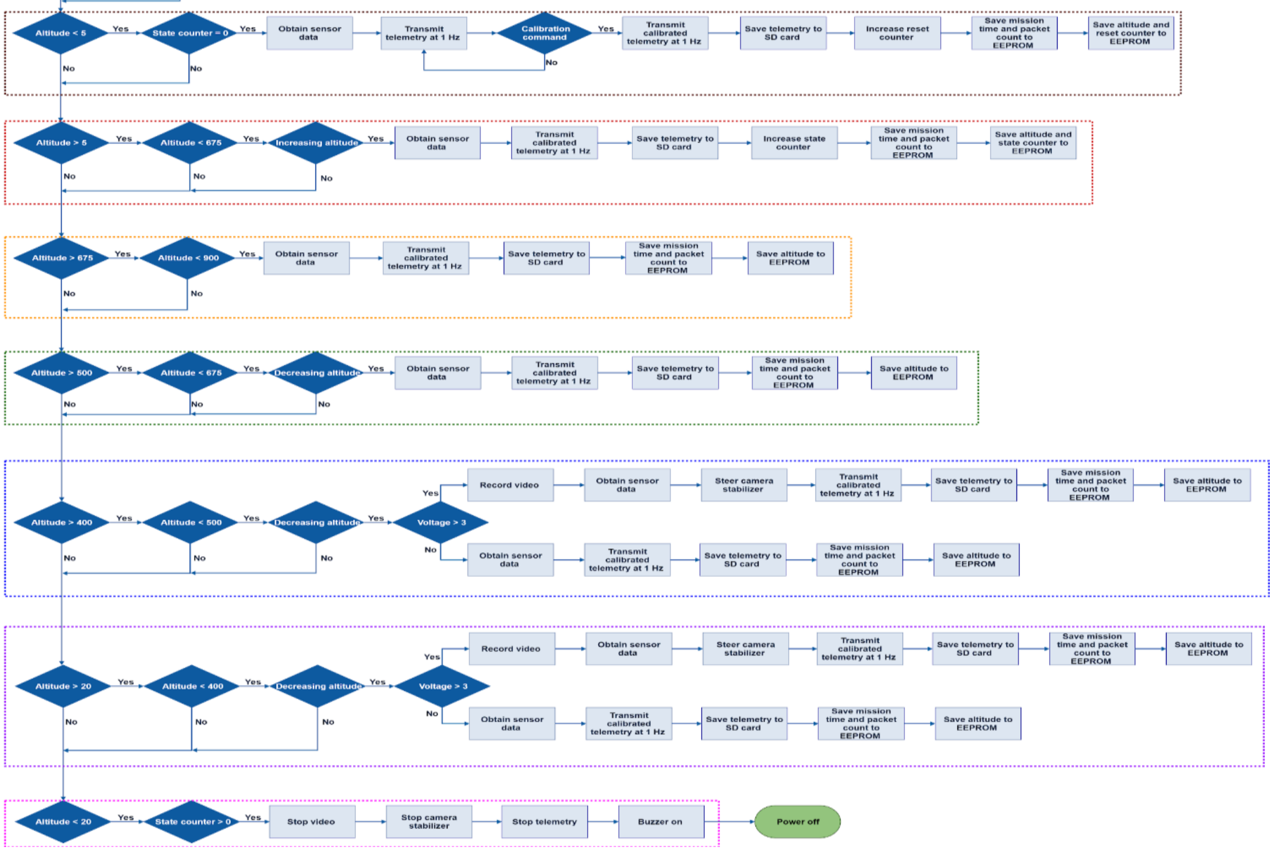
FSW Requirements (3/3)

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
FSW-13	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.	CReq	BR-42	CDH-4	Very High	√		√	√
FSW-14	An audio beacon is required for the payload. It may be powered after landing or operate continuously.	CReq	BR-47	EPS-4	Very High		√		√
FSW-15	Video shall be in color with a minimum resolution of 640x480 pixels and 30 fps.	Bonus Objective		SS-13	High	√	√	√	
FSW-16	After the separation of container and payload at 450 meters, camera of the payload records a video during the descent and store the video to the SD Card.	Bonus Objective	SY-27	SS-14	High	√		√	
FSW-17	The camera shall point downward 45 degrees from nadir of the science payload.	Bonus Objective	SY-28	SS-15	High	√		√	
FSW-18	It shall point in one direction relative to the earth's magnetic field with a stability of +/- 10 degrees in all directions during descent.	Bonus Objective	SY-29	SS-16	High	√		√	

Payload FSW State Diagram (1/6)



This slide shows the general flow of the payload flight software diagram. Diagram is divided into several parts for sharpness due to low quality view.



