CanSat 2019
Critical Design Review (CDR)
Outline
Version 1.4

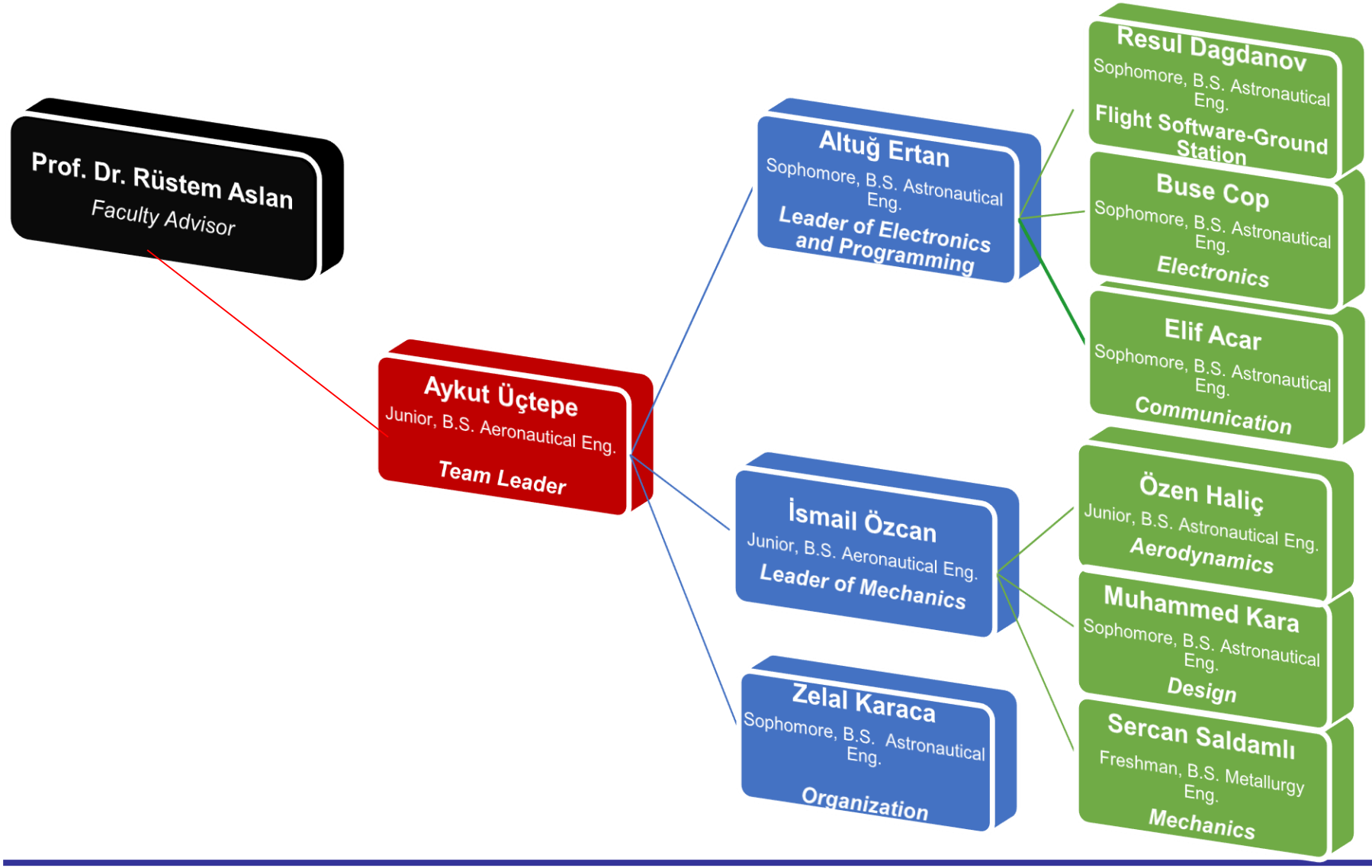
#6203

APIS ARGE TEAM

Presentation Outline

Section	Presenter	Pages
System Overview	Aykut ÜÇTEPE	5-26
Sensor Subsystem Design	Altuğ ERTAN	27-40
Descent Control Design	İsmail ÖZCAN	41-63
Mechanical Subsystem Design	Muhammed KARA	64-94
CDH Subsystem Design	Elif ACAR	95-115
EPS Design	Buse COP	116-133
FSW Design	Altuğ ERTAN	134-158
GCS Design	Resul DAGDANOV	159-171
CanSat Integration and Test	Özen HALİÇ	172-186
Mission Operations & Analysis	Aykut ÜÇTEPE	187-193
Requirements Compliance	Sercan SALDAMLI	194-204
Management	Aykut ÜÇTEPE	205-219

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	Electrical Power Subsystem
FSW	Flight Software
G	G-force
GCS	Ground Control System
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

System 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.

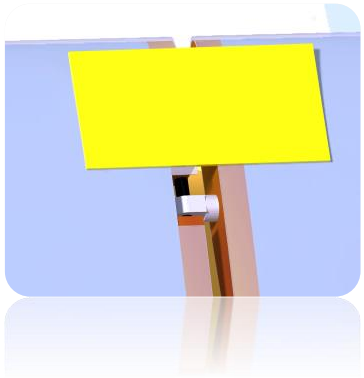
External Objectives

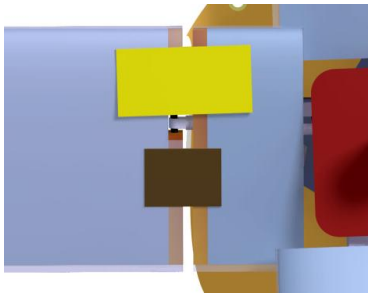
- Funding for project's hardware and logistic needs.
- Funding for flight tickets which covers round trip from Istanbul to Texas.
- Promoting APIS Ar-Ge with CanSat Competition and scientific developments achieved. The aim is to gain reputation in our home university and in Turkey.
- Organizing social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

Summary of Changes Since PDR (1/2)

Mechanical Changes

Component	Changes	Rationale
Rotor blade	Stopper apparatus was added	To overcome problems occurred after blades are opened.
Bearing	Bearing is changed with another model.	New bearing has less friction coefficient than previous one.

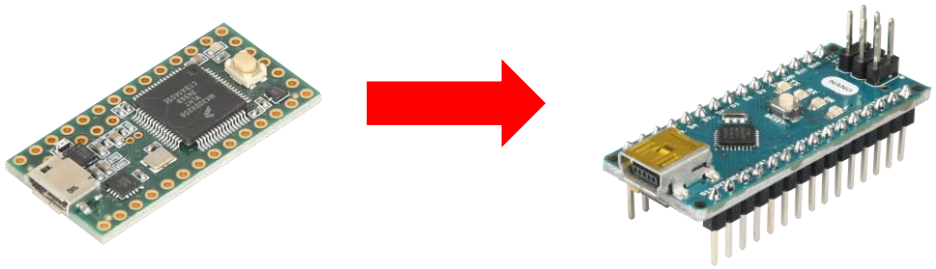




Summary of Changes Since PDR (2/2)

Electronical Changes

Component	Changes	Rationale
Camera Stabilizer	A servo was removed from the camera stabilizer.	After the free fall tests, it was decided that one of 2 servo motors was unnecessary.
Microprocessor of the Container	Teensy 3.2 is changed with Arduino Nano.	Teensy 3.2 is required a step-down regulator to be supplied, but Arduino can work by high power supplies.
Pitch/Roll Sensor	BNO055 is decided to use instead of MPU6050.	MPU6050 is insufficient to satisfy high data accuracy and does not include a magnetometer.
Battery of the Container	2 Orion 10440s are decided to use instead of OEM 16340.	Two batteries connected as series, because we needed high voltage.



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)

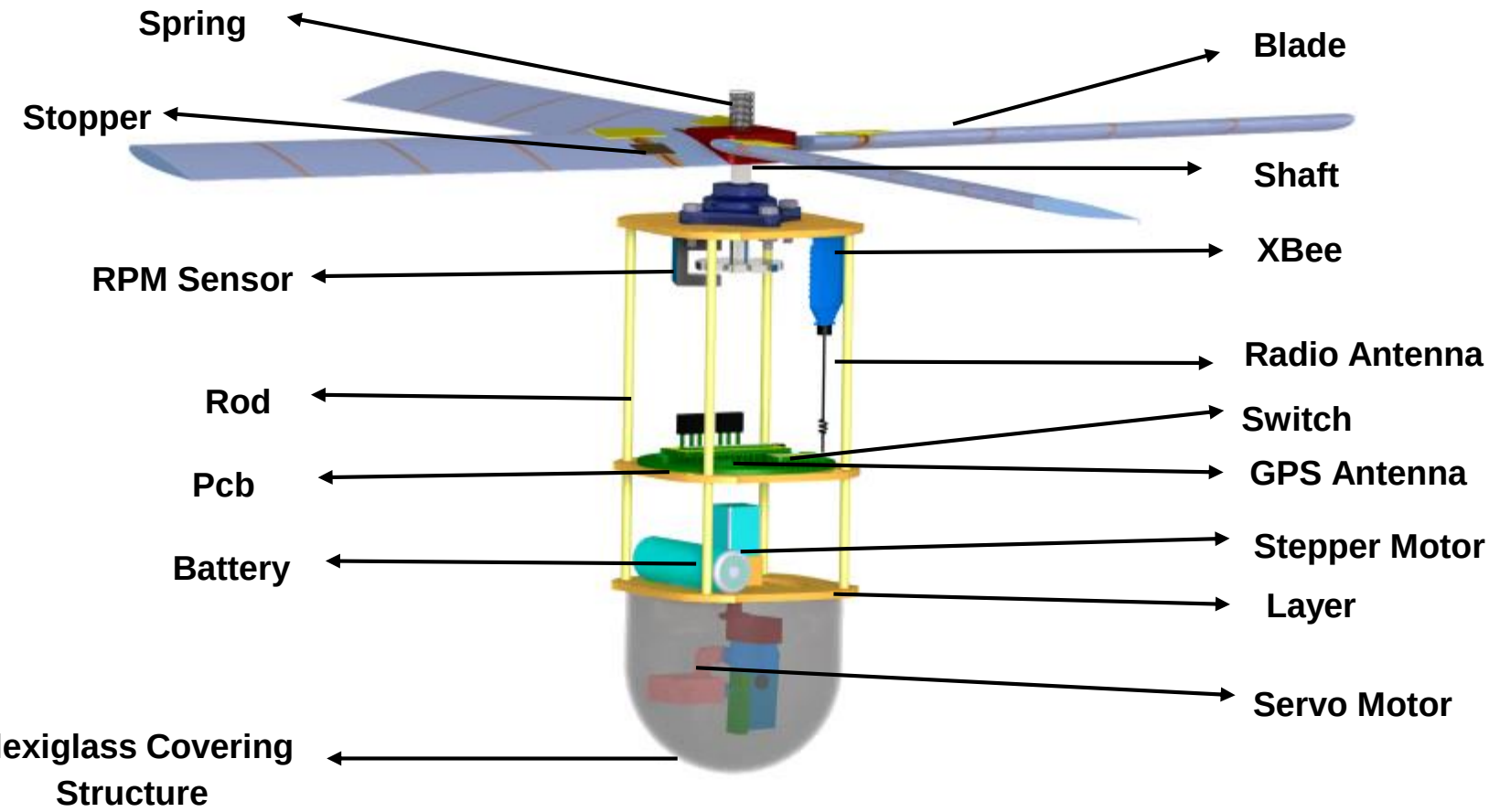
ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
SY-19	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	CReq	BR-31	CDH-10	Very High	✓	✓		✓
SY-20	Cost of the CanSat shall be under $1000. Ground support and analysis 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	✓		✓	

Payload Physical Layout (1/8)

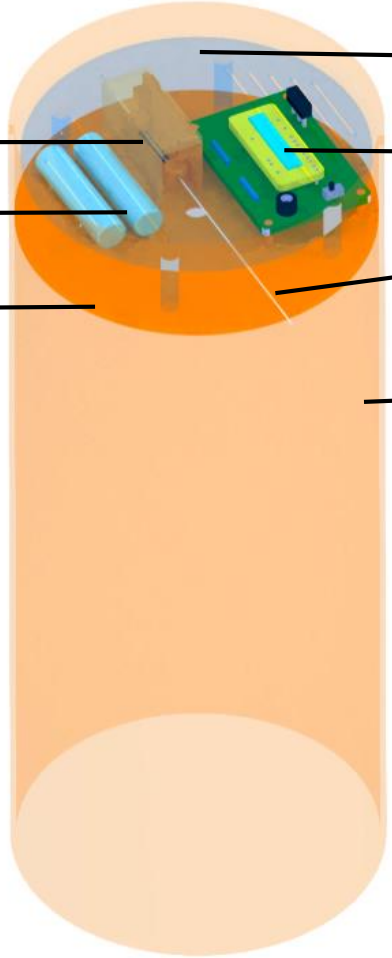
PAYLOAD



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

Payload Physical Layout (2/8)

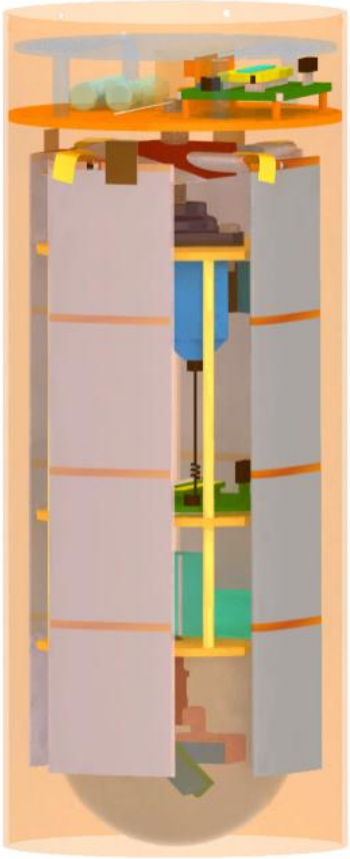
CONTAINER



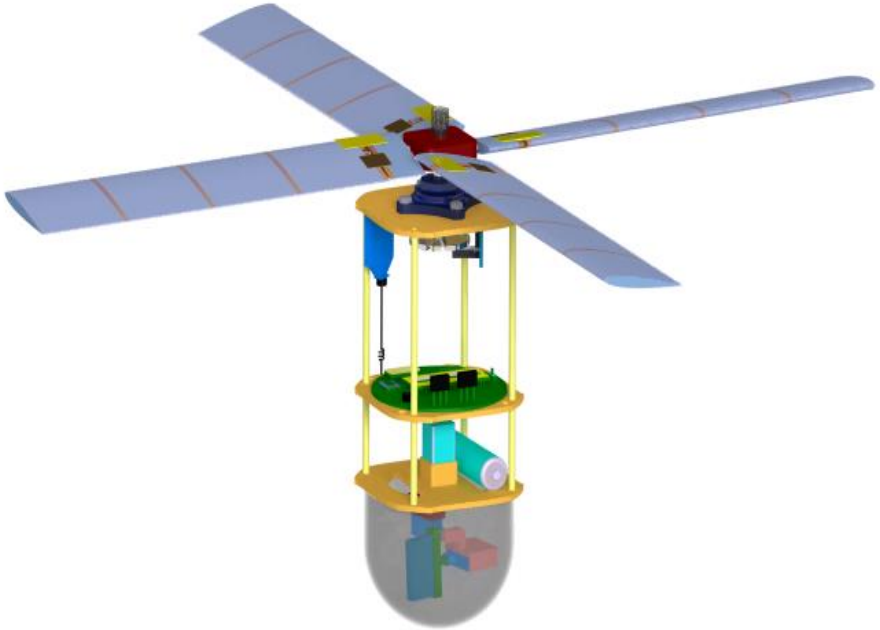
Payload Physical Layout (3/8)