FSW States

Brown -- Launchpad

Red -- Ascent

Orange -- Apogee

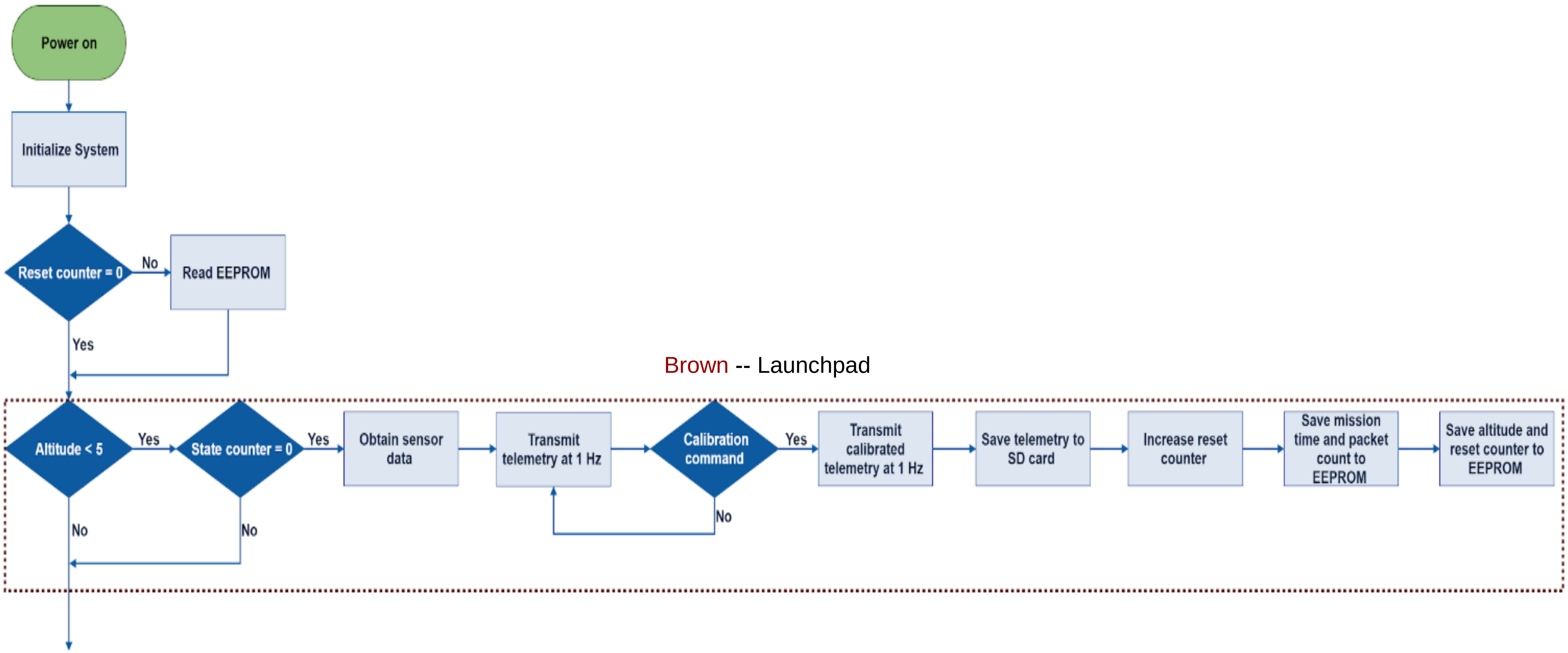
Green -- Descent

Navy Blue -- Separation

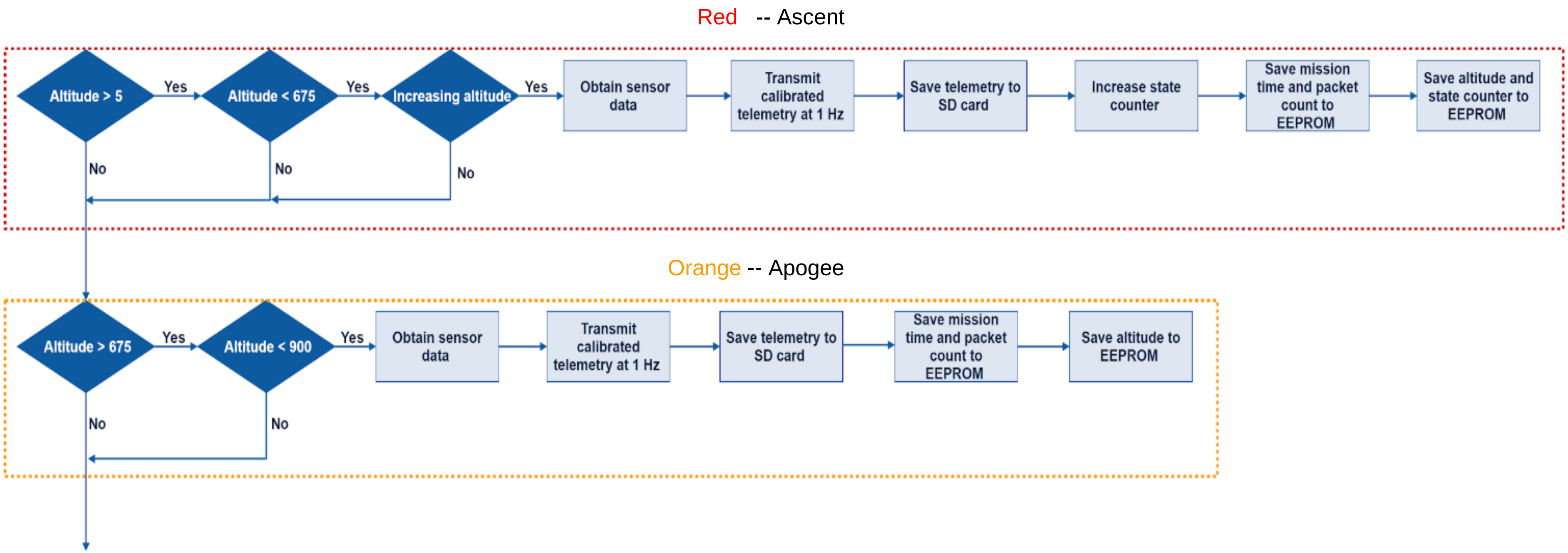
Purple -- Descent after separation

Pink -- Landing

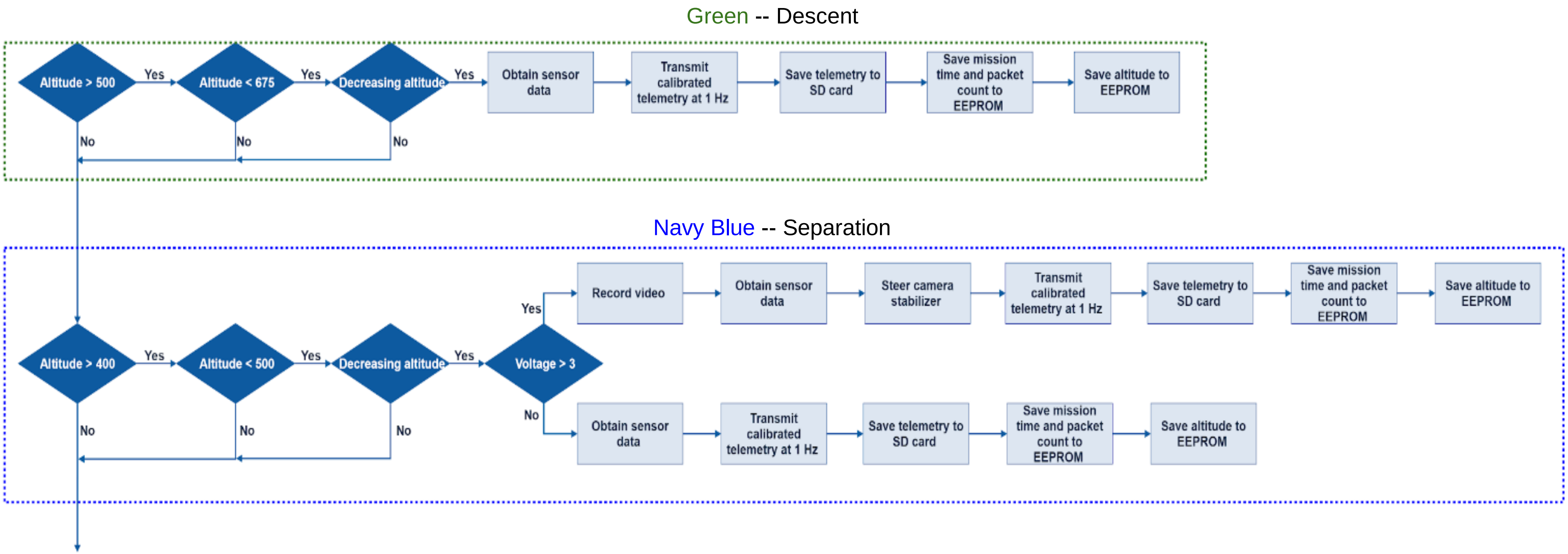
Payload FSW State Diagram (2/6)



Payload FSW State Diagram (3/6)

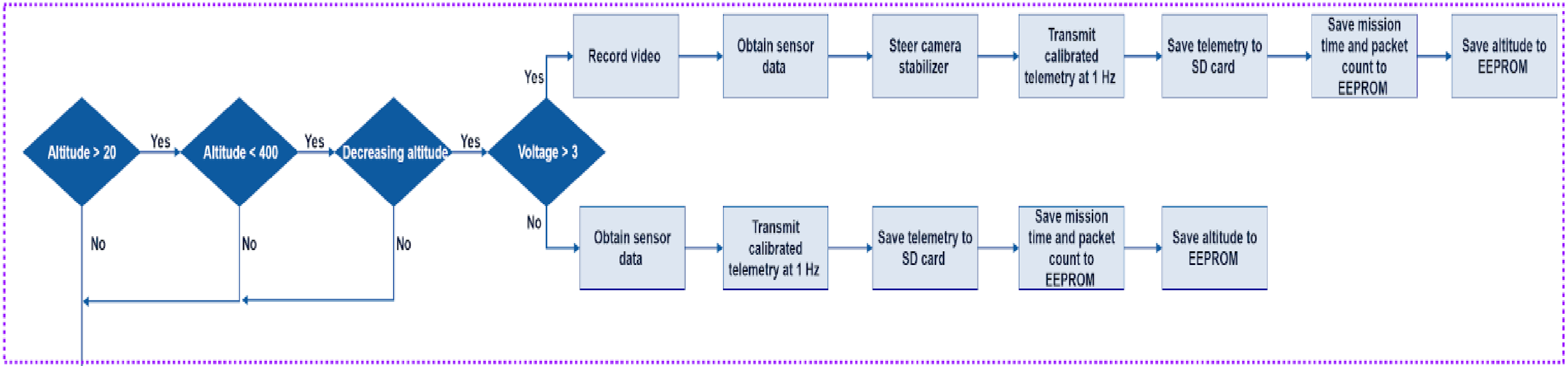


Payload FSW State Diagram (4/6)

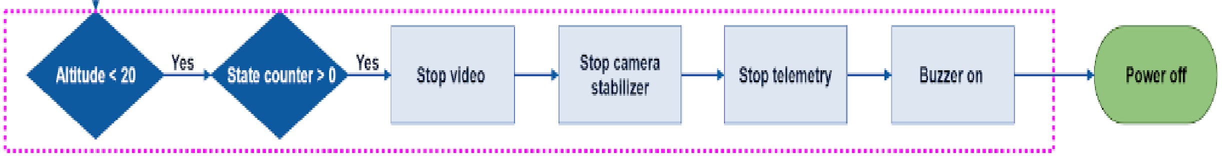


Payload FSW State Diagram (5/6)

Purple -- Descent after separation

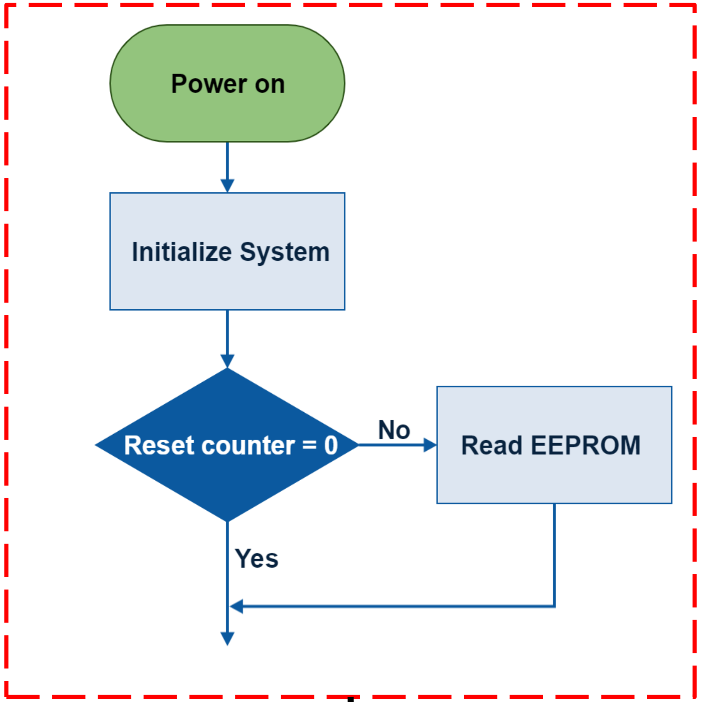


Pink -- Landing



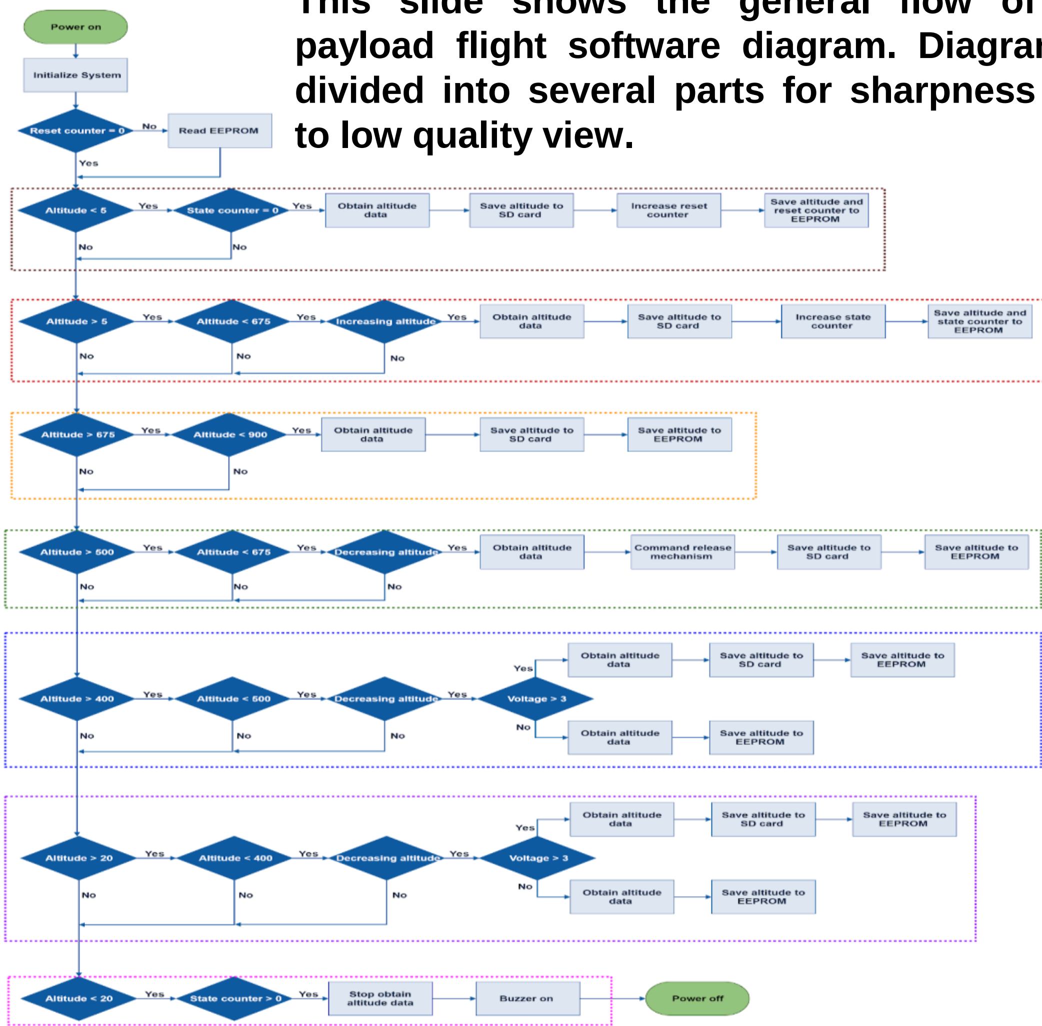
Payload FSW State Recovery

- Altitude data, reset counter and state counter variables will be used to recover FSW state if processor resets. Reset counter is an integer variable which helps to determine reset situation, and state counter is an integer variable which helps to determine software states.
- Reset reasons may be high temperatures affecting directly to microprocessor, high current exceeding limits of input and output pins of microprocessor, and flight software which closes to flash memory limit of microprocessor.
- Reset counter and state counter are increased in just first two states and save to EEPROM in these states. On the other hand, altitude data is saved to EEPROM in all states at every one second. If microprocessor resets, EEPROM is read based on the value of reset counter at beginning of the flight software. Thus, the value of the state counter and the last altitude data is obtained from EEPROM. As a result, according to values of state counter and last altitude data, the last software state will be found.



FSW state recovery part of flight software is shown.

Container FSW State Diagram (1/6)



This slide shows the general flow of the payload flight software diagram. Diagram is divided into several parts for sharpness due to low quality view.