CANSAT

Launch Configuration

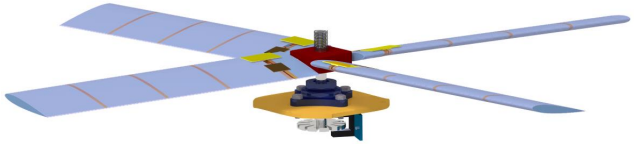


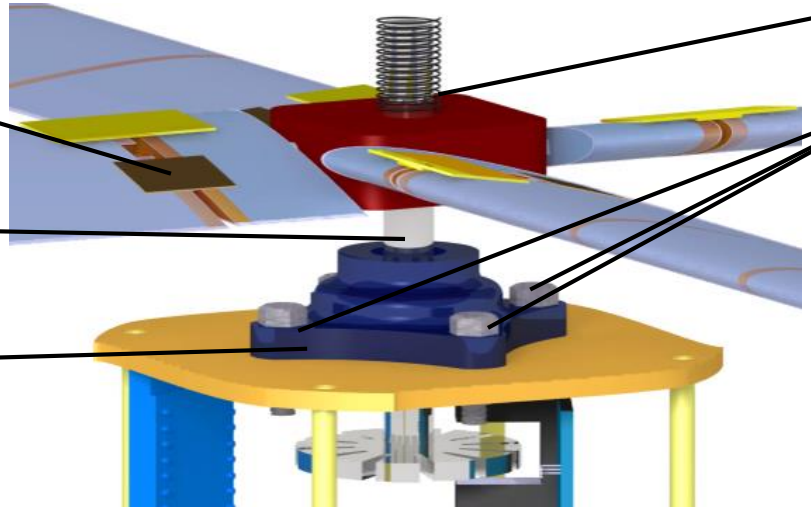
Deployed Configuration

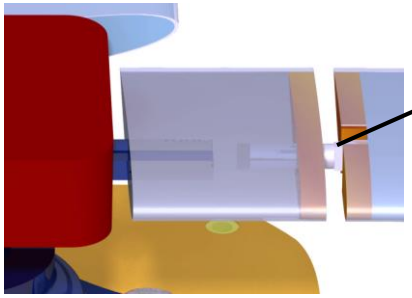


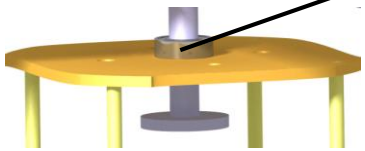
Payload Physical Layout (4/8)

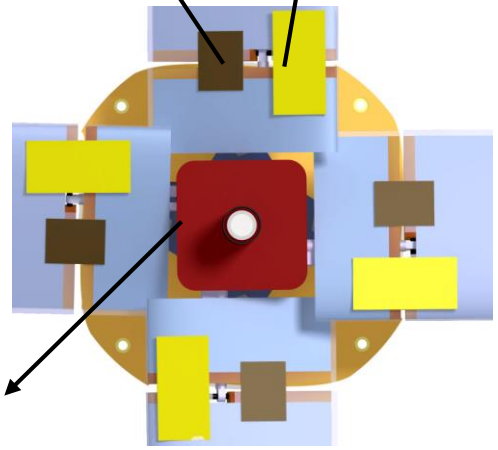
Auto-gyro Mechanism











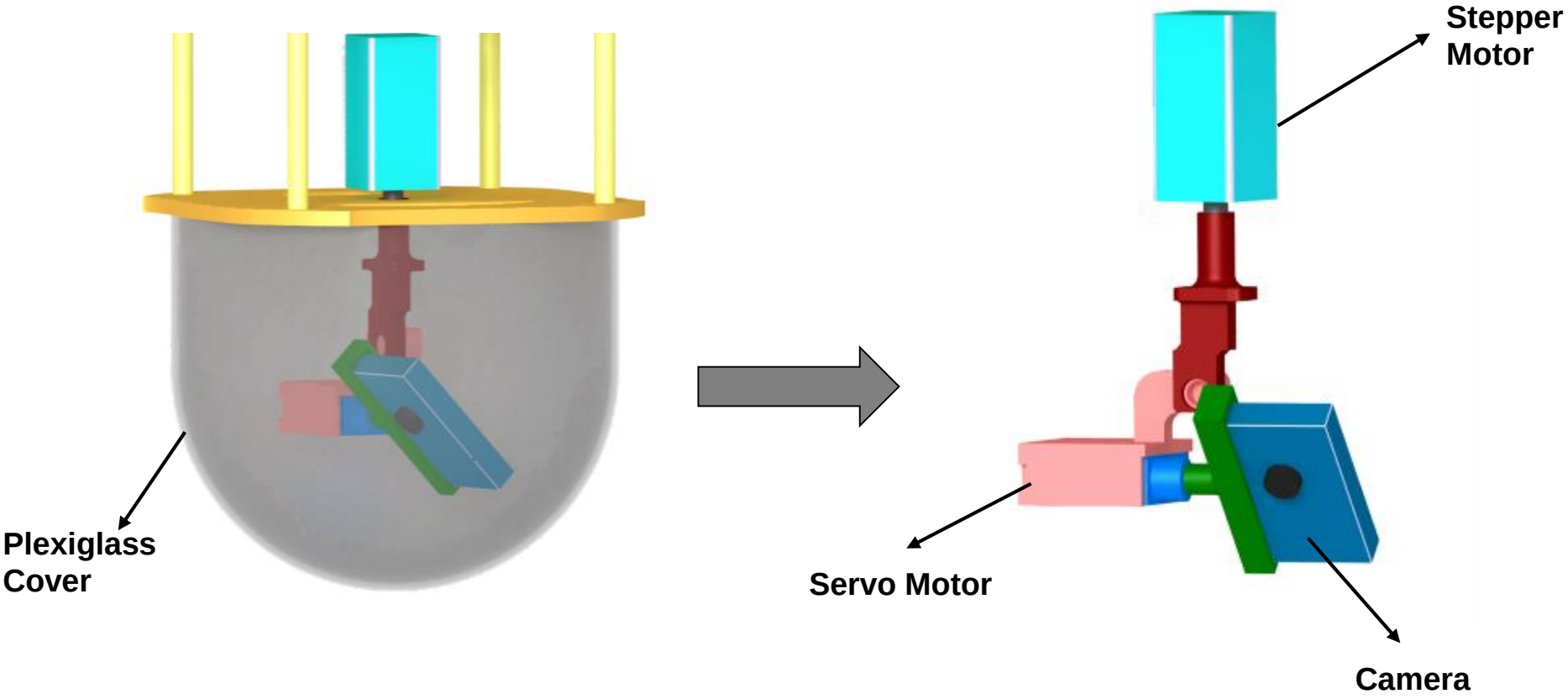
Payload Physical Layout (5/8)

Auto-gyro Mechanism

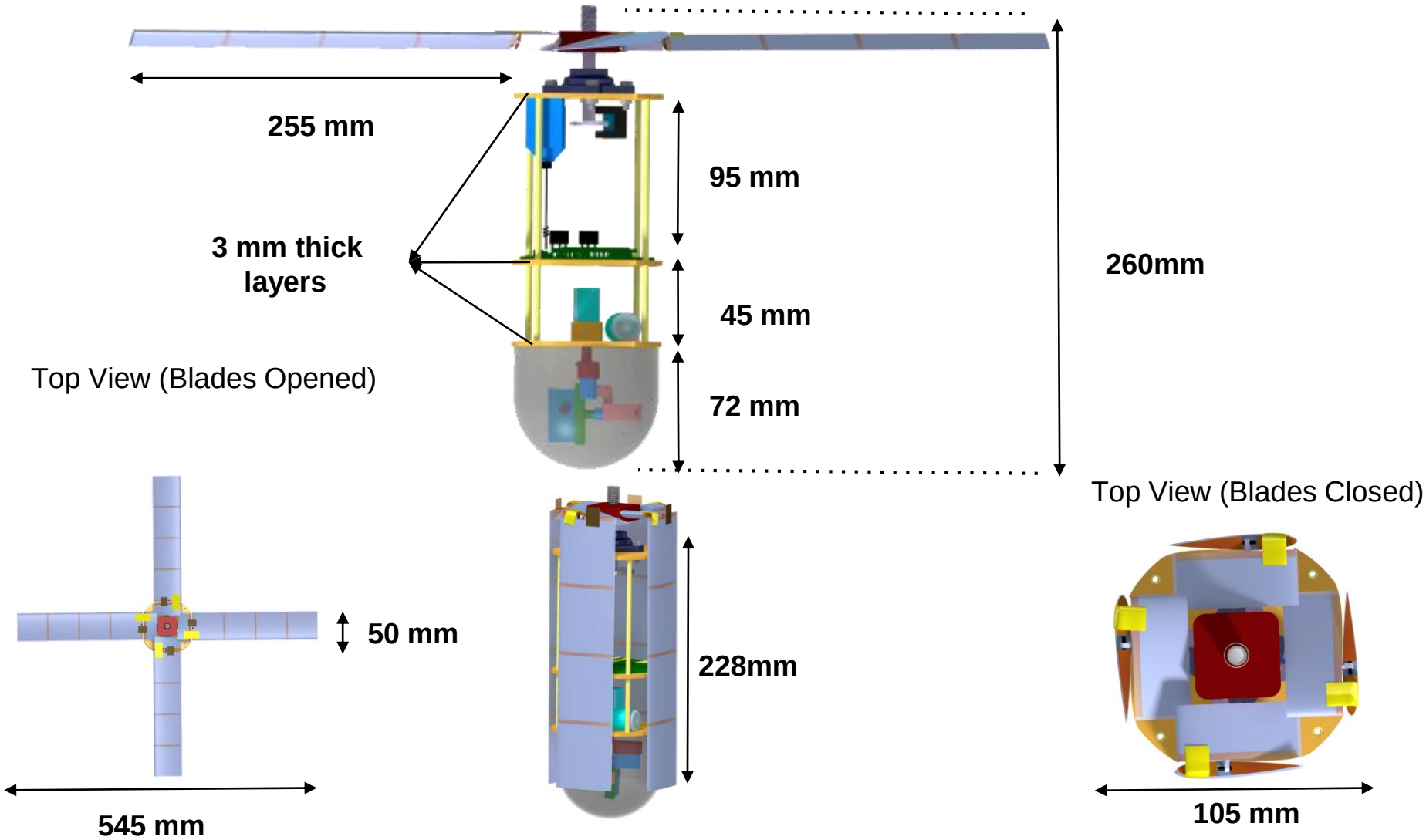
Prototypes

Payload Physical Layout (6/8)

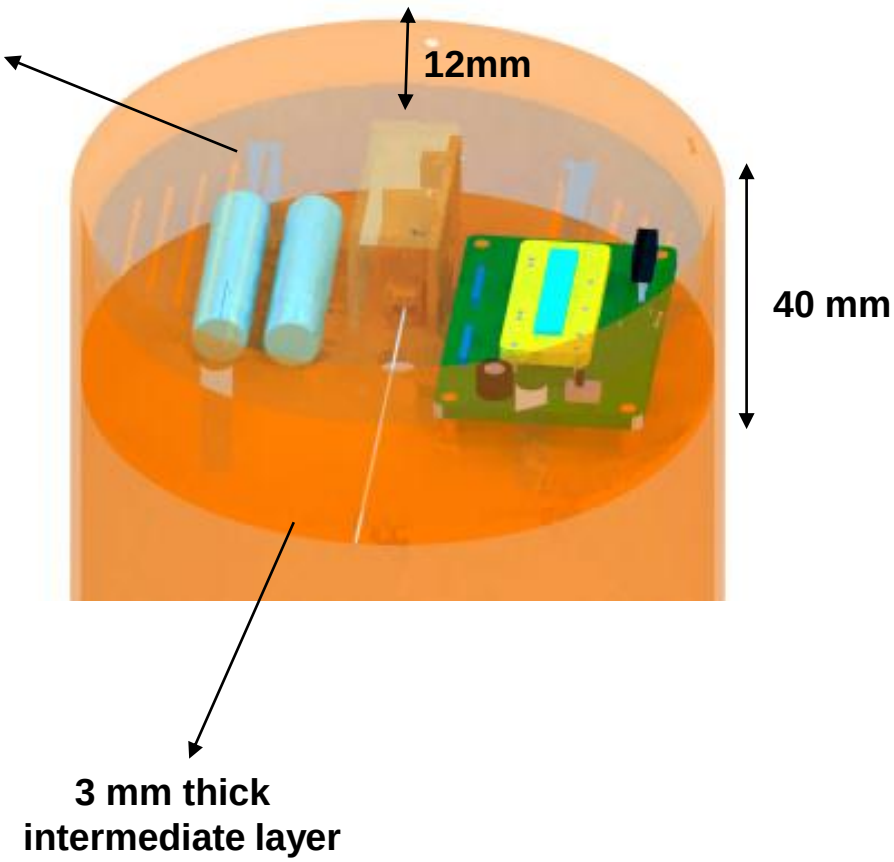
Camera Stabilizer Mechanism



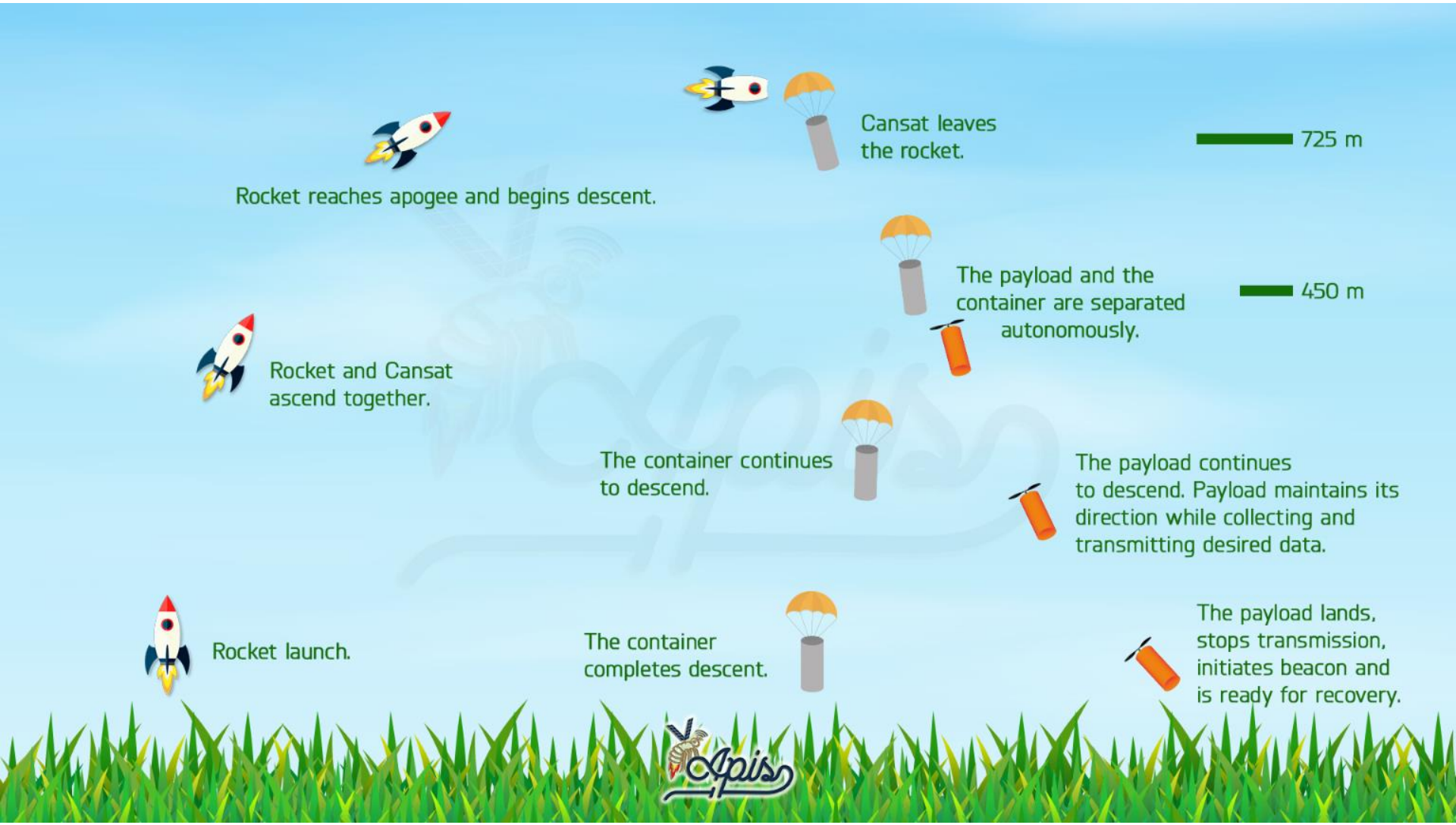
Payload Physical Layout (7/8)



Payload Physical Layout (8/8)



System Concept of Operations (1/3)



System Concept of Operations (2/3)

Pre-Launch	Launch	Post-Launch
• Competition area arrival. • Team briefing. • Electronic and mechanic integrity checks. • GCS and antenna set up. • Damage control before the flight by CanSat Crew. • Double check for final CanSat integrity configuration and release mechanism by Inspection Crew. • Making sure mass is between 490 g and 510 g	• Placement of Cansat into rocket payload section by Cansat Crew. • Launch, and events of CONOPS (given in previous slide). • Telemetry data obtaining and .csv file creation via GCS software.	• Recovery of payload with indicators fluorescent color, GPS telemetry and audio beacon. • Recovery of container with indicators fluorescent color. • Recovered CanSat is brought to GCS. • Analysis of sampled data. • Preparation of PFR. • PFR presentation to jury.

Inspection Crew

Mechanics: İsmail - Özen

Electronics: Altuğ - Resul

Cansat Crew

İsmail - Sercan

System Concept of Operations (3/3)

1	Placement	• Power on the Cansat. • Check the communication between payload and GCS. • Placement to rocket payload section.	**Mission Control Officer:** Aykut
2	Launch	• Rocket takes off. • Parachute opens at apogee. Cansat starts to descent with parachute until 450m.	**GCS Officer:** Resul
3	Seperation	• At 450m, the separation mechanism is activated and payload is released. • At same altitude, camera starts to capturing the descent. • During descend, CanSat continues to collect: air pressure,temperature,voltage,GPS data,tilting,software state, RPM until the landing..	Recovery Crew
4	Recovery	• The Payload lands with auto-gyro mechanism. • The payload finishes descent, stops telemetry and initiates audio beacon. • The Container lands with parachute.	**Payload:** Özen - Altuğ **Container:** İsmail - Buse
5	Data Analysis	• Analyzing the data retrieved from descent control devices. • Delivering requested data to jury. • Getting ready for PFR.	**PFR:** İsmail - Altuğ

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

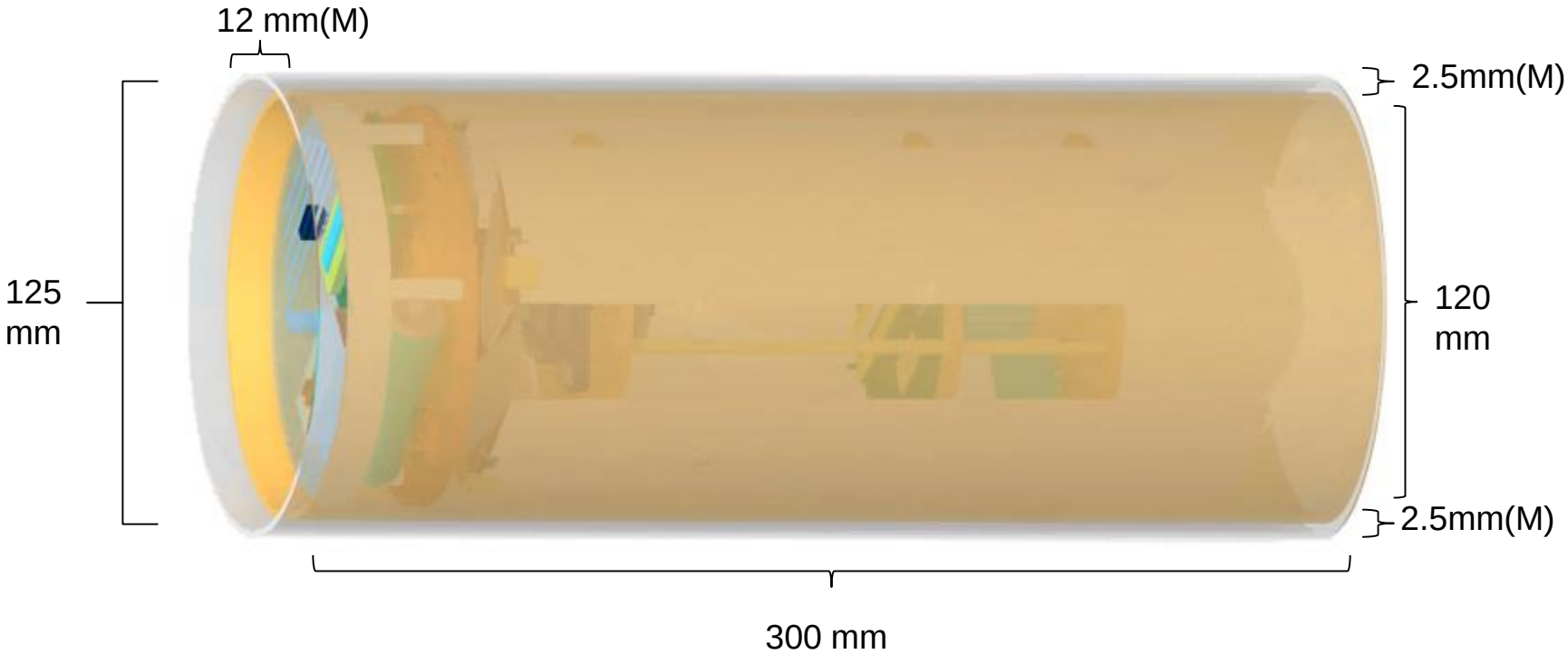
- ★ Payload dimensions after deployment:
  - Rotor Diameter: 545 mm
  - Structure Diameter: 102 mm
  - Height: 260 mm

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

➢ 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, the 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	Adafruit BNO055	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	Adafruit BNO055	Measurement of angle with respect to magnetic north	Payload

Sensor Changes Since PDR

- MPU6050 which is a **Pitch and Roll** sensor was changed because of the zero rate level value which is ±20 degree per second, this zero rate level is inefficient to determine instantaneous pitch and roll angle changes. Instead of MPU6050, Adafruit BNO055 was selected since BNO055 offers ±1 degree per second zero rate level value, so BNO055 gives healthy measurement about instant pitch and roll angle changes. Also, BNO055 is an Inertial Measurement Unit (IMU) sensor including accelerometer, gyroscope, and magnetometer together rather than MPU6050.

- HMC5883L which is a **Magnetometer** sensor was changed because of the programming and communication problems. HMC5883L cannot be found by our microcontroller on the I²C port usually, and libraries are hard to understand for controlling HMC5883L. Also, an IMU unit offers more accurate magnetic heading values than a single magnetometer. Therefore, BNO055 is selected because it is easy to program and is an IMU sensor.

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 Summary

Characteristics							
Model	**Interfaces**	**Range**	**Accuracy**	**Supply Voltage**	**Current**	**Mass**	**Data Format**
BMP180	I²C	300 hPa / 1100 hPa	±1 hPa	1.8 V / 3.6 V	5 µA	0.9 g	Integer XXXXXX (Pa)

Final Payload Air Pressure Sensor Selection is BMP180:

- Considering 1 hPa, high measurement accuracy .
- Wide range for healthy measurement.
- Draws low current on standard mode.

Data Output Sample:

```
Pressure = 101341 Pa

Pressure = 101340 Pa

Pressure = 101341 Pa

Pressure = 101343 Pa

Pressure = 101337 Pa

Pressure = 101338 Pa

Pressure = 101332 Pa

Pressure = 101330 Pa
```

Data Processing:

calculate true pressure
B6 = B5 - 4000
X1 = (B2 * (B6 * B6 / 2^{12})) / 2^{11}
X2 = AC2 * B6 / 2^{11}
X3 = X1 + X2
B3 = (((AC1*4+X3) << oss) + 2) / 4
X1 = AC3 * B6 / 2^{13}
X2 = (B1 * (B6 * B6 / 2^{12})) / 2^{16}
X3 = ((X1 + X2) + 2) / 2^{2}
B4 = AC4 * (unsigend long)(X3 + 32768) / 2^{15}
B7 = ((unsigned long)UP - B3) * (50000 >> oss)
if (B7 < 0x80000000) { p = (B7 * 2) / B4 }
else { p = (B7 / B4) * 2 }
X1 = (p / 2^{8}) * (p / 2^{8})
X1 = (X1 * 3038) / 2^{16}
X2 = (-7357 * p) / 2^{16}
p = p + (X1 + X2 + 3791) / 2^{4}

Payload Air Temperature Sensor Summary

Characteristics							
Model	**Interfaces**	**Range**	**Accuracy**	**Supply Voltage**	**Current**	**Mass**	**Data Format**
BMP180	I²C	-40 °C / 85 °C	±1 °C	1.8 V / 3.6 V	5 µA	0.9 g	Float XX.XX (°C)

Final Payload Air Temperature Sensor Selection is BMP180:

- Considering 1 °C, high measurement accuracy.
- Wide range for healthy measurement.
- Easy to access and useful library.

Data Output Sample:

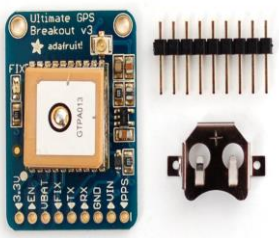
```
Temperature = 27.10 *C

Temperature = 27.80 *C

Temperature = 28.20 *C

Temperature = 27.90 *C

Temperature = 27.60 *C

Temperature = 27.40 *C

Temperature = 27.20 *C

Temperature = 27.20 *C
```

Data Processing:

calculate true temperature
$X1 = (UT - AC6) * AC5 / 2^{15}$
$X2 = MC * 2^{11} / (X1 + MD)$
$B5 = X1 + X2$
$T = (B5 + 8) / 2^{4}$

GPS Sensor Summary

Characteristics						
Model	**Interfaces**	**Accuracy**	**Supply Voltage**	**Current**	**Mass**	**Data Format**
Adafruit Ultimate GPS	UART	±1.8 m	3.0 V / 5.5 V	20 mA	8.5 g	Float and Integer



Final GPS Sensor Selection is Adafruit Ultimate GPS:

- Considering the maximum output voltage of the microprocessor being 3.3V, satisfies both 3.3V and 5V supply voltage pins.
- To satisfy high position accuracy as 1.8 meter.
- Uses NMEA 0183 GGA protocol meets mission requirements.

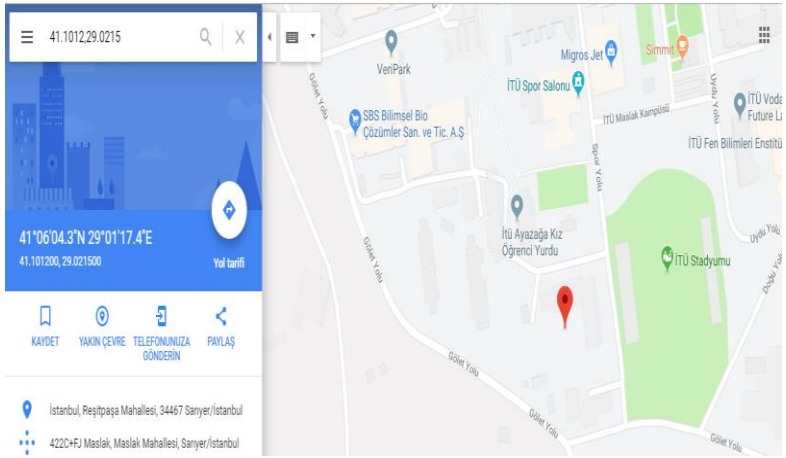
Data Processing:

```
if (Serial2.available() > 0) {
gps.encode(Serial2.read());
gps_hour = gps.time.hour();
gps_min = gps.time.minute();
gps_sec = gps.time.second();
gps_lat = gps.location.lat();
gps_lng = gps.location.lng();
gps_alt = gps.altitude.meters();
gps_sats = gps.satellites.value();
```

Data Output Sample:

- **Data output left to right**: UTC Time, Latitude, Longitude, Altitude, Satellite Number

```
14:3:27,41.1013,29.0215,152.10,4
14:3:28,41.1013,29.0215,152.70,4
14:3:29,41.1012,29.0215,149.20,4
14:3:30,41.1012,29.0215,146.80,4
14:3:31,41.1012,29.0215,145.10,4
14:3:32,41.1012,29.0215,145.50,4
14:3:33,41.1012,29.0215,146.90,4
14:3:34,41.1012,29.0215,146.60,4
14:3:35,41.1012,29.0215,141.30,4
14:3:36,41.1012,29.0215,133.50,4
14:3:37,41.1012,29.0215,129.40,4
14:3:38,41.1012,29.0215,128.70,4
14:3:39,41.1012,29.0215,129.10,4
14:3:40,41.1012,29.0215,130.00,4
14:3:41,41.1012,29.0215,128.50,4
14:3:42,41.1012,29.0215,129.90,4
```



Payload Voltage Sensor Summary

Characteristics				
Model	**Interfaces**	**Range**	**Error Rate**	**Data Format**
Teensy 3.5's Analog Input Pin	Analog	0 V / 5 V	% 0.03	Float X.XX (V)

Final Payload Voltage Sensor Selection is 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.

Data Output Sample:

```
Voltage: 3.30 V

Voltage: 3.30 V

Voltage: 3.30 V

Voltage: 3.30 V

Voltage: 3.30 V

Voltage: 3.30 V

Voltage: 3.30 V

Voltage: 3.30 V
```

Data Processing:

$$A_{is} = \text{Analog Input Signal } (0/1023)$$
$$V_{in} = \text{Input Voltage } (0/5\text{V})$$

$$V_{in} = \frac{A_{is} \times 5}{1023}$$

```
anlg_sgnal = analogRead(A0);

V_in = (anlg_sgnal * 5) /1023.0;
```

Pitch/Roll Sensor Summary

Characteristics						
Model	**Interfaces**	**Zero Rate Level**	**Supply Voltage**	**Current**	**Mass**	**Data Format**
Adafruit BNO055	I²C	±1 dps	2.4 V / 3.6 V	12.3 mA	2 g	Integer XXX (°/s)

Final Pitch/Roll Sensor Selection is Adafruit BNO055:

- Considering zero rate level, BNO055 offers high accuracy about angle changes.
- Easy to communicate owing to I²C interface.
- IMU structure offers different data in a single sensor module, so it is useful.

Data Output Sample:

```
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
Roll: 359      Pitch: -8      Yaw: -3
```

Data Processing:

```
accXnorm = accRaw[0]/sqrt(accRaw[0]* accRaw[0]+ accRaw[1] * accRaw[1] + accRaw[2] * accRaw[2]);
accYnorm =accRaw[1]/sqrt(accRaw[0] *accRaw[0] + accRaw[1] * accRaw[1] + accRaw[2] * accRaw[2]);
pitch = asin(accXnorm);
roll = -asin(accYnorm/cos(pitch));

magXcomp = *mag_raw*cos(pitch)+*(mag_raw+2)*sin(pitch);
magYcomp = *mag_raw*sin(roll)*sin(pitch)+*(mag_raw+1)*cos(roll)-*(mag_raw+2)*sin(roll)*cos(pitch);
heading = 180*atan2(magYcomp,magXcomp)/M_PI;
```

Auto-Gyro Blade Spin Rate Sensor Summary

Characteristics							
Model	**Interfaces**	**Measurement Technique**	**Supply Voltage**	**Current**	**Mass**	**Data Format**	**Accuracy**
FC-33 Sensor Module	Digital	Infrared Radiation	3.3 V / 5 V	15 mA	3.2 g	Integer XX (RPM)	±(5-10) rpm

Final Auto-Gyro Blade Spin Rate Sensor Selection is FC-33 Sensor Module:

- 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.