FSW States

Brown -- Launchpad

Red -- Ascent

Orange -- Apogee

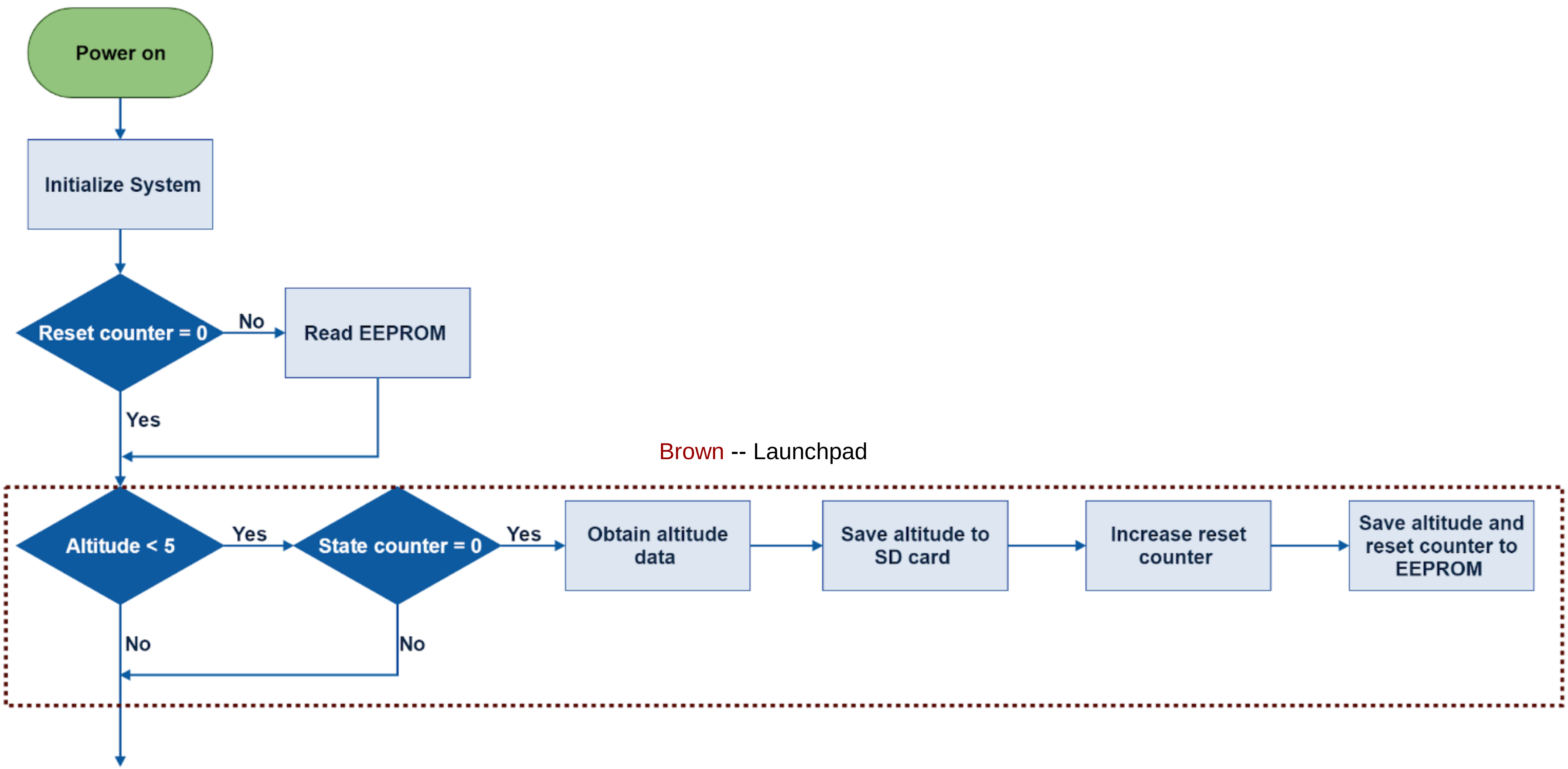
Green -- Descent

Navy Blue -- Separation

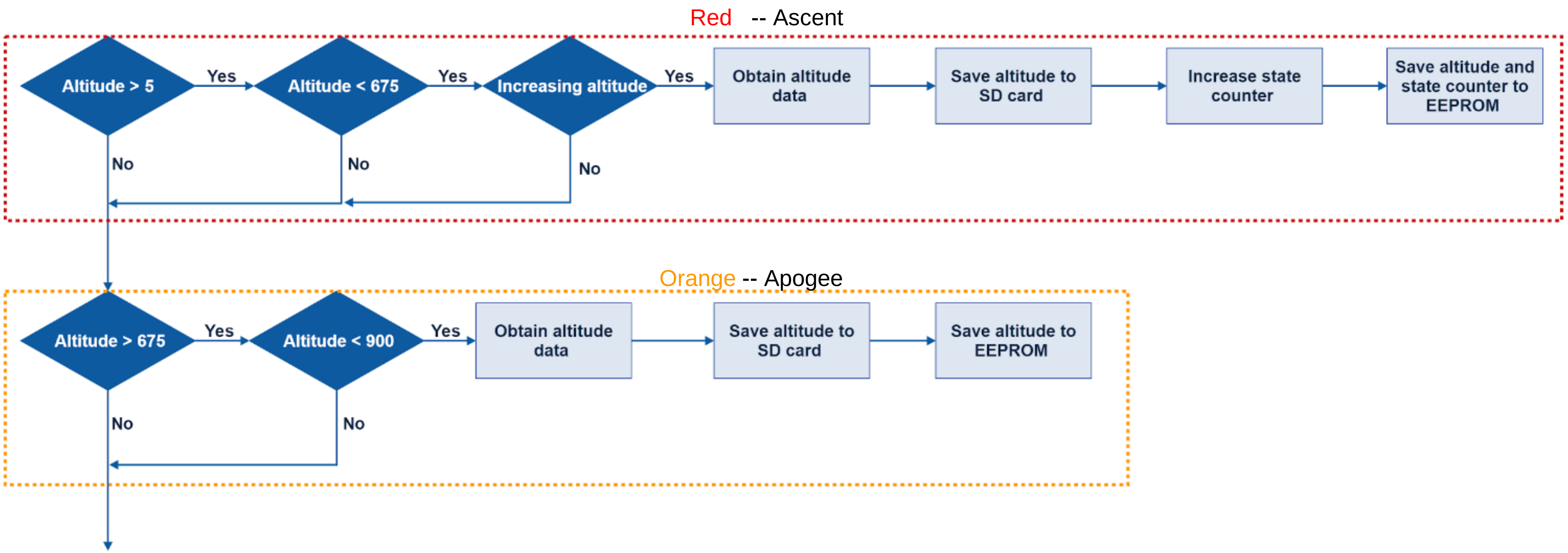
Purple -- Descent after separation

Pink -- Landing

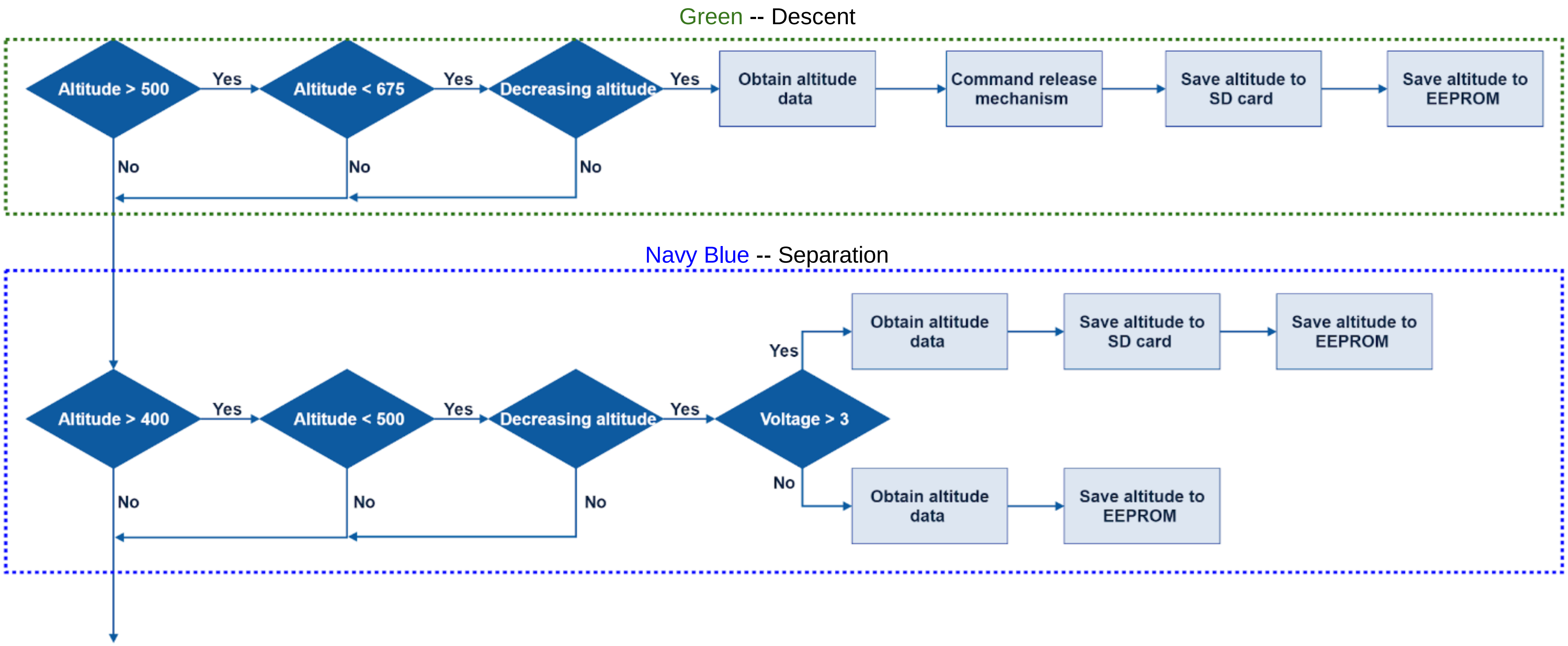
Container FSW State Diagram (2/6)



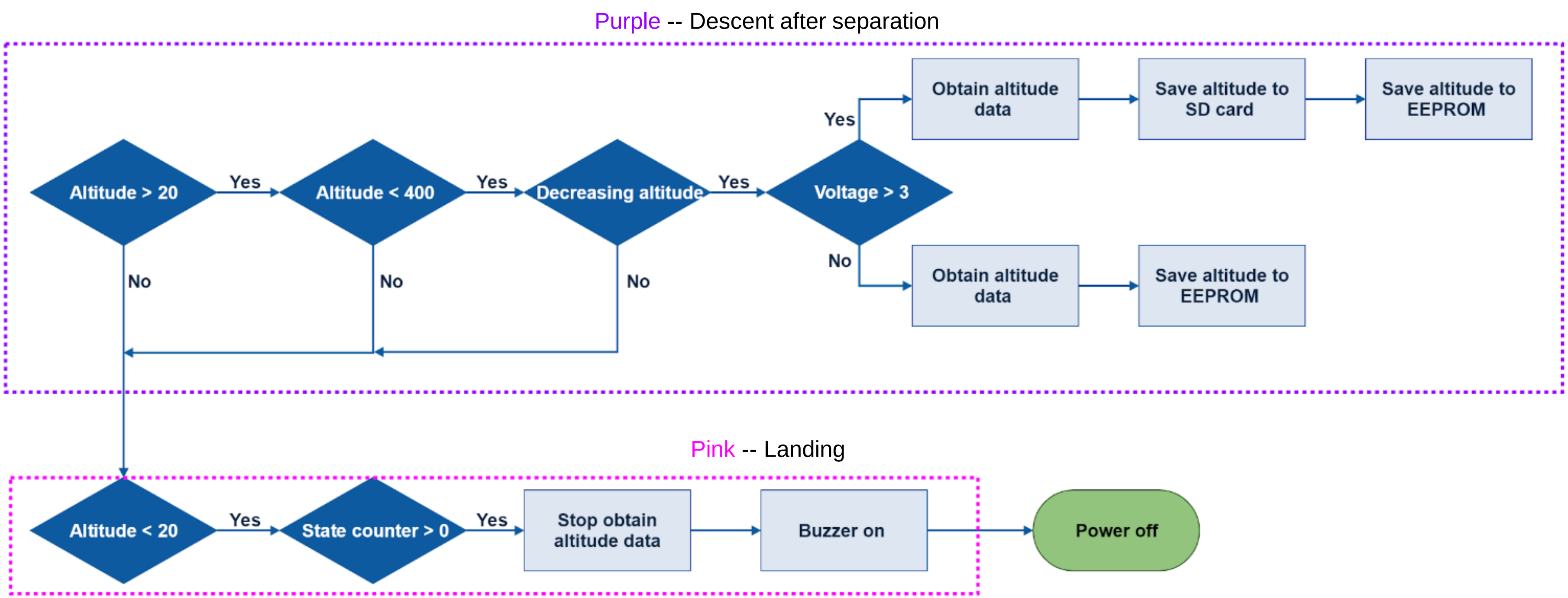
Container FSW State Diagram (3/6)



Container FSW State Diagram (4/6)

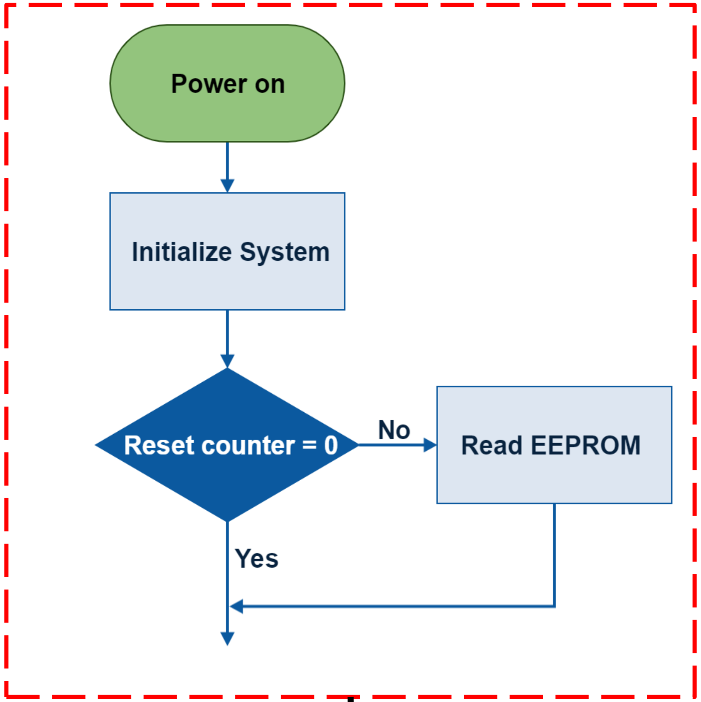


Container FSW State Diagram (5/6)



Container FSW State Recovery

- Altitude data, reset counter and state counter variables will be used to recover FSW state if processor resets. Reset counter is an integer variable which helps to determine reset situation, and state counter is an integer variable which helps to determine software states.
- Reset reasons may be high temperatures affecting directly to microprocessor, high current exceeding limits of input and output pins of microprocessor, and flight software which closes to flash memory limit of microprocessor.
- Reset counter and state counter are increased in just first two states and save to EEPROM in these states. On the other hand, altitude data is saved to EEPROM in all states at every one second. If microprocessor resets, EEPROM is read based on the value of reset counter at beginning of the flight software. Thus, the value of the state counter and the last altitude data is obtained from EEPROM. As a result, according to values of state counter and last altitude data, the last software state will be found.



FSW state recovery part of flight software is shown.

Software Development Plan (1/4)

- **Prototyping and Prototyping Environments**

  - Each sensor is tested on breadboard by supplying required power voltage and obtained data are evaluated on serial monitor of Arduino IDE.
  - All sensors are brought together on breadboard by supplying required power voltage and a prototype of payload circuit is formed. Obtained data are evaluated on serial monitor of Arduino IDE.
  - Boot time of microprocessor is measured by uploading blink code to the microprocessor. Thus, at the first moment when LED is on is measured by using a stopwatch after supplying power to the microprocessor.
  - A prototype circuit will be built for 3-axis camera stabilizer on breadboard, so reaction time and rotation speeds of motors with respect to changing angles will be determined.
  - A prototype circuit of the container will be formed on a breadboard by using a barometric sensor and an N-channel MOSFET for testing the time required to melt fishing line connected to nichrome wire and determining whether separation works properly.

Software Development Plan (2/4)

Software Subsystem Development Sequence (Payload)		
Task List	**Situation**	**Deadline**
Selection of sensors for mission requirements.	Completed	Early October
Library researching and code modifications for each sensor.	Completed	Mid October
Testing of each sensor individually with microcontroller.	Completed	Early November
Calibration of each sensor and repairing codes according to tests.	Completed	Late November
Bringing each sensor code together and testing all sensors simultaneously.	Completed	Mid December
Using of EEPROM for recovery of mission time,packet count and flight software data .	Completed	Late December
Wired serial communication test with ground station prototype.	Completed	Mid January
Storage of telemetry to SD Card.	Completed	Late January
Calibration command for altitude,pitch and roll data at launchpad.	In progress	Mid February
Recording video by using camera and storing the video to SD Card.	Not started	Late February
Magnetometer data analysis and calibration for bonus objective.	Not started	Early March
Coding of servo and stepper motors for camera stabilizer with respect to varying gyroscope and magnetometer data.	Not started	Early March
PCB and software compatibility test.	Not started	Mid March
Testing 3-axis camera stabilizer by bringing all components together.	Not started	Mid March
Wireless communication test with ground station.	Not started	Late March

Software Development Plan (3/4)

Software Subsystem Development Sequence (Container)		
Task List	**Situation**	**Deadline**
Selection of barometer sensor.	Completed	Early October
Library researching and code modifications for barometer sensor.	Completed	Mid October
Testing of barometer sensor individually with microcontroller.	Completed	Early November
Calibration of barometric sensor and repairing code according to tests.	Completed	Late November
Storage of altitude data to SD Card.	Completed	Late January
Algorithm of separation mechanism at 450 meters.	In progress	Late February
MOSFET logic signal efficiency test to melt the fishing line for separation mechanism.	Not started	Early March
PCB and software compatibility test.	Not started	Mid March

Software Development Plan (4/4)

- **Test Methodology**
  - ➢ Meteorology Observation Park located in Aeronautics and Astronautics faculty of ITU are used for testing air pressure and air temperature values.
  - ➢ Obtained longitude and latitude values from GPS sensor are controlled on Google Maps.
  - ➢ RPM value is measured by a real tachometer and it is compared with the data generated by blade spin rate sensor.
  - ➢ Power Bus voltage is measured by a real multimeter and it is compared with the data obtained by analog pin of the Teensy 3.5.
  - ➢ Magnetometer calibration test will be held at Upper Atmosphere and Space Air Laboratory located in Aeronautics and Astronautics faculty of ITU.
  - ➢ Telemetry transmission test will be done between the two sides of Bosphorus which have the distance of 1.6 km.
  - ➢ At 200 meters a free falling test will be conducted at ITU stadium, so flight software will be examined in terms of corporation with other subsystems.

- **Development Team**
  - ➢ Altuğ ERTAN
  - ➢ Resul DAGDANOV

Ground Control System (GCS) Design

Resul DAGDANOV

GCS Overview

PAYLOAD

UART

XBEE

Data transmission via Xbee Pro S2C

HAND-HELD ANTENNA

N Type to RP-SMA Converter

XBEE MODULE

Connected to GCS via Xbee Adapter

XBEE ADAPTER

Connected to serial port via USB

GROUND STATION LAPTOP

GCS Requirements

ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
GCS-1	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.	CReq	BR-29	-	Very High	√		√	
GCS-2	Each team shall develop their own ground station.	CReq	BR-35	-	Very High	√			
GCS-3	All telemetry shall be displayed in real time during descent.	CReq	BR-36	FSW-10	Very High	√	√	√	
GCS-4	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	CReq	BR-37	FSW-10	Very High	√	√	√	
GCS-5	Teams shall plot each telemetry data field in real time during flight.	CReq	BR-38	-	Very High	√	√		√
GCS-6	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	CReq	BR-39	-	Very High	√	√	√	
GCS-7	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.	CReq	BR-40	-	High		√		

GCS Design

Antenna connected to XBee with N- type to RPSMA connector.

XBee module will be connected to the explorer with a 2mm header.

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

- The GCS Laptop can operate 2.5 hours with battery.
- On the field, there will be an external laptop cooling fan to prevent overheating and the cooler has its own battery.
- On Windows OS, the auto update function will be disabled from the windows update center before the launch.
- There will be an umbrella to avoid the direct exposure from the sun.
- The ground station software will also be downloaded to the backup laptop.

GCS Antenna Trade & Selection (1/3)

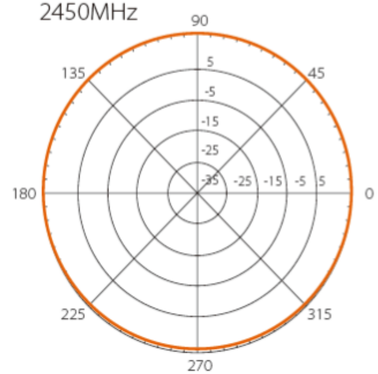
Model	Connection Type	Frequency	Direction	Gain	Price
TP-LINK TL-ANT2415D	N-Female	2.4 Ghz	Omni - Directional	15 dBi	$ 66
TP-LINK TL-ANT2412D	N-Female	2.4 Ghz	Omni - Directional	12 dBi	$ 40.99
L-COM HG2409Y-RSP	SMA	2.4 Ghz	Directional	9 dBi	$ 59.61

Selected Antenna : TP-LINK TL-ANT2415D

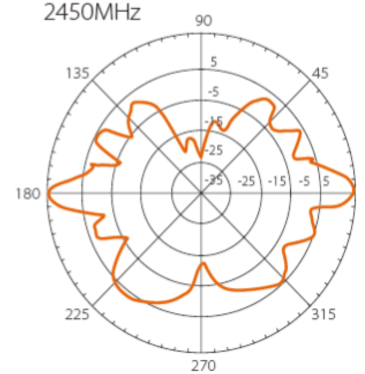
- Omni-Directional antennas receive and transmit signals in all directions.
- Considering radiation patterns, wide communication ranges.
- High gain compared to other antennas.
- Affordable cost.