Data Output Sample:

```
RPM: 15

RPM: 22

RPM: 18

RPM: 30

RPM: 33

RPM: 33

RPM: 30

RPM: 22
```

Data Processing:

```
unsigned long new_second, old_second = 0,rpm;
volatile float counter;

void setup(){

 Serial.begin(115200);
 attachInterrupt(digitalPinToInterrupt(1),spin_rate,FALLING);
}

void loop(){
   new_second = millis();

 if(new_second - old_second >= 1000) {
  noInterrupts();
  rpm = (int) ((counter/16)* 60);
  Serial.print("RPM: ");
  Serial.println(rpm);
  Serial.println("");
  rpm = 0;
  counter = 0;
  old_second = new_second;
  interrupts();
 }
}

void spin_rate () {
  counter++;
}
```

Bonus Objective Camera Summary

Characteristics							
Model	**Interfaces**	**Video Resolution**	**Frame Per Second**	**Supply Voltage**	**Size**	**Current**	**Video Format**
Adafruit Mini Spy Camera	Digital	640 x 480p	30 fps	3.7 V / 5 V	28 mm x 17 mm x 4 mm	110 mA	AVI

Final Camera Selection is Adafruit Mini Spy Camera:

- 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.

Photo sample taken by Adafruit Mini Spy Camera:

Container Air Pressure Sensor Summary

Characteristics							
Model	**Interfaces**	**Range**	**Accuracy**	**Supply Voltage**	**Current**	**Mass**	**Data Format**
BMP180	I²C	300 hPa / 1100 hPa	±1 hPa	1.8 V / 3.6 V	5 µA	0.9 g	Integer XXXXXX (Pa)

Final Container Air Pressure Sensor Selection is BMP180:

- Considering 1 hPa, high measurement accuracy .
- Wide range for healthy measurement.
- Draws low current on standard mode.

Data Output Sample:

```
Pressure = 101341 Pa

Pressure = 101340 Pa

Pressure = 101341 Pa

Pressure = 101343 Pa

Pressure = 101337 Pa

Pressure = 101338 Pa

Pressure = 101332 Pa

Pressure = 101330 Pa
```

Data Processing:

calculate true pressure
$B6 = B5 - 4000$
$X1 = (B2 * (B6 * B6 / 2^{12})) / 2^{11}$
$X2 = AC2 * B6 / 2^{11}$
$X3 = X1 + X2$
$B3 = (((AC1*4+X3) << oss) + 2) / 4$
$X1 = AC3 * B6 / 2^{13}$
$X2 = (B1 * (B6 * B6 / 2^{12})) / 2^{16}$
$X3 = ((X1 + X2) + 2) / 2^{2}$
$B4 = AC4 * (unsigend\ long)(X3 + 32768) / 2^{15}$
$B7 = ((unsigned\ long)UP - B3) * (50000 >> oss)$
if (B7 < 0x80000000) { p = (B7 * 2) / B4 }
else { p = (B7 / B4) * 2 }
$X1 = (p / 2^{8}) * (p / 2^{8})$
$X1 = (X1 * 3038) / 2^{16}$
$X2 = (-7357 * p) / 2^{16}$
$p = p + (X1 + X2 + 3791) / 2^{4}$

Descent Control Design

İsmail ÖZCAN

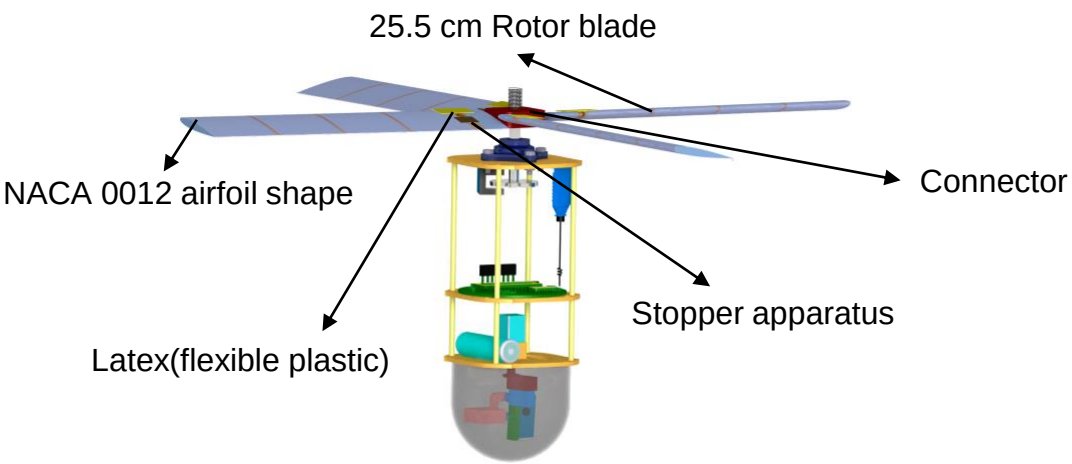
Descent Control Overview (1/3)

Rotor Blades (Payload Descent Control System) :

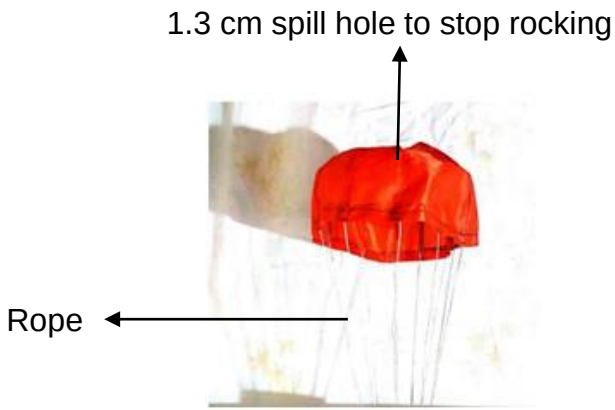
Rotor blades are chosen as 25.5 cm to be fit in container. They are covered by fiberglass which makes them rigid body. Rotor blades are held by connector part to carry the payload. Rotor blades also have stowing mechanism to be fit in the container. NACA 0012 airfoil is selected for rotor blades because of its 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.

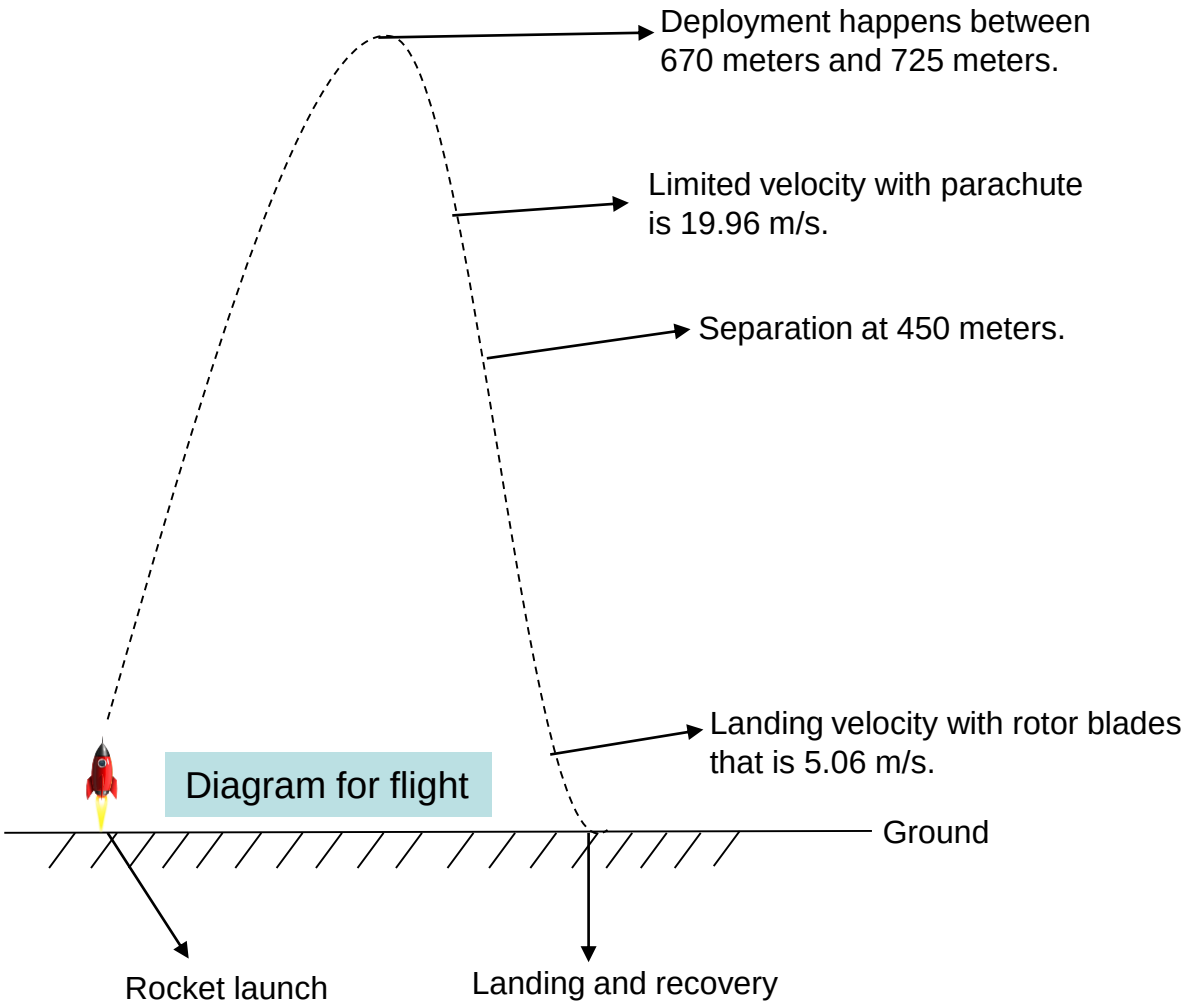


(Cylindrical Shaped Payload with Rotor blades)



(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
Stopper apparatus	Plywood

Descent Control Changes Since PDR (1/3)

Component	Changes	Rationale
Rotor blade	Stopper apparatus was added	Rotor blades have some opening stabilization problems which can be stopped by an apparatus to stabilize rotor blade movement.
Bearing	Type of bearing	Bearing was changed because high friction force has negative effects on auto-rotation.

Descent Control Changes Since PDR (2/3)

PROTOTYPE TESTING:

• Drop test for container+payload was made and observations showed that container+payload did not tumble in 18 meters drop tests.(Passed ✓)

• Opening system for rotor blades was tested and rotor blades opened without troubles.(Passed ✓)

• Parachute stabilized the container+payload as we expected.(Passed ✓)

• Parachute was tested and desired velocity values are observed.(Passed ✓)

• Auto-rotation test was done in ITU Trisonic Laboratory and payload had no troubles for auto-rotation.(Passed ✓)

• Rotor blades were tested for drop test and there were no stabilization problem during the drop test.(Passed ✓)

Descent Control Changes Since PDR (3/3)

PROTOTYPE TESTING:

Payload was thrown out of the window of the top floor of our faculty and the descent was observed. Required time to start the autorotation was found as nearly 0.7 seconds. Also landing velocity was calculated as nearly 6 m/s from the video.

Youtube Links:

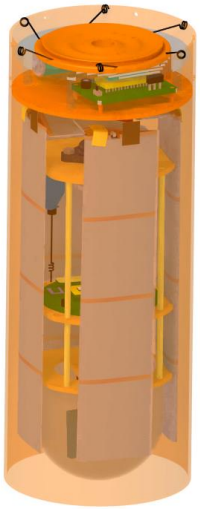
Time Required to Start the Autorotation Test: https://youtu.be/gOvjbd_DVJE

Guessing the Landing Velocity Test: https://youtu.be/oz2EttrN5RQ

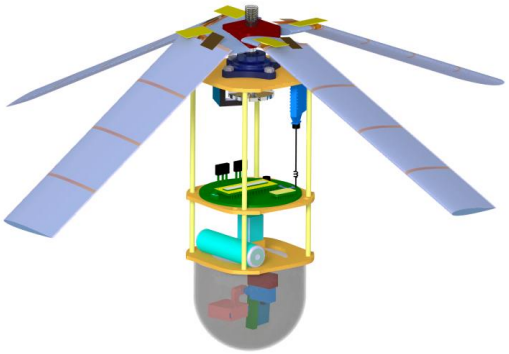
Descent Control Requirements

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	✓	✓	✓	

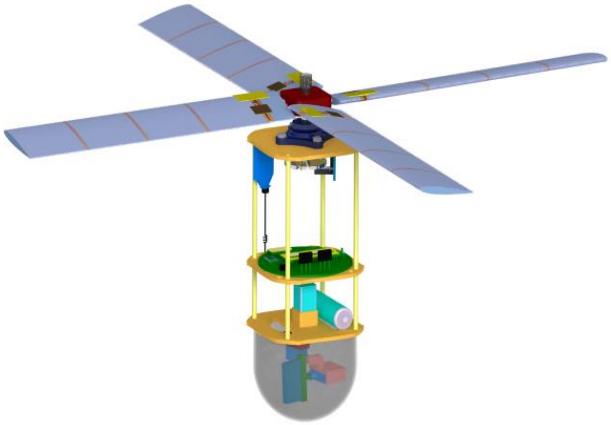
Payload Descent Control Hardware Summary (1/3)



Stowed Configuration



Deployed Configuration



After separated completely

Deployment Method

The container will keep payload in stowed configuration via a fishing line. After rocket deployment, container and payload descend together until 450 meters. In 450 meters, payload is released by container via heating the holder fishing line. The payload is pushed by spring and it helps the seperation from the container. After separation, latexes(flexible plastic) apply force to open and stabilize rotor blades. Finally, payload reaches 11 m/s descent rate during the flight.

Payload Descent Control Hardware Summary (2/3)

Component Sizing :

- Mechanical components and dimension informations were mentioned in System Overview section with details.
- Rotor Blade diameter is 255 mm.
- Plexiglass cover diameter is 88 mm.
- Connector dimensions are 35 mm x 35 mm x 12 mm with 5 mm radius edges

Key Considerations :

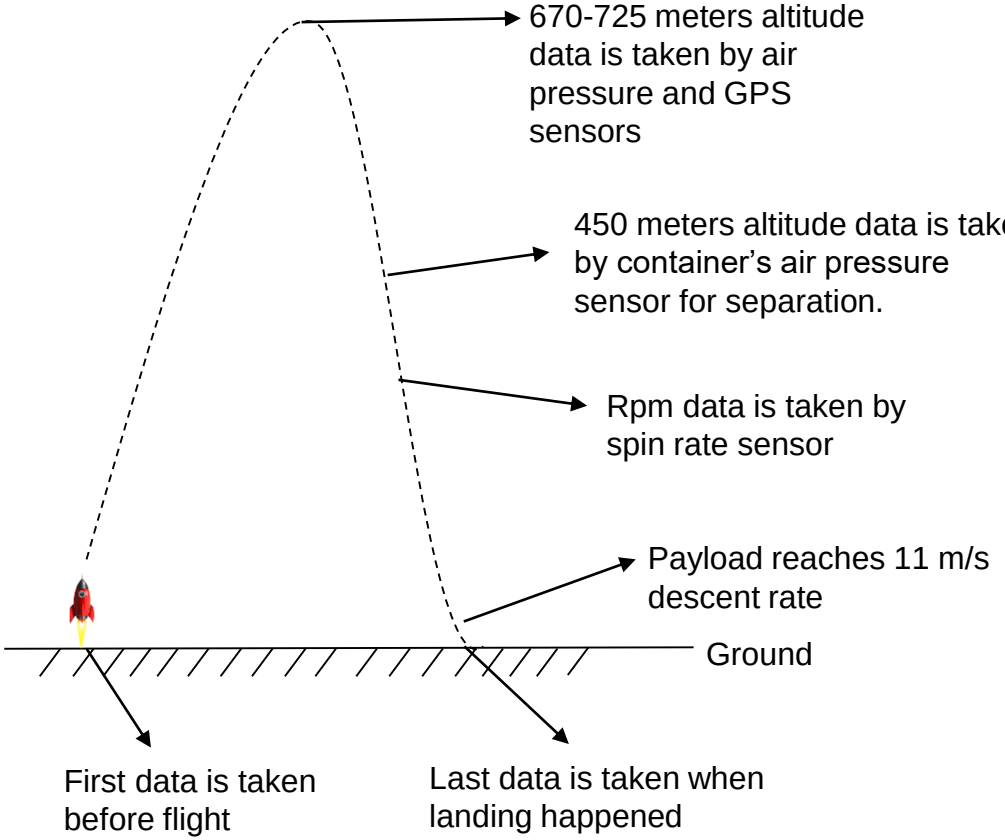
- Rotor blades have to be solid during the flight.
- Plexiglass structure helps to create convenient airflow pattern during the flight.
- Bearing selection is made carefully to get minimum friction force.
- Latexes(flexible plastic) should hold rotor blades strongly.
- Bearing should stick to main shaft and the payload.