Radiation Patterns:

H-Plane Co-Polarization Pattern
2450MHz



V-Plane Co-Polarization Pattern
2450MHz



Antenna Mounting Design Selection

Model	Type	Mass	Material	Price
Table Top	3 Foot	1.8 kg	Metal and Plastic	$ 23
Hand Held	Hand held	1 kg	3D Printed ABS	$ 6

Table Top:

Hand Held:

GCS Antenna Trade & Selection (3/3)

Selected Design: Hand Held

- Cost effective.
- Easily operated.
- Lightweight.
- Small and can be carried easily.
- It can be oriented easily.

GCS Software (1/3)

Telemetry Prototype:

<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>

Real Time Plotting:

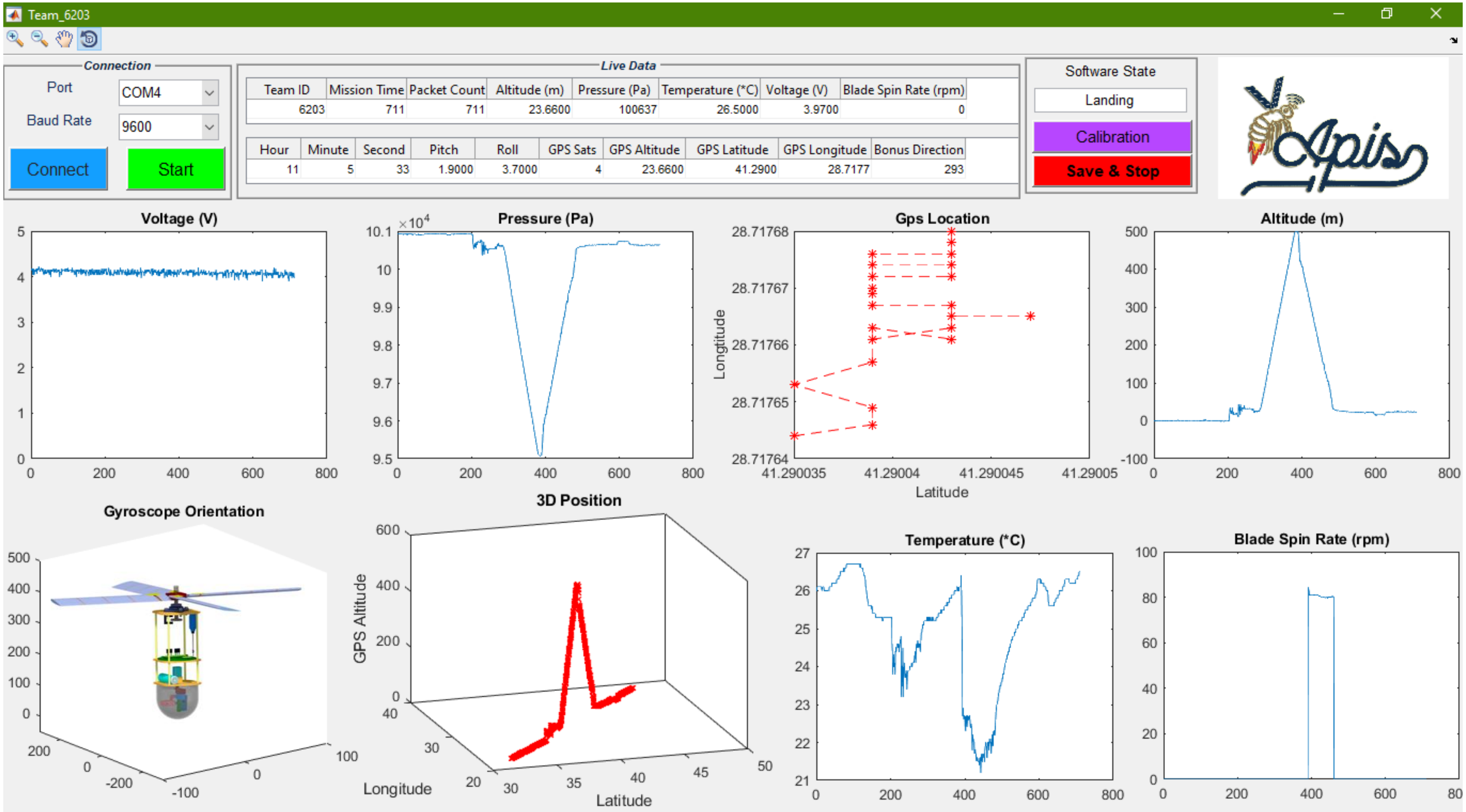
- Ground station software will be designed with MATLAB GUI Package.
- Received telemetry data will be recorded in a .csv file right after being read throughout the ground station Xbee Module.
- This received data will then be displayed on the real time plots.
- Real time plots will be labeled with engineering units.

Commercial off the shelf (COTS) software packages:

- XCTU (Xbee Program Software)
- MATLAB 2018b Student Version

GCS Software (2/3)

Media Presentation



GCS Software (3/3)

The Calibration Command for Barometric Sensor and Row/Pitch Angles:

While Cansat is inside the rocket, the command from the ground station will be given to calibrate the altitude, roll, and pitch data to zero. The ground station software will include the push button which will send a byte to the payload xbee module. As soon as the byte is received and recognized by the payload microprocessor, the calibration function will be activated once. The calibration function inside the payload microprocessor will be written with Arduino IDE.

Telemetry Data Recording to Judges for Inspection:

- All received telemetry data will be saved as .csv file. In csv format, data will be separated with commas.
- Data from this csv file will later be processed with MS Excel to show at the PFR.
- Real time telemetry data will be shown on the ground station software.
- This csv file will be directed to the judges via memory storage device.

CSV Telemetry File Creation:

- .csv file is created during the setup of the ground station.
- Real time received telemetry packets are continuously appended to this csv file.
- CSV file name will be “Flight_6203.csv”

CanSat Integration and Test

Özen HALİÇ

CanSat Integration and Test Overview (1/2)

Mechanical Subsystem Tests

-Descent Velocity Test

-Unfolding Mechanism Test

-Total Mass Control

-Autorotation Test

-Vibration Test

-Camera Stabilizer Test

-Release Mechanism Test

Sensor Subsystem Test

-Sensor Calibration

-Test sensors with microcontroller

CDH Subsystem Tests

-Microcontroller interfaces communication test

-Real Time Clock timekeeping test

-Data storage test

EPS Subsystem Tests

-Power sufficiency test

-Current leakage test

FSW Subsystem Tests

-Separation Algorithm Test

-EEPROM last data recovery Test

-Camera Test

Radio Communication Tests

-Xbee Communication Test

-Antenna Range Test

Descent Tests

-Separation from Container

-Parachute Test

Test plan:

1)Subsystem tests are going to be done.

2)All subsystems are going to be integrated and the required tests will be applied.

3)Appropriate environment conditions will be selected for testing.

CanSat Integration and Test Overview (2/2)

After the first plan is done, the integrated systems will be tested and following tests will be performed.

Payload Tests

Autorotation of the blades will be tested to make sure that flight of the payload will be smooth. And also the unfolding of the blades is another main concern that will be tested.

Communication Tests

Signal quality and healthy data transfer tests are planned to be done with XBee integrated to payload.

Pin connections on PCB are planned to test by realizing data transmission between sensors and microcontroller.

Mechanism Tests

Camera stabilizer will be tested whether it is turning to right direction as we asked in attached to payload and unfolding mechanism of the blades is to be done while integrated in payload.

Spring will be tested for providing sufficient force to separate payload from container.

Deployment Tests

While payload is stowed in the container, nichrome wire, hinge and latexes will be tested for smooth deployment.

Environmental Tests

Drop test will be done with drone in clear weather.

Vibration test will be done by using the the machine in the faculty laboratories.

Another machine in our faculty will be used for thermal test.

Subsystem Level Testing Plan (1/2)

Sensors

•Breadboard is used to test sensors and the accuracy of data.

•Accuracy of each sensor is calibrated individually for required conditions such as sea level condition.

CDH

•CDH system is tested on breadboard and on PCB.

•It is ensured that each sensor communicates with microcontroller correctly.

•Data storage capability is tested with SD Card.

•Data accuracy and transmission speed are tested using the necessary program and breadboard.

EPS

•It will be looked on PCB whether there is current leakage.

•Calculated voltage and current level is satisfied by the measured values read on multimeter.

Radio Communication

•Xbee configurations and signal level tests are actualized with X-CTU software.

•Transmission with Xbees is tested in distance 100m.

FSW

•The algorithm of video record after separation is tested by using a barometric sensor in an arbitrary altitude interval.

•Time keeping algorithm is to be tested on EEPROM in case of microcontroller resets by plugging out the USB connection.

•Roll, pitch and altitude data calibration command is tested by sending a character on serial port.

Subsystem Level Testing Plan (2/2)

Mechanical

•Verify that unfolding mechanism has enough strength in the air when its position is changing from close to open. It will be controlled by hand to see the mechanism is working.
•Endurance of the Payload will be tested first theoretically on one of the analysis programs such as ANSYS.
•Autorotation of the blades will be tested as dropping probe from different altitudes to see the blades are beginning to rotate itself.
•Maximum torque that servos in gimbal mechanism can handle is tested with dynamometer.
*All mechanical subsystem tests will be done as a whole system inside container apart from stated above with drone in 100m. The container will release the payload immediately after the separation from drone.

Descent Control

•Verify that the parachute that is made enough for the descent operation.
•Verify that spring meets the needed force. Formula of spring potential energy will be used to calculate needed force. Then it will be tested on drone.
•Separation from container will be tested with drone.

*All descent operations will be tested with drone in 300m. After the separation the systems will be observed in the air to make sure that the operations are done.

Integrated Level Functional Test Plan (1/2)

Descent Testing

Auto-gyro system will be tested with drone by letting payload free fall from different heights to prepare a prediction for a stable flight to make sure the payload is not exposed to tumble.

Free fall with drone also give the opportunity to test whole system to ensure that blades of payload and parachute of container is going to open.

The center of mass and center of pressure will be calculated as a whole system including electronic components. To calculate the center of pressure the rope will be tightened around the payload and if the bottom demonstrates the turning direction then the center of pressure can be found on this point.

Communications

Communication among components on the PCB will be tested to determine any failure on circuit ways and short circuits by supplying power to the PCB.

XBee will be tested between the layers to observe amount of signal quality drop in signal interruption.

Telemetry transmission will be tested between endpoint and coordinator XBees at the two sides of the Bosphorus (1.6 km) for determining antenna range which will provide the distance as approximately equal as that we will face in the competition.

Mechanism Test

It will be tested the performance of burning capability of Nichrome wire system for separation of payload from container on Breadboard.

It will be observed how much time required for opening of blades during free fall from drone.

The spring used in the payload release mechanism will be tested first on land with hand to make sure that it generates enough force and then the real test will be done with drone to see that the deployment can occur easily.

Deployment Test

Be sure that the altitude sensor and nichrome wire mechanism are calibrated on Breadboard.

Separation with Nichrome wire mechanism and the spring used for separation from container is to be tested both in land by using Breadboard and in air with drone.

The strengths of the latexes and hinges located at the folding points of the blades will be tested by applying force to the points one by one to see that the blades' are not fall apart from connector .

The connector which colligates payload and blades will be tested to see behaviours under emerging stress when blades open theoretically on ANSYS.

Ensure that the parachute ropes are securely attached to container by tension test.