Color Selections :

- Rotor blades are blue.
- Connector part is Brown.
- Latexes(flexible plastic) are yellow.
- Plexiglass cover is transparent.
- Bearing is grey.

Payload Descent Control Hardware Summary (3/3)

Sensors	Accuracy
Air pressure sensor	±(1 hPa)
GPS sensor	±(1.8 m)
Spin Rate Sensor	±(5-10 rpm)



Data Formats :

Altitude : XXX.X (m)

Lateral, Long : XX.XXXX (°)

Spin Rate : XXX (rpm)

Data Processing:

calculate true pressure
B6 = B5 - 4000
X1 = (B2 * (B6 * B6 / 2^{12})) / 2^{11}
X2 = AC2 * B6 / 2^{11}
X3 = X1 + X2
B3 = (((AC1*4+X3) << oss) + 2) / 4
X1 = AC3 * B6 / 2^{13}
X2 = (B1 * (B6 * B6 / 2^{12})) / 2^{16}
X3 = ((X1 + X2) + 2) / 2^{2}
B4 = AC4 * (unsigend long)(X3 + 32768) / 2^{15}
B7 = ((unsigned long)UP - B3) * (50000 >> oss)
if (B7 < 0x80000000) { p = (B7 * 2) / B4 }
else { p = (B7 / B4) * 2 }
X1 = (p / 2^{8}) * (p / 2^{8})
X1 = (X1 * 3038) / 2^{16}
X2 = (-7357 * p) / 2^{16}
p = p + (X1 + X2 + 3791) / 2^{4}

BMP 180

```
 if (Serial2.available() > 0) {
gps.encode(Serial2.read());
gps_hour = gps.time.hour();
gps_min = gps.time.minute();
gps_sec = gps.time.second();
gps_lat = gps.location.lat();
gps_lng = gps.location.lng();
gps_alt = gps.altitude.meters();
gps_sats = gps.satellites.value();
```

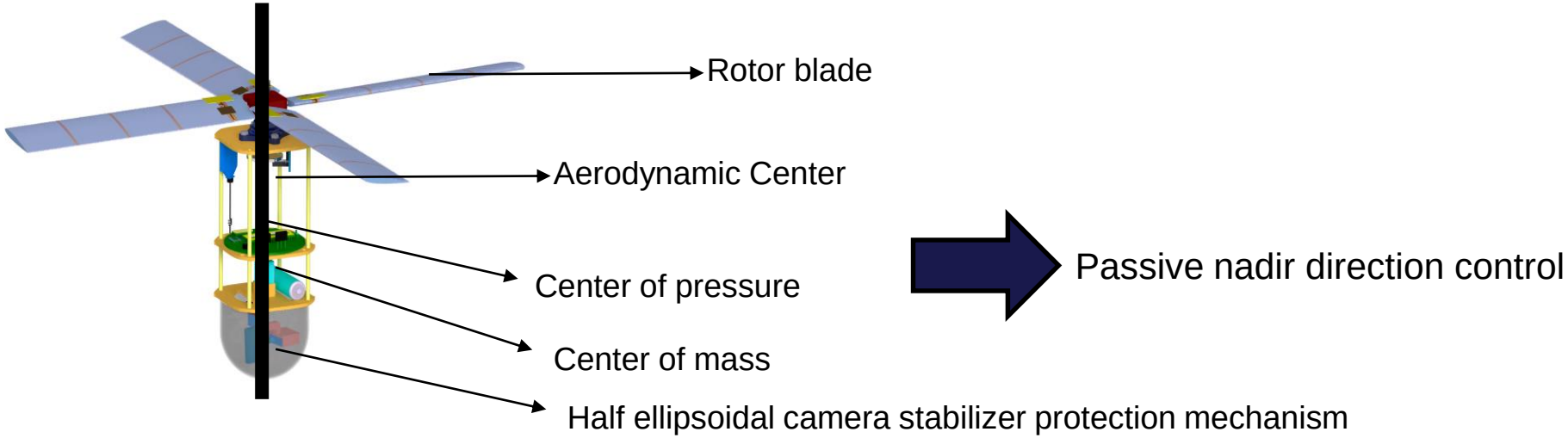
GPS

```
if(new_second - old_second >= 1000
 noInterrupts();
 rpm = (int) ((counter/16)* 60);
 Serial.print("RPM: ");
 Serial.println(rpm);
 Serial.println("");
 rpm = 0;
 counter = 0;
 old_second = new_second;
 interrupts();
}
```

RPM SENSOR

Descent Stability Control Design (1/3)

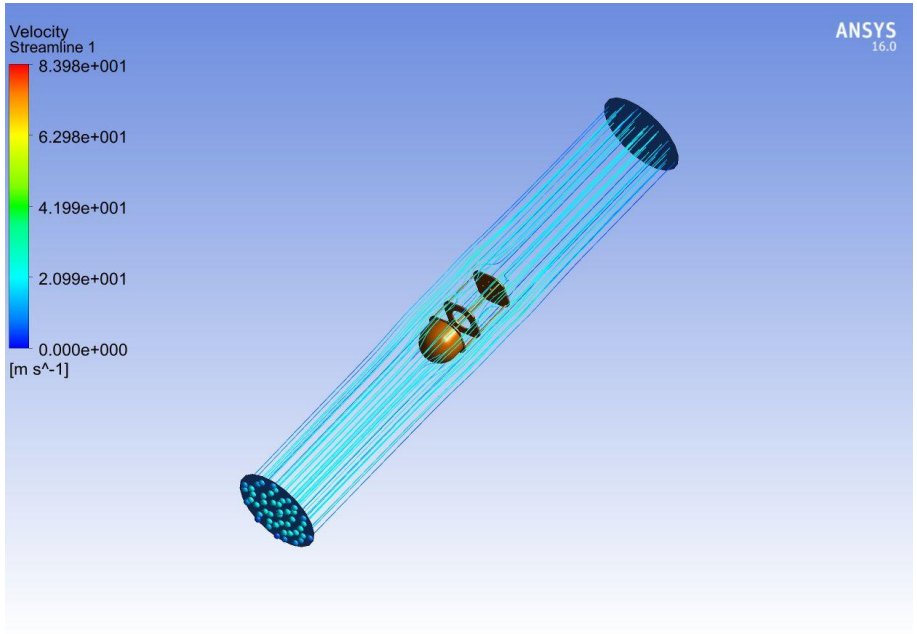
Descent stability control system should be reliable for a safe landing. Parachute stops tumbling of the CanSat (container+payload) due to reaching its limited velocity fastly and keeping its nadir direction easily. After separation, container maintains its nadir direction and is not exposed to tumbling. Payload keeps its nadir direction via passive controls. Rotor blades act like a parachute when they rotate enough. Rotor blades have stopper apparatus to stop unstable forces on the blades during the flight. The aerodynamic, pressure and mass centers of the payload are located on the same vector which helps to prevent tumbling. Nadir direction is also maintained because the center of mass will be positioned below the pressure center and aerodynamic center. In order to have a lower mass center, electronic components are also located below. Design of stability control is given below. (Half ellipsoidal camera stabilizer protection mechanism and rotor blades)

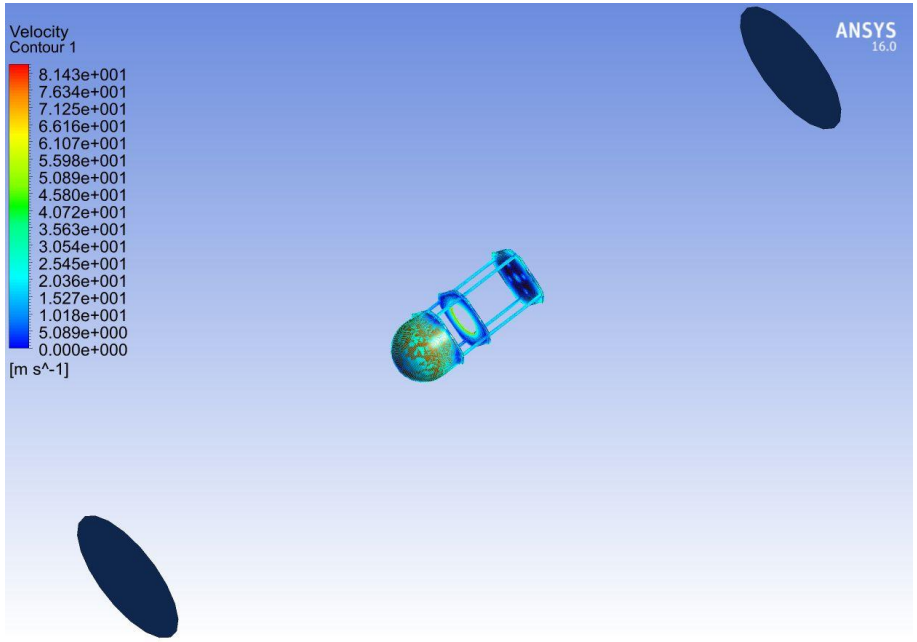


Descent Stability Control Design (2/3)

Mechanisms used to maintain stability: Camera stabilizer protection mechanism and rotor blades

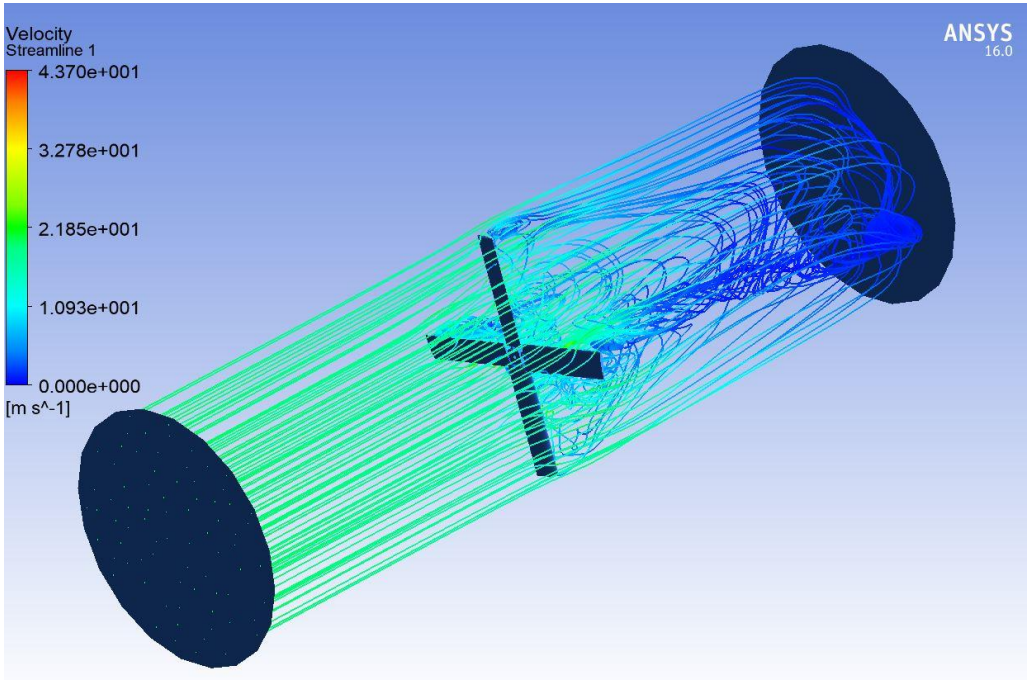
Payload has a half ellipsoidal camera stabilizer mechanism protection body. Half ellipsoidal shape distributes airflow equally which helps to prevent tumbling during the flight. Half ellipsoidal body contributions were analyzed by Ansys 16.0 Fluent module and airflow was distributed equally by half ellipsoidal shape. Equally distributed airflow helps to maintain nadir direction for the payload. Also equally distributed airflow is needed for rotor blades to maintain stability during the flight.



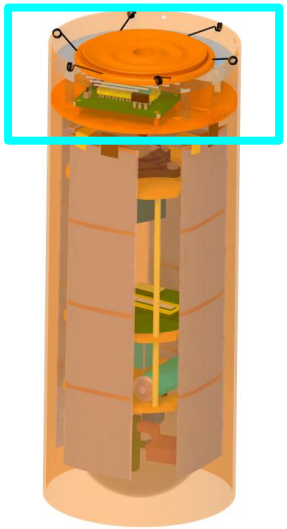


Descent Stability Control Design (3/3)

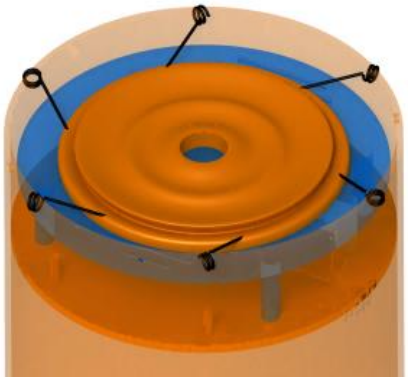
As it is mentioned before, nadir direction is maintained also by the rotor blades. Rotor blades gather airflow at the z-axis of payload which brings the stability for systems. Rotor blades analyzed by Ansys 16.0 CFX module which is used for rotating bodies. Results showed us that the airflow was gathered at the middle. Results show tumbling is stopped by rotor blade movement which means nadir direction is maintained during the flight and there is no sign of tumbling during the flight.



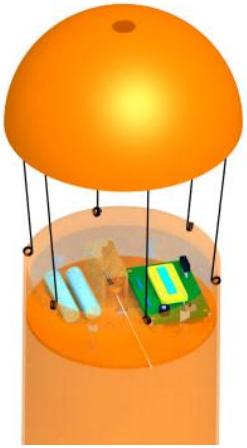
Container Descent Control Hardware Summary (1/3)



Stowed Configuration



Stowed Configuration (Zoomed in)



Container Parachute Deployed Configuration

Deployment Method

Container will keep the payload in stowed configuration via a fishing line. After the rocket deployment, container and payload will descend together until 450 meters via the parachute. In 450 meters, payload will be released from the container by heating the holder fishing line. After payload separation, parachute will decrease the speed of container to 10.176 m/s.

Container Descent Control Hardware Summary (2/3)

Component Sizing :

- Mechanical components and dimension informations were mentioned in System Overview section with details.
- Parachute diameter is 132 mm.
- Spill hole diameter is 13 mm.