Environmental Test Plan (1/2)

Drop Test

Many drop tests will be performed at different heights.
First of all, Cansat will be released from the top floor (approximately 18m) of the ITU Faculty of Aeronautical and Astronautical. Then, recovery team survive Payload and container. As a result of this test, the proper separation of the container and payload and the operation of the autogyro system will be observed.

Another important test is Cansat will be raised to 700 meters with the drone and will be released from there. Then, payload and container will separate, parachute will be open, folding blades will open and auto-gyro system is going to start to work. After that, Payload and container will be recovered and checked. Damage assessment will be done when payload and container drop the land.

Fit Check

A layer which has 18 cm x 18 cm x 3 cm dimensions and has a hole with 125 mm diameter will be cut from plywood and then it will be used for fit check.
After that length of container will be measured and will be sure that it is not longer than 310 mm.
If the container can pass smoothly then the test will be considered as successfully done.

Environmental Test Plan (2/2)

Thermal Test

Thermal tests will be done in the laboratory of the university in order to see the effect of extreme temperatures in mechanical and electronic components. The payload will be held in the test machine as much as estimated time that payload stay in the air. Then, electronic and mechanical parts will be controlled to make sure there is no heat damage.

Vibration Test

The payload will be placed in the machine, the sander will be set to its highest power, then the sander will be turned off for 2 seconds and this operation will be repeated for one minute. After the test will be finished, the parts of the payload will be checked by team members. The test will give us information about structural integrity, strength and fatigue of the probe. The test will be considered successful if the system's integrity would not change.

Mission Operations & Analysis

Zelal KARACA

Overview of Mission Sequence of Events (1/2)

Arrival	Pre-Launch	Installation
• Team will arrive to the launch site. • Integrity of CanSat will be checked for any damage may be occured during travel. • GCS and Antenna will be prepared.	• Separation mechanism will be connect to container with fishing line. • Assembly will be done. • The electronic components will be tested as an integrated system and telemetry will be controlled. • Mass of CanSat will be configured to 500 gr. • Finally, checklist will be controlled.	• Cansat will be switched on before installing to rocket. • Data transfer with GCS will be confirmed. • Rocket will be delivered to staff member.
Damage Control: Sercan - Muhammed	Assembling: Altuğ	GCS officer: Resul

Overview of Mission Sequence of Events (2/2)

Launch → Airborne → Recovery → Analysis

Launch

- Rocket will launch after Mission Control Officer completes flight procedures.
- When the rocket reaches apogee, CanSat will begin to free fall.

Mission Control Officer: Aykut

Airborne

- CanSat will stay integrated until it comes to 450m. After that Container and Payload will be separated.
- Payload will start autorotation and will decrease its speed between 10 to 15 m/s.
- Container will open parachute after separation.
- Payload will collect telemetry data and transfer to the GCS during descent.

Recovery

- Container will land with parachute.
- With the help of GPS telemetry and initialized audio beacon, recovery team will locate the payload.
- Recovery team will start searching when all launches are completed and area is safe.

Payload Recovery: Özen - Altuğ

Container Recovery: İsmail - Buse

Analysis

- Transmitted data will be analyzed.
- Damage control will be done.
- Flight data will be delivered to jury.
- Moving on to PFR.

Damage Control: Sercan - Muhammed

Mission Operations Manual Development Plan

Mission Operation Manual is combination of mission guide and also required to complete competition successfully.

1. Configure the Ground Control Station
2. Prepare the CanSat for Launch
3. Checklist Control
4. Launch Procedure
5. Removal Procedure
6. Recovery of Payload and Container

Mission Operation Manual

Mission operation manual may change as a result of our testing and rehearsals until the launch day.

Main Objectives:

- To make sure each member of Apis Ar-Ge comprehend competition, safety rules and their responsibilities.
- To complete competition safely.

CanSat Location and Recovery

Container Recovery	Payload Recovery
Container's color will be bright red to easily detect. **Parachute will have a florescent orange color to also easily detect.** ↓ **Recovery Crew of Container will find it due to both container and parachute's bright color.**	**Payload will initialize buzzer after landing.** **GPS sensor will provide information about landing position.** ↓ **Recovery Crew will find payload with the help of obtained GPS data and the voice of buzzer.**

Team name, team leader's phone number and team's e–mail address will be labeling on both Container and Payload. (BR-41)

Requirements Compliance

Sercan SALDAMLI

Requirements Compliance Overview

Most of the requirements have been completed. *(39/54)*

There is not any requirement that does not comply with our design.

➢ <u>Further Improvement Stages Until CDR</u>

- The table filled according to requirement based compliance help us to see which subsystem is needed to be developed.

- Mechanical system is theoretically completed but practical tests has not been done yet. Auto-gyro blade opening mechanism is to be tested practically.

- Parachute opening mechanism test is to be done via drop tests.

- Structural tests including impact, vibration and thermal must be done to check whether integrated system withstands.

- The whole electronic systems must be integrated and communication test shall be done inside the container.

- Shock survivability tests for blade opening mechanism is to be done via drop tests with various scenarios.

- Aerodynamic results obtained with computer based calculations shall be actualized with free fall tests.

- Payload separation test should be done frequently since it is our system priority.

Requirements Compliance(1/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
01	Total mass of the CanSat (science payload and container) shall be 500 grams +/- 10 grams.	Comply	p.90-91-92	*Completed.*
02	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.	Comply	p.24-25	*Completed.*
03	The container shall not have any sharp edges to cause it to get stuck in the rocket payload section which is made of cardboard.	Comply	p.78	*Completed.*
04	The container shall be a fluorescent color; pink, red or orange.	Comply	p.81	*Completed.*
05	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	p.83-84-85	*Completed.*
06	The rocket airframe shall not be used as part of the CanSat operations.	Comply	p.83-84-85	*Completed.*
07	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	Comply	p.81-85	*Completed.*

Requirements Compliance(2/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
08	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	Partial	p.56	*Theoretically complies but not yet tested.*
09	The container shall release the payload at 450 meters +/- 10 meters.	Partial	p.56-142-145	*Theoretically complies but not yet tested.*
10	The science payload shall descend using an auto-gyro/ passive helicopter recovery descent control system.	Comply	p.42	*Completed.*
11	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.	Partial	p.55-56	*Theoretically complies but not yet tested.*
12	All descent control device attachment components shall survive 30 Gs of shock.	Partial	-	*Theoretically complies but not yet tested.*
13	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Comply	p.64-65-83	*Completed.*
14	All structures shall be built to survive 15 Gs of launch acceleration.	Partial	-	*Theoretically complies but not yet tested.*

Requirements Compliance(3/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
15	All structures shall be built to survive 30 Gs of shock.	Partial	-	*Theoretically complies but not yet tested.*
16	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	p.65	*Completed.*
17	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Partial	-	*Theoretically complies but not yet tested.*
18	Mechanisms shall not use pyrotechnics or chemicals.	Comply	p.64/69	*Completed.*
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.	Comply	p.78-81-82	*No heat mechanism trade is selected.*
20	The science payload shall measure altitude using an air pressure sensor.	Partial	p.31-39-119	*Theoretically complies but not yet tested.*
21	The science payload shall provide position using GPS.	Partial	p.33-119	*Theoretically complies but not yet tested.*

Requirements Compliance(4/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
22	The science payload shall measure its battery voltage.	Partial	p.118-119	*Theoretically complies but not yet tested.*
23	The science payload shall measure outside temperature.	Partial	p.32-118-119	*Theoretically complies but not yet tested.*
24	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.	Partial	p.36-37-118-119	*Theoretically complies but not yet tested.*
25	The science payload shall measure pitch and roll.	Partial	p.35-118-119	*Theoretically complies but not yet tested.*
26	The probe shall transmit all sensor data in the telemetry.	Partial	p.104-105	*Theoretically complies but not yet tested.*
27	The Parachute shall be fluorescent Pink or Orange.	Comply	p.45	*Completed.*
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.	Partial	p.130-161	*Theoretically complies but not yet tested.*
29	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.	Comply	p.159-161	*Completed.*

Requirements Compliance(5/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
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.	Comply	p.102	*Completed.*
31	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	Comply	p.105	*Completed.*
32	XBEE radios shall have their NETID/PANID set to their team number.	Comply	p.105	*Completed.*
33	XBEE radios shall not use broadcast mode.	Comply	p.105	*Completed.*
34	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Comply	p.183-184-185-186	*Completed.*
35	Each team shall develop their own ground station.	Comply	p.154-155	*Completed.*
36	All telemetry shall be displayed in real time during descent.	Comply	p.159-160-161	*Completed.*

Requirements Compliance(6/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
37	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	p.159-160	*Completed.*
38	Teams shall plot each telemetry data field in real time during flight.	Comply	p.159-160	*Completed.*
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.	Comply	p.155-158	*Completed.*
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.	Comply	p.155	*Completed.*
41	Both the container and probe shall be labeled with team contact information including email address.	Comply	p.175	*Completed.*
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.	Comply	p.141	*Completed.*

Requirements Compliance(7/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
44	No lasers allowed.	Comply	-	*Completed.*
45	The payload must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	Comply	p.15	*Completed.*
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.	Comply	p.121	*Completed.*
47	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Comply	p.113-118-119	*Completed.*
48	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Comply	-	*Completed.*
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.	Comply	p.120-125	*Completed.*

Requirements Compliance(8/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
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.	Comply	p.15-16	*Completed.*
51	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	p.89	*Completed.*
52	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.	Comply	p.46-47	*Completed.*
53	The GPS receiver must use the NMEA 0183 GGA message format.	Comply	p.33	*Completed.*
54	The CANSAT must operate during the environmental tests laid out in Section 3.5.	Comply	p.169-170	*Completed.*
55	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	Comply	p.120/128	*Completed.*

Requirements Compliance(9/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
Bonus	A video camera shall be integrated into the science payload to record the descent after being released from the container. The camera shall point downward 45 degrees from 10 nadir of the 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. Direction does not matter as long as it is in one direction. The payload can pick the direction. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The direction the camera is pointed relative to earth's magnetic north shall be included in the telemetry.	Partial	p.19-38	*Theoretically complies but not yet tested.*

Management

Aykut ÜÇTEPE

CanSat Budget – Hardware (1/3)

Electronics				
Component	Model	Quantity	Unit Price[$]	Total[$]
Gyroscope	MPU6050	1	2,97 (Actual)	2,97
Barometer	BMP180	2	9,95 (Actual)	19,90
GPS	Adafruit Ultimate GPS	1	39,95 (Actual)	39,95
Camera	Adafruit Mini Spy Camera	1	12,50 (Actual)	12,50
SD Card	SANDISK 16 GB	3	7,00 (Actual)	21,00
XBEE	XBEE PRO S2C	1	44,00 (Actual)	44,00
Antenna (Payload)	TL-ANT2405CL	1	5,00 (Actual)	5,00
Microcontroller (Payload)	Teensy 3.5	1	24,95 (Actual)	24,95
Microcontroller (Container)	Teensy 3.2	1	19,80 (Actual)	19,80
RPM Sensor	FC-33	1	1,82 (Actual)	1,82
Voltage Regulator	Pololu 5V	1	7,00(Actual)	7,00
Buzzer	Buzzer	1	1,00(Actual)	1,00
Battery (Container)	OEM 16340	1	4,00(Actual)	4,00
Battery (Payload)	LG M50 21700	1	9,00 (Actual)	9,00
Magnetometer	HMC5883L	1	9,26 (Actual)	9,26

CanSat Budget – Hardware (2/3)