Key Considerations :

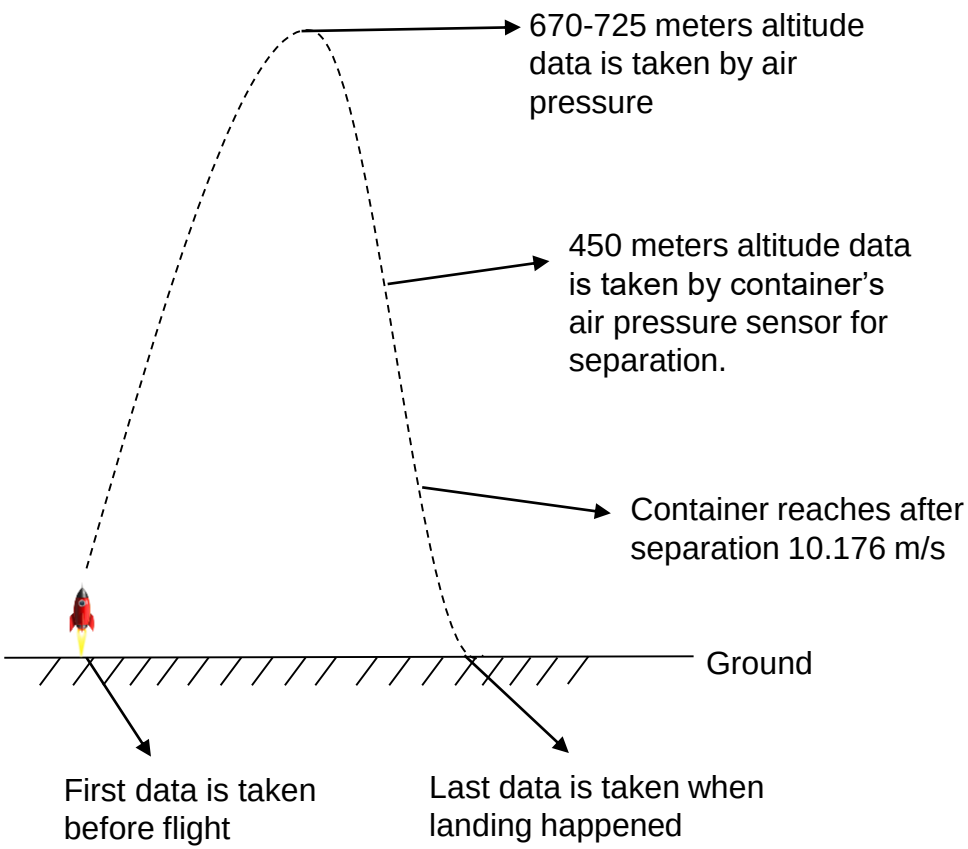
- Parachute should be attached to container well.
- Ropes have to be separate during the flight because it may affect the stability.
- Spill hole is made to reduce rocking during the flight.
- Air pressure sensor should be protected from high velocity of airflow.
- There should be no lateral forces during the separation.
- Spring for the separation system should not produce lateral forces.

Color Selections :

- Parachute ropes are white.
- Parachute is orange.
- Container is red.
- Spring is grey.
- Fishing line is transparent.

Container Descent Control Hardware Summary (3/3)

Sensors	Accuracy
Air pressure sensor	±1 hPa



Data Formats :

Altitude : XXX.X (m)

Data Processing:

calculate true pressure
B6 = B5 - 4000
X1 = (B2 * (B6 * B6 / 2^{12})) / 2^{11}
X2 = AC2 * B6 / 2^{11}
X3 = X1 + X2
B3 = (((AC1*4+X3) << oss) + 2) / 4
X1 = AC3 * B6 / 2^{13}
X2 = (B1 * (B6 * B6 / 2^{12})) / 2^{16}
X3 = ((X1 + X2) + 2) / 2^{2}
B4 = AC4 * (unsigend long)(X3 + 32768) / 2^{15}
B7 = ((unsigned long)UP - B3) * (50000 >> oss)
if (B7 < 0x80000000) { p = (B7 * 2) / B4 }
else { p = (B7 / B4) * 2 }
X1 = (p / 2^{8}) * (p / 2^{8})
X1 = (X1 * 3038) / 2^{16}
X2 = (-7357 * p) / 2^{16}
p = p + (X1 + X2 + 3791) / 2^{4}

BMP 180

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)

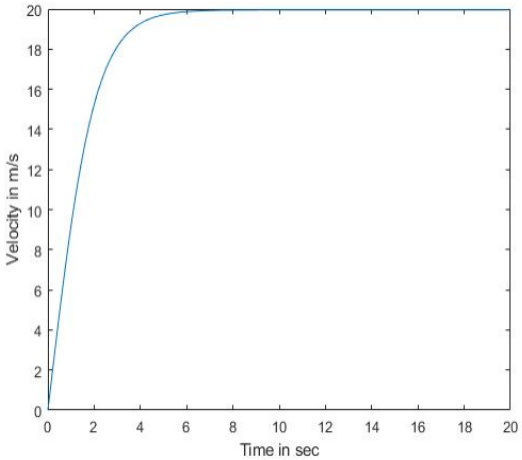
A = area (Circular area of parachute = π x R x R)

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, initial 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 the formula. Parachute has 13.2 cm in diameter.



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

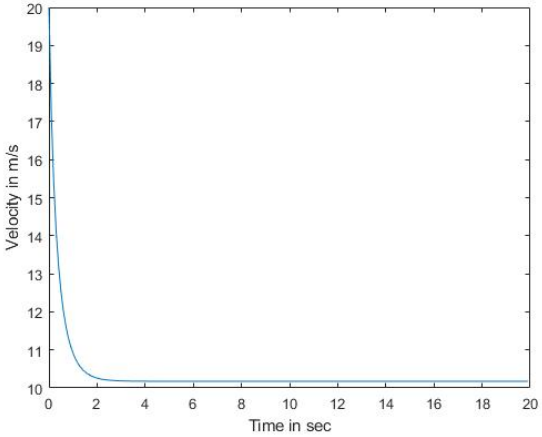
Descent Rate Estimates (2/6)

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, initial velocity of the 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)

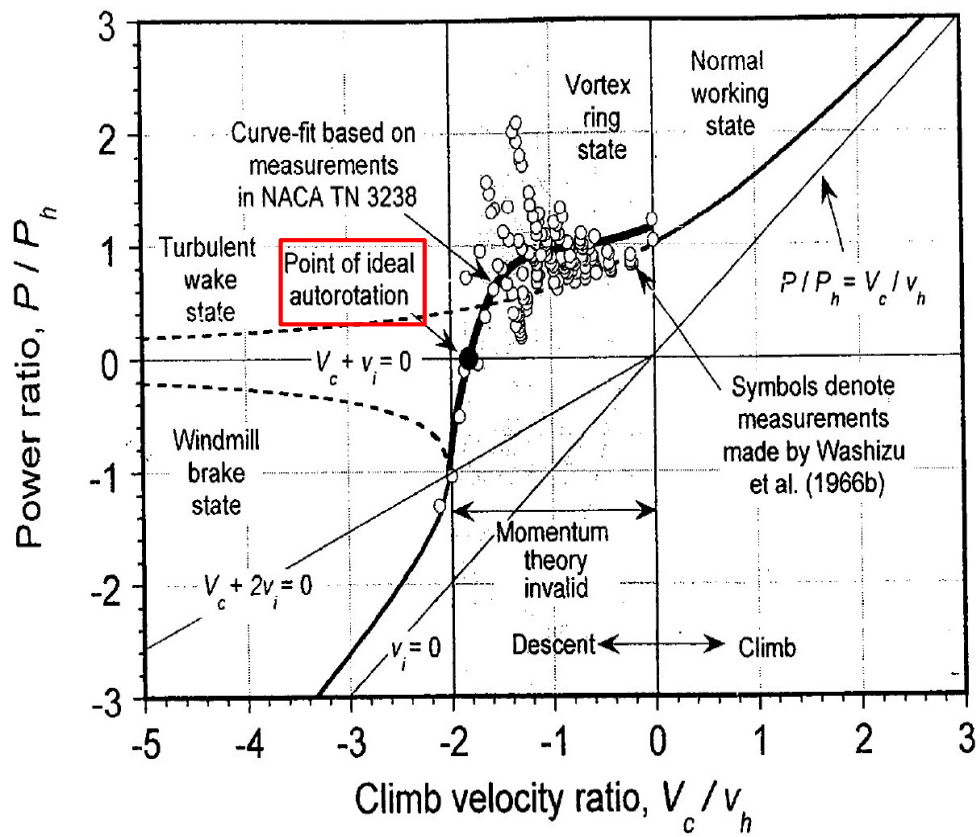
Descent for Payload (1/3)

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.

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

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

$$1.10 \leq C_d \leq 1.16$$

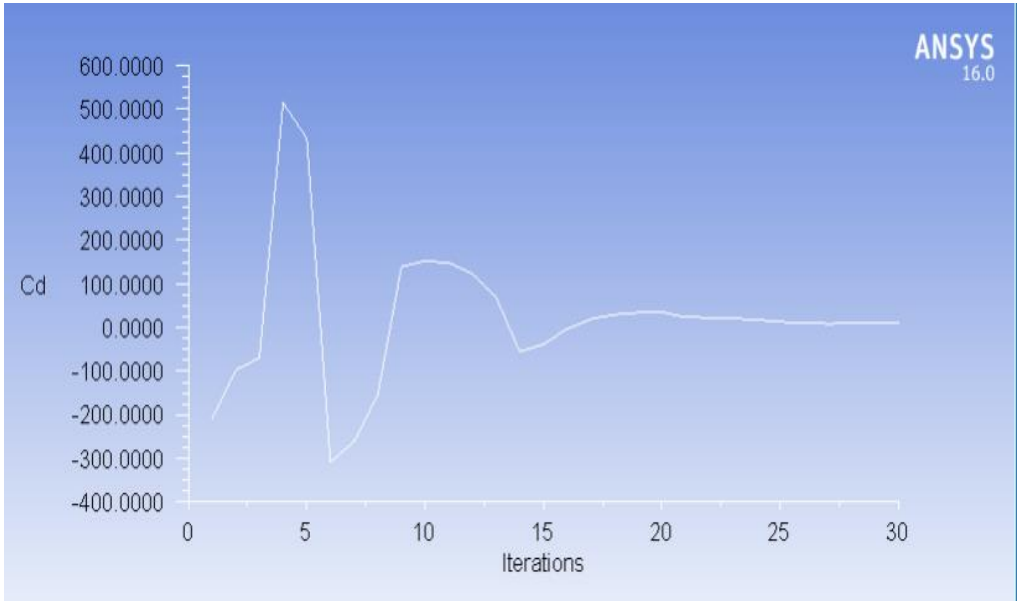


Taken from (Principles of Helicopter Aerodynamics – J.GORDON LEISHMAN)

Descent Rate Estimates (4/6)

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 Rate Estimates (5/6)

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

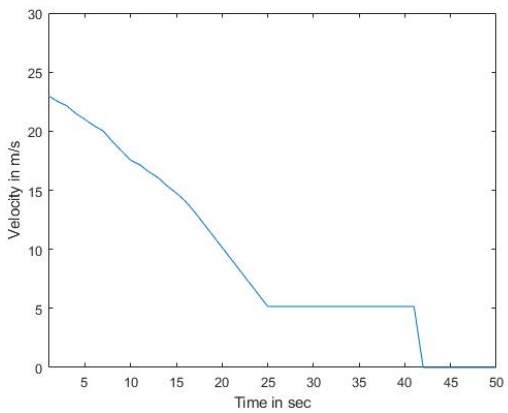
m = mass (Payload only)

A = area (Rotor disk area)

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

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

C_d = drag coefficient (1.16 for Auto-gyro)

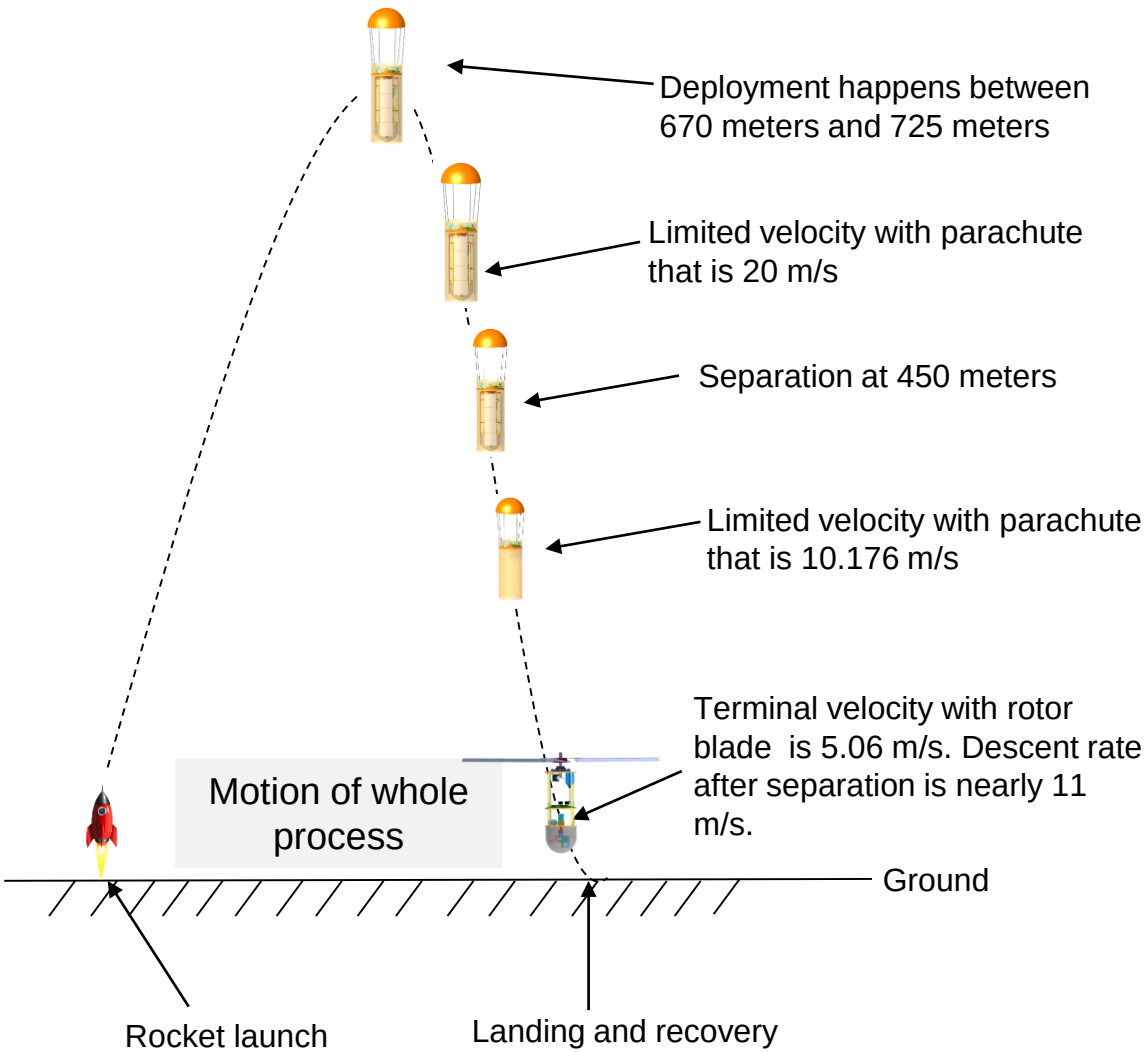


Possible vertical velocity graph for payload

Our initial velocity is higher than 20 m/s because of spring force on the payload. Descent rate of payload after separation is between 10 m/s - 15 m/s because rotor *blades does not reach maximum rpm value immediately*. Descent rate of the payload was found as nearly **11 m/s** referring to vertical velocity graph. Velocity graph was plotted by MATLAB.

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

Descent Rate Estimates (6/6)

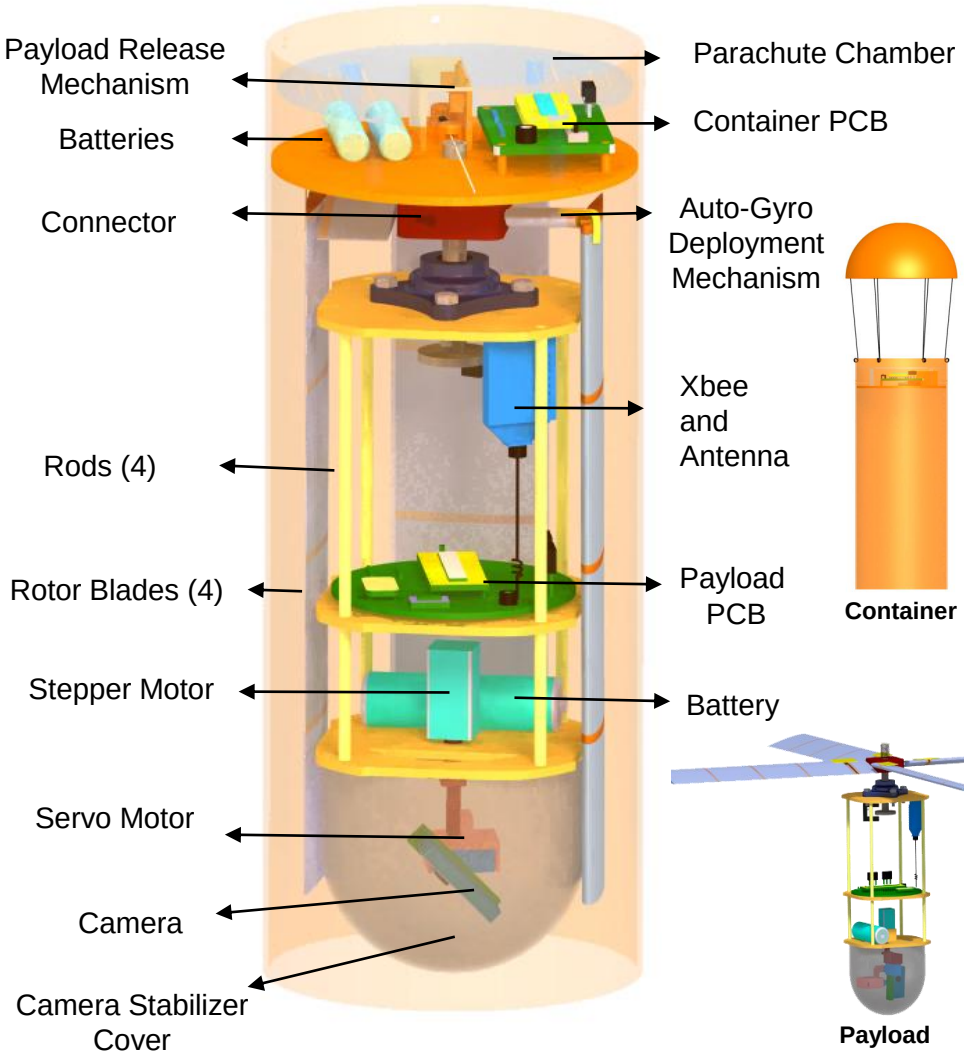


- The descent velocity for container+payload is 19.96 m/s before the separation.
- After separation, container descent velocity decreased to limited velocity 10.176 m/s via parachute.
- After separation, payload velocity increased to nearly 25 m/s due to spring force. Landing velocity decreased to 5.06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

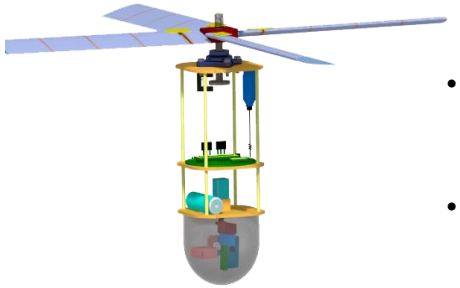
Mechanical Subsystem Design

Muhammed KARA

Mechanical Subsystem Overview



Container



Payload

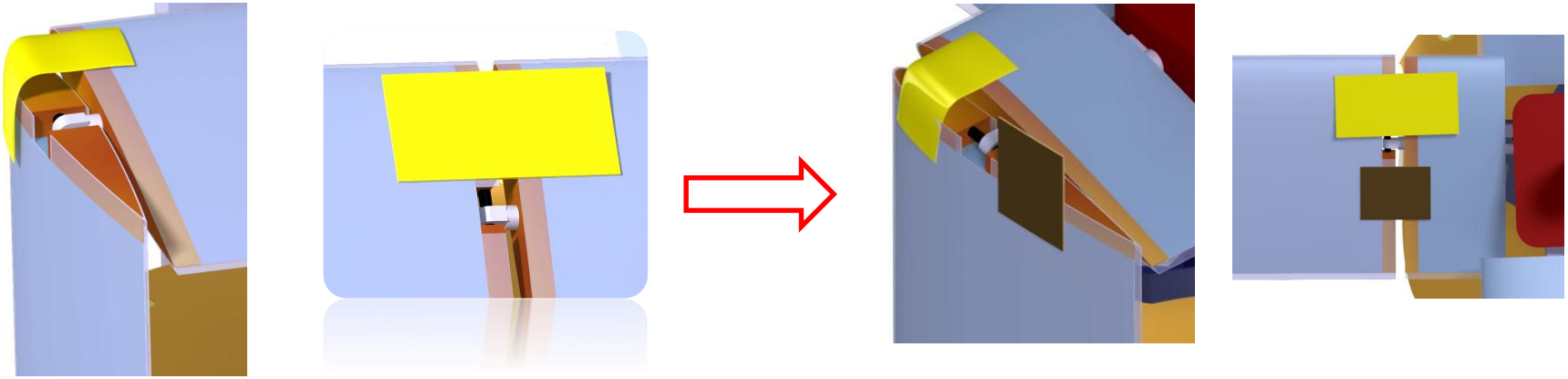
Structure	Material Selection
Container	Fiberglass
Payload	Plywood for Layers, Fiberglass Rods, 3D Printed ABS for Rotor Blade Connector, Styrofoam, Fiberglass, Resin and Balsa Wood for Rotor Blades, Plexiglas for Camera Cover
Payload Release Mechanism	Nichrome Wire, Fishing Line, Spring
Auto-Gyro Deployment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

Interface Definitions

- There is a top plate on the container to separate 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 Subsystem Changes Since PDR

Component	Changes	Rationale
Rotor blade	A stopper is added to blade.	It is noticed that open blades make dihedral angle.
Bearing	Type of bearing.	To prevent the rotation of payload body.



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	✓	✓		✓

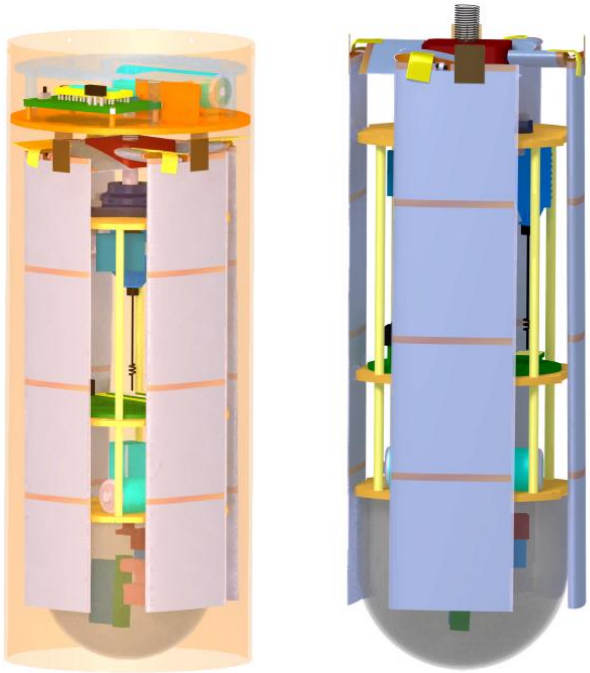
Mechanical Sub-System Requirements (2/2)

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		✓		✓

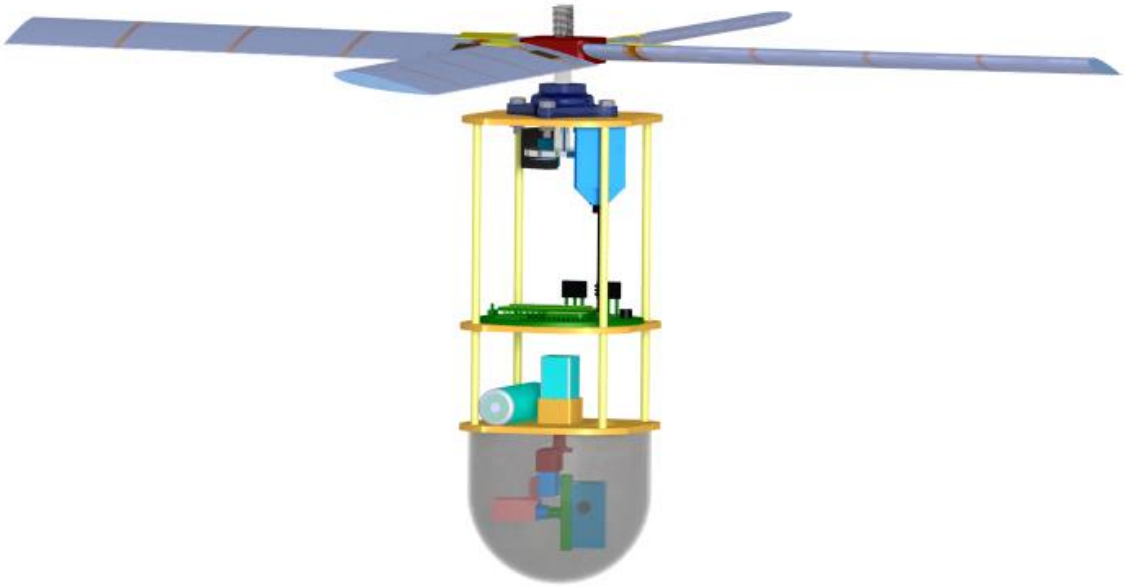
Payload Mechanical Layout of Components (1/9)

Payload Structure

Structure on Different Phases of Flight



Before Payload is released from container.

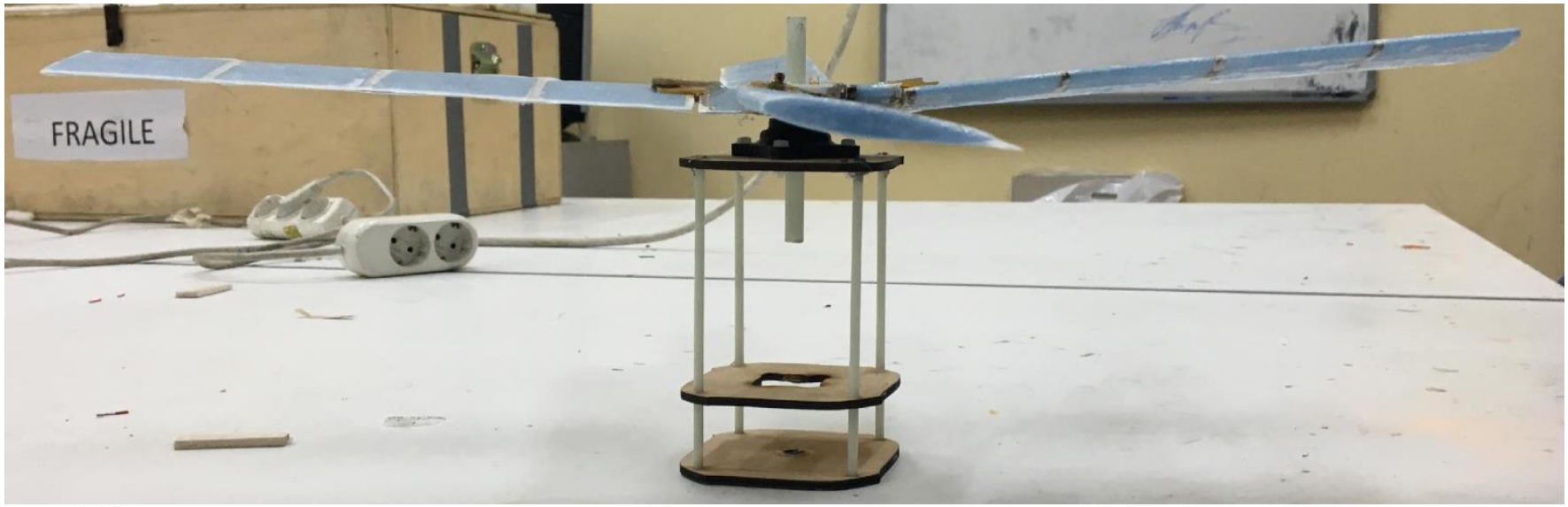


After Payload is released from container.

Payload Mechanical Layout of Components (2/9)

Payload Structure

Structure of Prototype

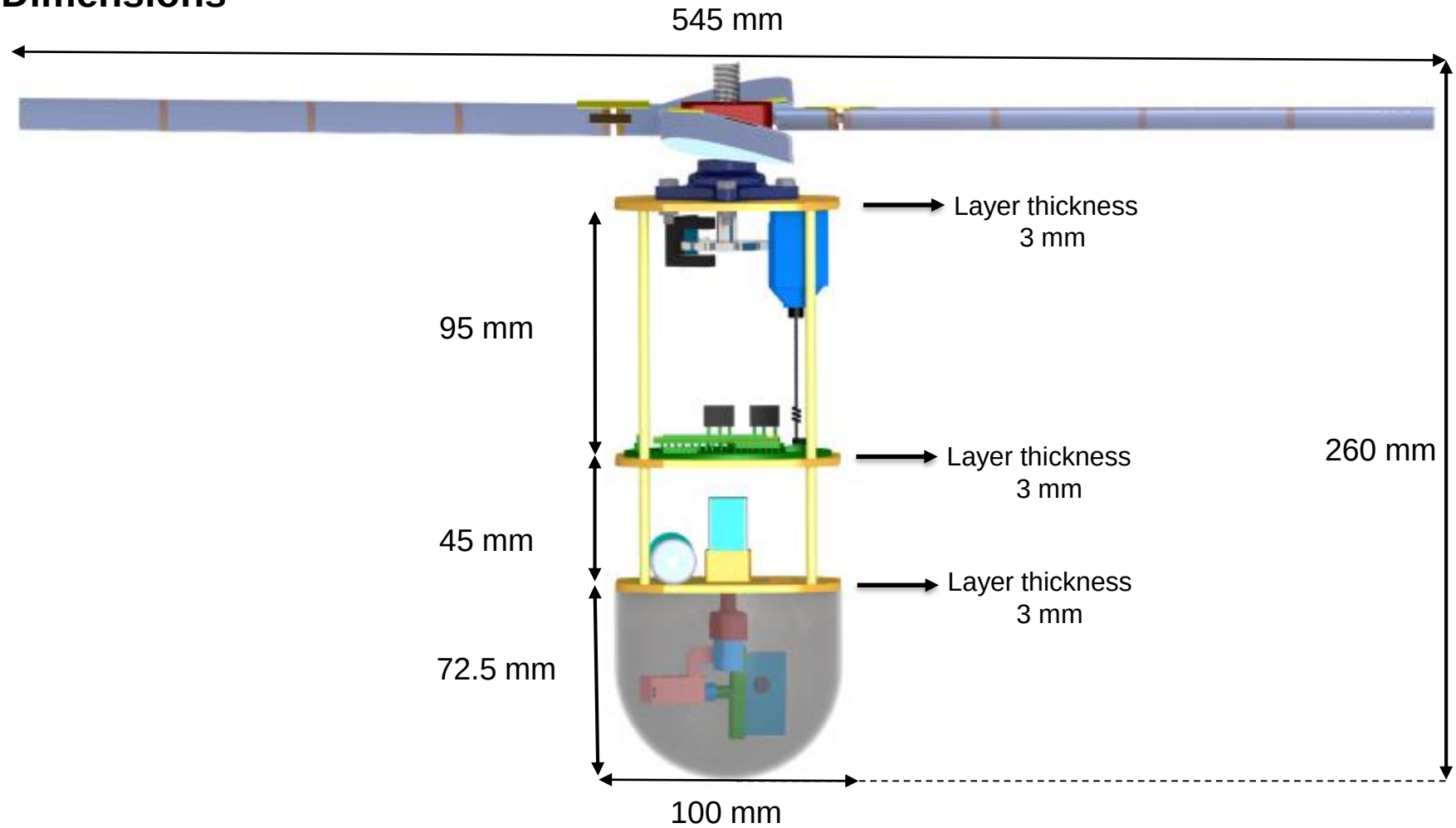


- It is decided that the all system will occupy as little volume as possible.
- Joint sections of the payload are designed to perform high burst strength against impacts.
- To protect the camera stabilizer from any damage, a transparent plexiglass structure will be used.
- The center of mass is positioned below the both pressure and aerodynamic center to prevent tumbling.
- After deployment, rotor blades maintain their positions by latex materials(flexible 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 (3/9)