Electronics				
Component	**Model**	**Quantity**	**Unit Price[$]**	**Total[$]**
XBEE Adapter	XBEE Explorer Dongle	1	24,95 (Actual)	24,95
Servo Motor	PowerHD DSM44	2	18,40 (Actual)	36,80
Stepper Motor	Sanyo Miniature Stepper	1	99,95 (Actual)	99,95
Stepper Motor Driver	DRV8834	1	5,95 (Actual)	5,95

ELECTRONICS TOTAL:	$ **389,80**

CanSat Budget – Hardware (3/3)

Mechanical				
Component	Model	Quantity	Unit Price[$]	Total[$]
Payload Body	Fiberglass Stick	1 m	7,00 per m	7,00 (Actual)
Payload Body	Plywood Layers	0,5 m2	6,00 per m2	3,00 (Actual)
Container	Fiberglass fabric	1 m2	20,00 per m2	20,00 (Actual)
Parachute	30d silicone nylon 66 cloth	1 m2	5,00 per m2	5,00 (Actual)
Mechanism	Spring	1 m	5,00 per m	5,00 (Actual)
Release Mechanism	Nichrome Wire + MOSFET	0,2 m	1,00 per m	0,2 (Actual)
Other tools	Adhesive,hinge, etc	-	25,00	30,00 (Estimated)

MECHANICS TOTAL:	$ **70,2**
OVERALL TOTAL:	$ **460,00**
MARGIN (%10)	$ **3**

CanSat Budget – Other Costs (1/3)

Ground Station				
Component	Model	Quantity	Unit Price[$]	Total[$]
XBEE	XBEE PRO S2C	1	44,00 (Actual)	44,00
XBEE Adapter	XBEE Explorer Dongle	1	24,95 (Actual)	24.95
Antenna (Ground Station)	TL-ANT2415D	1 (Re-Used)	66,00 (Actual)	66,00
Computer	Dell-inspiron 3542	1 (Re-Used)	Private	Private
Antenna Holder	Self Made	1	6,00 (Actual)	6,00 (Actual)

TOTAL:	$ **140,95**

CanSat Budget – Other Costs (2/3)

Other Costs	Quantity	Unit Price[$]	Total[$]
Travel	10	500 (Estimate)	5000
Hotel	3 rooms for 3 nights	100 (Estimate)	900
Rent Cars	2 cars for 3 days	150 (Estimate)	900
Prototyping	2	140 (Estimate)	280
Test facilities and equipment	University Provided	University Provided	University Provided
Fee	1	100 (Actually)	100

TOTAL	$ **7180**
MARGIN (%10)	$ **708**

CanSat Budget – Other Costs (3/3)

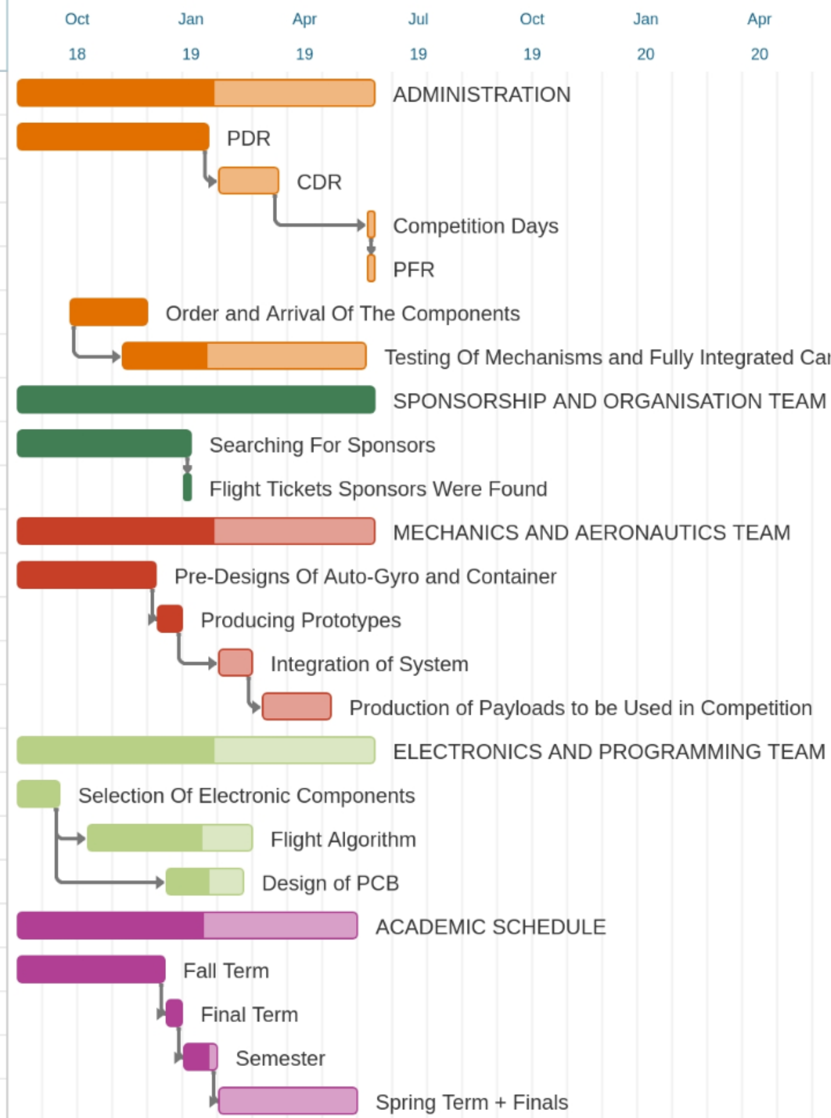
Categories	Cost [$]
Electrical and Mechanical	460,00
Ground Station	140,95
Other Costs	7180
TOTAL	$ 7780,95
MARGIN	$ 711
INCOME	$ **10000**

- Main source of 10000$ income is companies that agreed to finance our team throughout the competition.

Program Schedule Overview

Summary

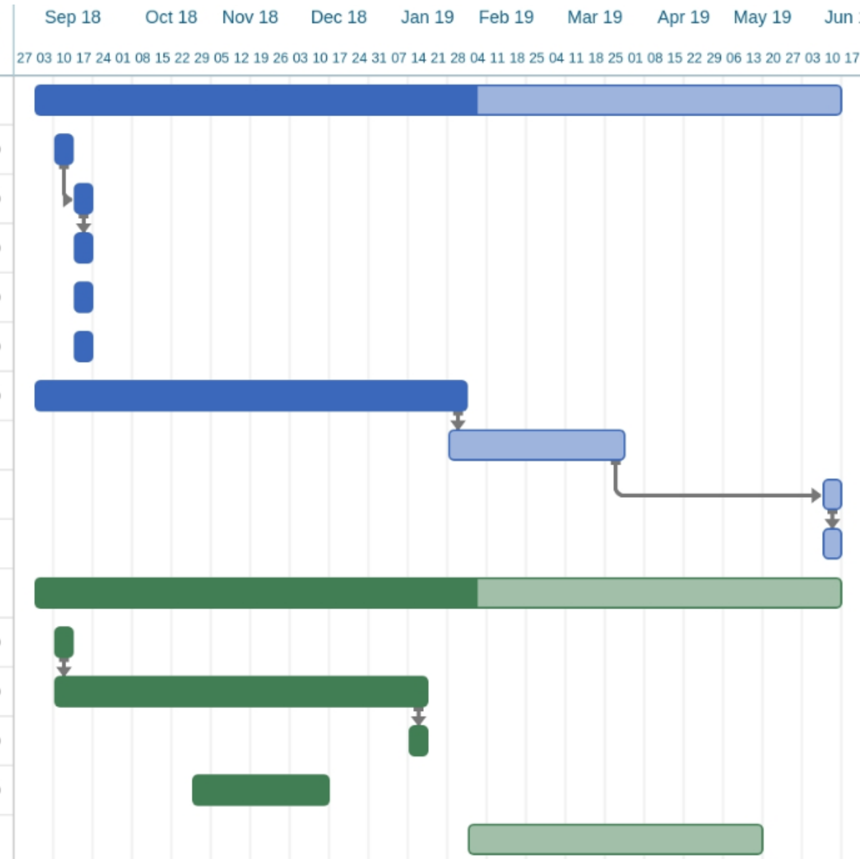
		Assignee	Start Date	Cal. Days	Due Date	Task Prog.
AÜ	ADMINISTRATION	Aykut Üçtepe	09/Sep	281d	16/Jun	55%
AT	PDR	VU: All Team	09/Sep	146d	01/Feb	100%
AT	CDR	VU: All Team	14/Feb	44d	29/Mar	0%
AT	Competition Days	VU: All Team	16/Jun	1d	16/Jun	0%
AT	PFR	VU: All Team	16/Jun	1d	16/Jun	0%
AÜ	Order and Arrival Of The Components	Aykut Üçtepe	21/Oct	56d	15/Dec	100%
AT	Testing Of Mechanisms and Fully Integrated Cansat	VU: All Team	01/Dec	188d	06/Jun	35%
ZK	SPONSORSHIP AND ORGANISATION TEAM	VU: Zelal Karaca	09/Sep	281d	16/Jun	100%
ZK	Searching For Sponsors	VU: Zelal Karaca	09/Sep	132d	18/Jan	100%
ZK	Flight Tickets Sponsors Were Found	VU: Zelal Karaca	18/Jan	1d	18/Jan	100%
İÖ	MECHANICS AND AERONAUTICS TEAM	VU: İsmail Özcan	09/Sep	281d	16/Jun	55%
A	Pre-Designs Of Auto-Gyro and Container	VU: Aykut-İsmail	09/Sep	100d	17/Dec	100%
Ö	Producing Prototypes	VU: Özen	30/Dec	9d	07/Jan	100%
M	Integration of System	VU: Muhammed	12/Feb	23d	06/Mar	0%
AM	Production of Payloads to be Used in Competition	VU: All Mecha…	23/Mar	50d	11/May	0%
AE	ELECTRONICS AND PROGRAMMING TEAM	VU: Altuğ Ertan	09/Sep	281d	16/Jun	55%
RD	Selection Of Electronic Components	VU: Resul Dag…	09/Sep	24d	02/Oct	100%
AE	Flight Algorithm	VU: Altuğ Ertan	02/Nov	127d	08/Mar	70%
BC	Design of PCB	VU: Buse Cop	31/Dec	60d	28/Feb	55%
AT	ACADEMIC SCHEDULE	VU: All Team	03/Sep	271d	31/May	55%
AT	Fall Term	VU: All Team	03/Sep	117d	28/Dec	100%
AT	Final Term	VU: All Team	02/Jan	8d	09/Jan	100%
AT	Semester	VU: All Team	14/Jan	22d	04/Feb	75%
AT	Spring Term + Finals	VU: All Team	15/Feb	106d	31/May	0%



Detailed Program Schedule (1/3)

Detailed Gantt Chart

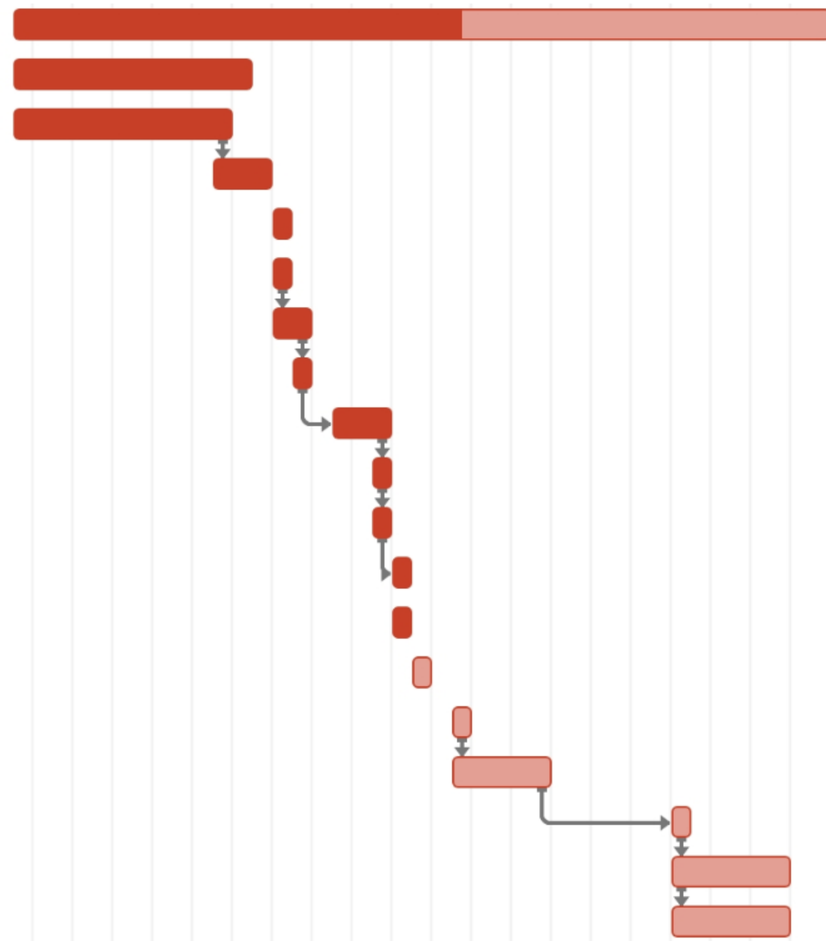
	Task	Assignee	Start Date	Cal. Days	Due Date	Task Prog.
AÜ	ADMINISTRATION	Aykut Üçtepe	09/Sep	281d	16/Jun	55%
AÜ	Recruiting new team members	Aykut Üçtepe	10/Sep	1d	10/Sep	100%
AÜ	The first meeting of this term	Aykut Üçtepe	18/Sep	1d	18/Sep	100%
AÜ	Task Sharing	Aykut Üçtepe	18/Sep	1d	18/Sep	100%
AÜ	Planning to Team meetings in every Tuesday	Aykut Üçtepe	18/Sep	1d	18/Sep	100%
AT	Analyzing PDRs of last year	VU: All Team	17/Sep	2d	18/Sep	100%
AT	PDR	VU: All Team	09/Sep	146d	01/Feb	100%
AT	CDR	VU: All Team	01/Feb	57d	29/Mar	0%
AT	Competition Days	VU: All Team	14/Jun	3d	16/Jun	0%
AT	PFR	VU: All Team	16/Jun	1d	16/Jun	0%
ZK	SPONSORSHIP AND ORGANISATION TEAM	VU: Zelal Karaca	09/Sep	281d	16/Jun	55%
ZK	Created Sponsorship File	VU: Zelal Karaca	16/Sep	1d	16/Sep	100%
ZK	Searching For Sponsors	VU: Zelal Karaca	16/Sep	125d	18/Jan	100%
ZK	Flight tickets sponsors were found	VU: Zelal Karaca	18/Jan	1d	18/Jan	100%
AÜ	Designing Team T-shirts	Aykut Üçtepe	01/Nov	40d	10/Dec	100%
AT	Team Members Start To Give Robotic Lessons to …	VU: All Team	10/Feb	94d	14/May	0%



VU = Virtual User

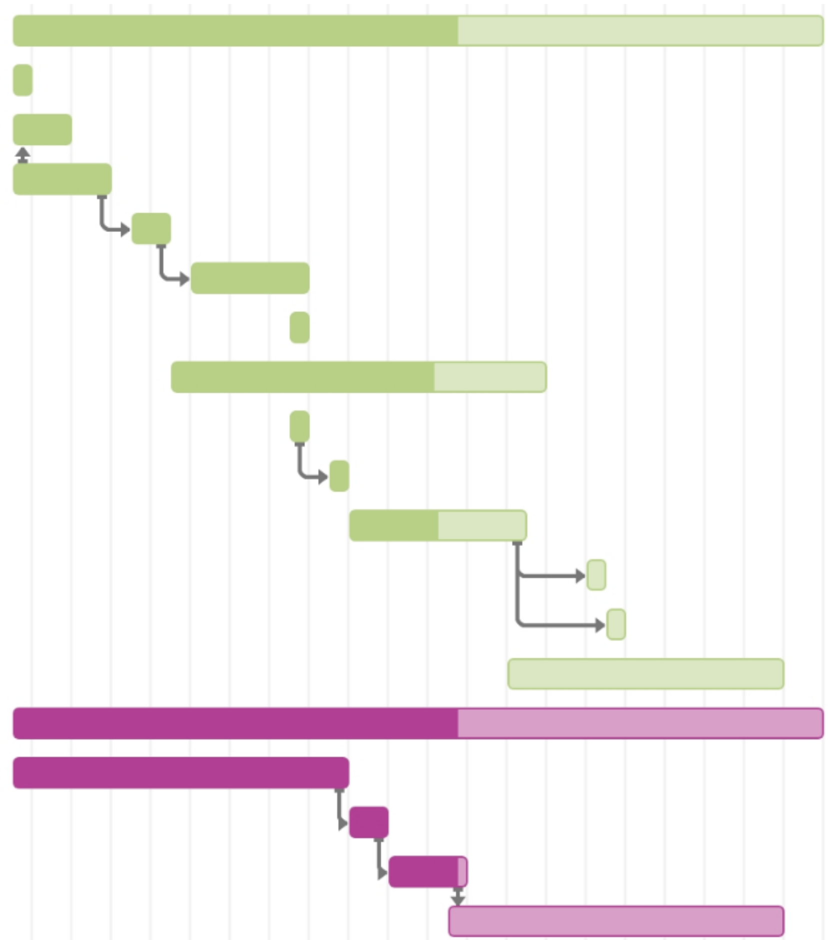
Detailed Program Schedule (2/3)

	Task	Assigned	Start	Duration	End	Progress
IÖ	MECHANICS AND AERODYNAMICS TEAM	VU: İsmail Özcan	09/Sep	281d	16/Jun	55%
S	Payload Structural Design	VU: Sercan-M...	09/Sep	72d	19/Nov	100%
AÜ	AutoGyro Blade Design	Aykut Üçtepe	09/Sep	65d	12/Nov	100%
ÖH	AutoGyro Blades Folding Mechanism Design	VU: Özen Haliç	12/Nov	21d	02/Dec	100%
IÖ	Container Design	VU: İsmail Özcan	04/Dec	1d	04/Dec	100%
SS	Material Selection	VU: Sercan Sa...	04/Dec	6d	09/Dec	100%
AÜ	Order of Some Materials For Prototypes	Aykut Üçtepe	09/Dec	3d	11/Dec	100%
AÜ	Arrival of Mechanic Components	Aykut Üçtepe	11/Dec	5d	15/Dec	100%
ÖH	To Produce the First Prototype	VU: Özen Haliç	25/Dec	14d	07/Jan	100%
S	AutoGyro Blades Rotation Test	VU: Sercan-M...	11/Jan	1d	11/Jan	100%
S	AutoGyro Blades Loading Test	VU: Sercan-Öz...	11/Jan	1d	11/Jan	100%
IÖ	Testing Friction of the Roller	VU: İsmail Özcan	16/Jan	1d	16/Jan	100%
IÖ	Impact Test of the Structure	VU: İsmail Özcan	15/Jan	1d	15/Jan	100%
SS	Impact Test of the Gimball Protection Shield	VU: Sercan Sa...	23/Jan	1d	23/Jan	0%
S	Testing the Prototypes	VU: Sercan-Öz...	06/Feb	1d	06/Feb	0%
M	Integration Of Parts into the Payload	VU: Muhammed	06/Feb	29d	06/Mar	0%
AM	Testing All System via Rocket or Drone	VU: All Mecha...	22/Apr	1d	22/Apr	0%
AM	Making Modifications Due to Test Results	VU: All Mecha...	22/Apr	40d	31/May	0%
AM	Production Of Probes to be Used in Competition	VU: All Mecha...	22/Apr	40d	31/May	0%



Detailed Program Schedule (3/3)

AE	ELECTRONICS AND PROGRAMMING TEAM	VU: Altuğ Ertan	09/Sep	281d	16/Jun	55%
AE	Project Start	VU: Altuğ Ertan	09/Sep	1d	09/Sep	100%
RD	Selection of Microcontroller	VU: Resul Dag…	09/Sep	13d	21/Sep	100%
RD	Selection of sensors	VU: Resul Dag…	08/Sep	25d	02/Oct	100%
AÜ	Order of hardware components	Aykut Üçtepe	21/Oct	3d	23/Oct	100%
AÜ	Arrival of Elecronic Components	Aykut Üçtepe	10/Nov	36d	15/Dec	100%
RD	Separation system algorithm	VU: Resul Dag…	10/Dec	1d	10/Dec	100%
AE	Flight algorithm	VU: Altuğ Ertan	02/Nov	127d	08/Mar	70%
RD	Battery Selection	VU: Resul Dag…	10/Dec	1d	10/Dec	100%
AE	Test on the Breadboard	VU: All Electro…	29/Dec	1d	29/Dec	100%
BC	Design of PCB	VU: Buse Cop	31/Dec	60d	28/Feb	50%
AE	Seperation System Test	VU: All Electro…	25/Mar	1d	25/Mar	0%
EA	Xbee Communucation Test in Bosphorus	VU: Elif Acar	04/Apr	1d	04/Apr	0%
AE	Making Changes and Redesign	VU: All Electro…	25/Feb	96d	31/May	0%
AT	ACADEMIC SCHEDULE	VU: All Team	09/Sep	281d	16/Jun	55%
AT	Fall Term	VU: All Team	09/Sep	111d	28/Dec	100%
AT	Final Term	VU: All Team	02/Jan	8d	09/Jan	100%
AT	Semester	VU: All Team	14/Jan	22d	04/Feb	90%
AT	Spring Term + Finals	VU: All Team	04/Feb	117d	31/May	0%



Conclusions

Administration & Finance

Major Accomplishments:

1. Schedule was created.
2. Financial income was secured.
3. Airline tickets sponsors were found.
4. PDR was completed.

Major Unfinished Work:

1. 4 team members visas are not applied yet.

Electronics & Programming

Major Accomplishments:

1. Electronic component choosing is fully completed.
2. FSW is done except bonus mission.

Major Unfinished Work:

1. The fully integrated electronic systems will be tested in order to have perfect functionality.

Mechanics & Aerodynamics

Major Accomplishments:

1. Payload and Container were elaborately discussed and a choice that seemed the best for every branch was made.

Major Unfinished Work:

1. The fully finished CanSat needs to be tested.

Conclusion: **Nothing has been delayed, the schedules and deadlines have been met. APIS AR-GE Team is ready to move on to CDR.**