Payload Structure

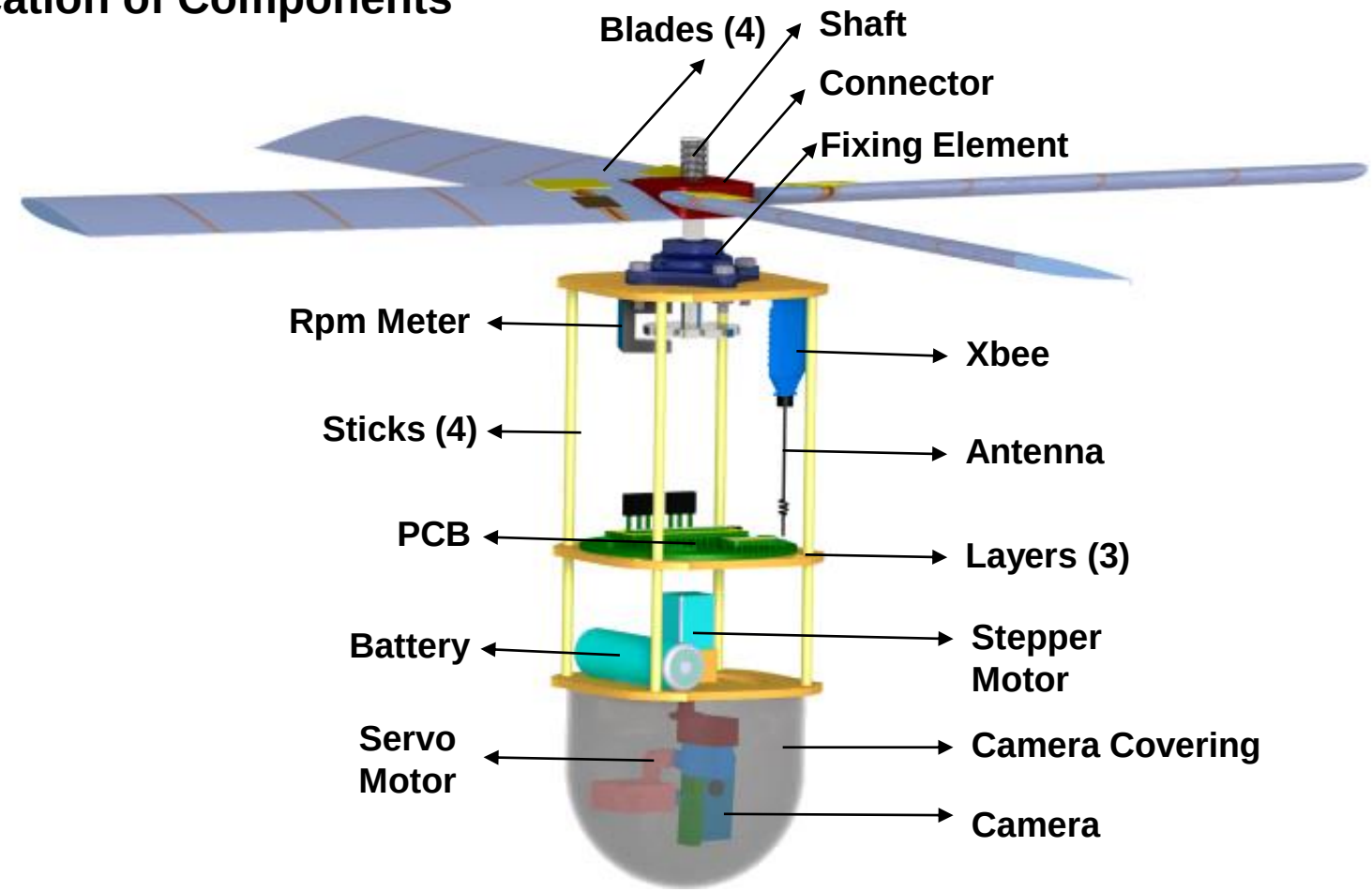
Dimensions



Payload Mechanical Layout of Components (4/9)

Payload Structure

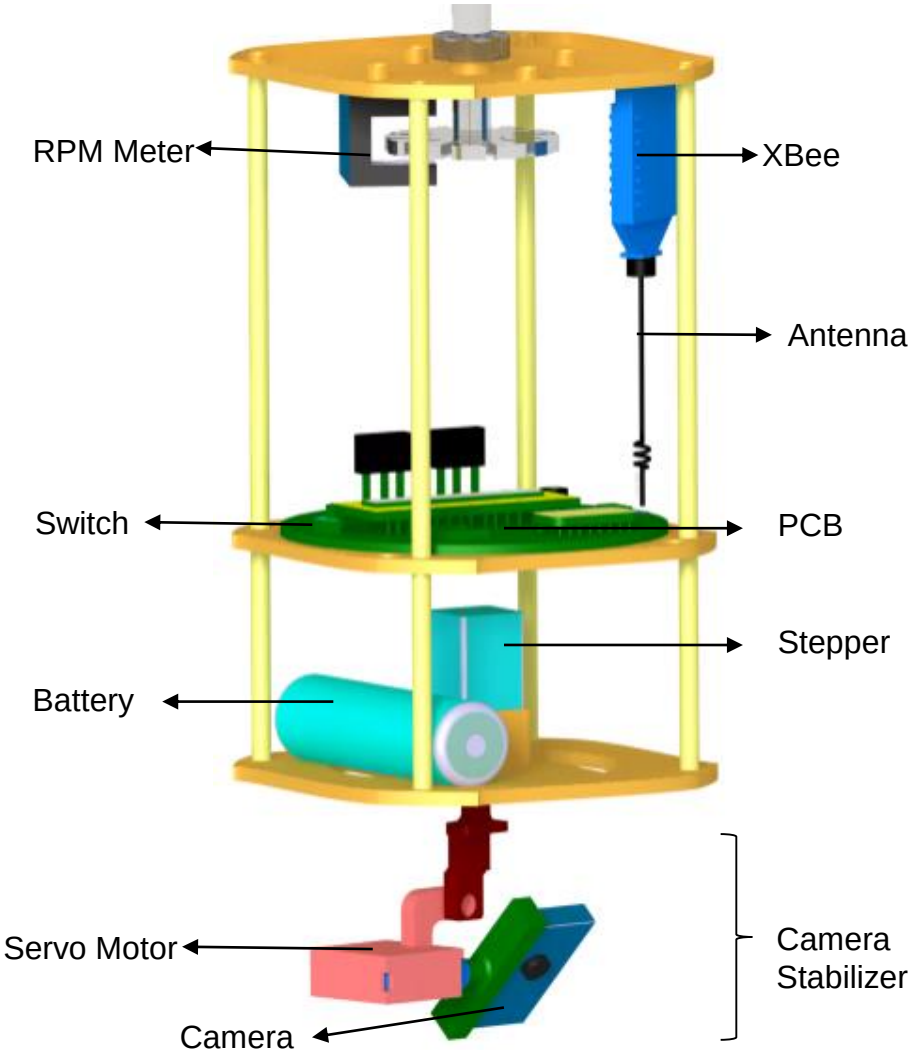
Location of Components



Payload Mechanical Layout of Components (5/9)

Electrical Components

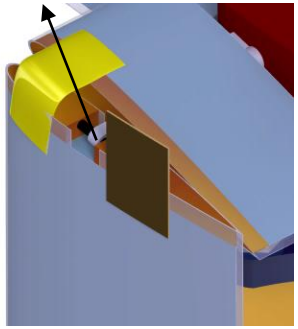
- The PCB is placed in the middle of payload and fixed to the payload plate.
- The battery is placed on the lower layer.
- Camera Stabilizer Mechanism is located at the bottom of payload.
- There is a servo motor and a stepper motor to provide 3-axis motion to the Camera Stabilizer.
- The camera is properly 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.



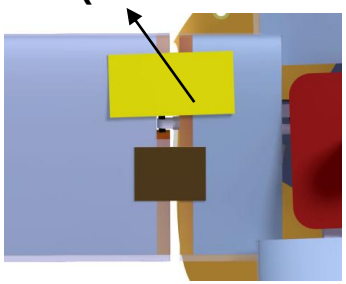
Payload Mechanical Layout of Components (6/9)

Major Mechanical Parts

Hinge



Latex (Flexible Plastic)

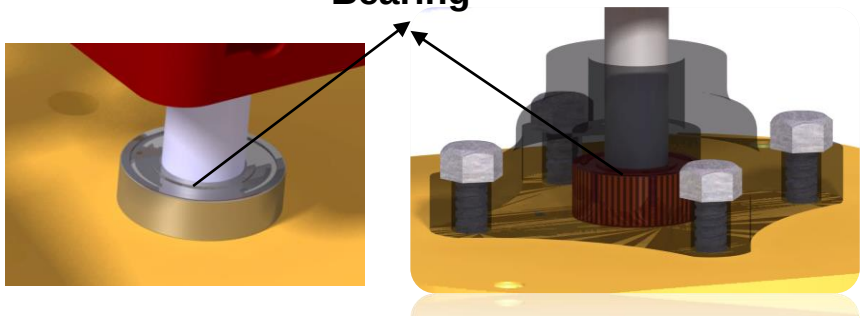


Folded Blade

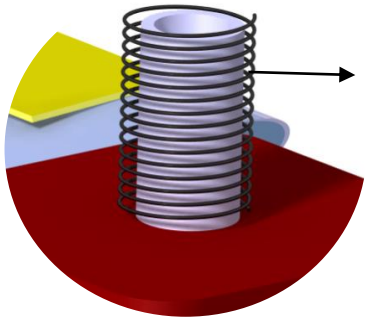
Open Blade

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

Bearing



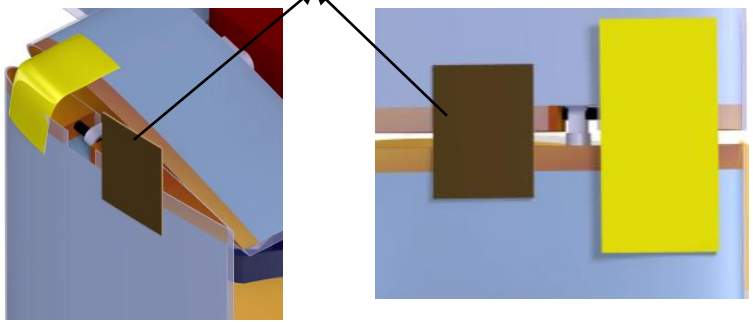
- The effect of shaft moment created by the auto-gyro is minimized by connecting the shaft to the bearing.



Spring

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

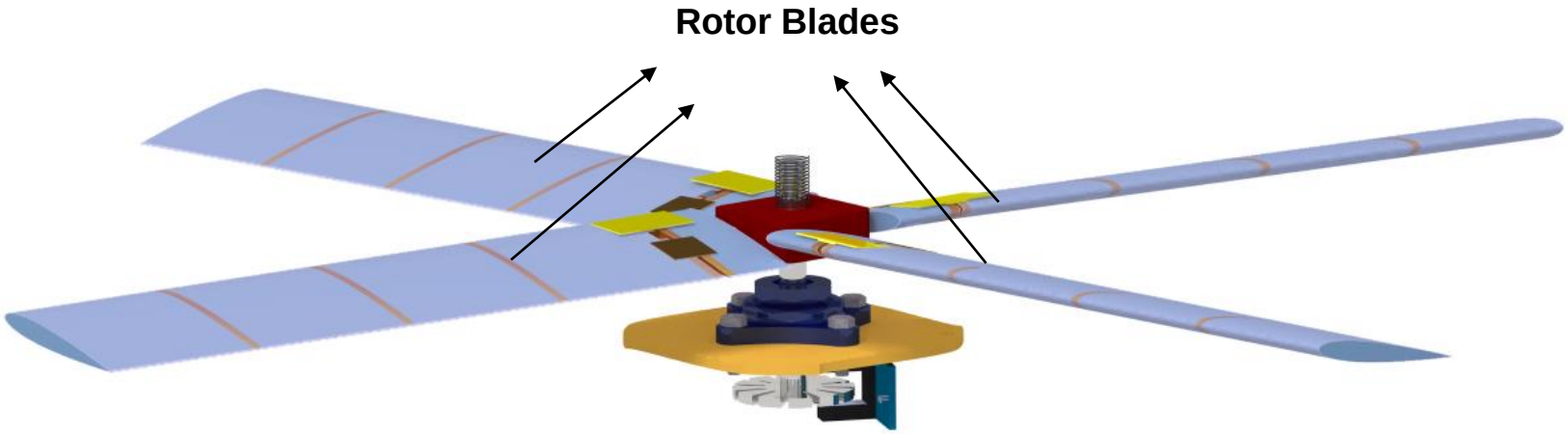
Stoppers

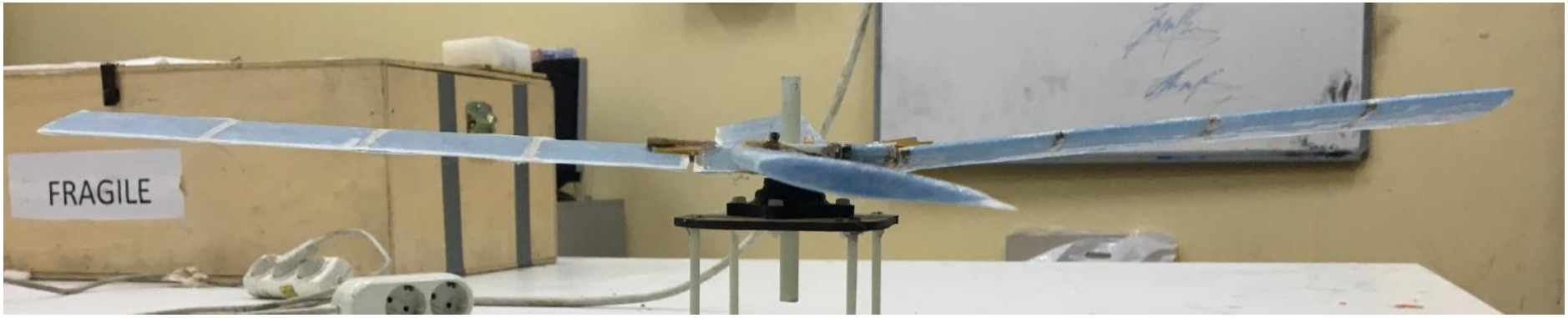


- Stoppers pretend to blades to make dihedral angle.

Payload Mechanical Layout of Components (7/9)

Major Mechanical Parts

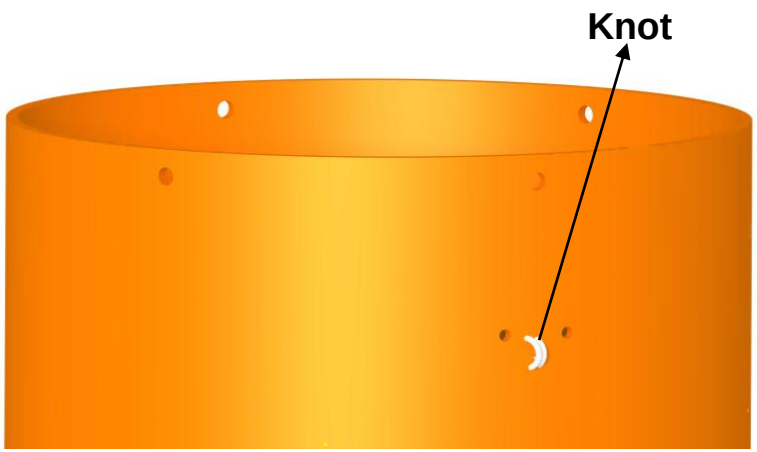


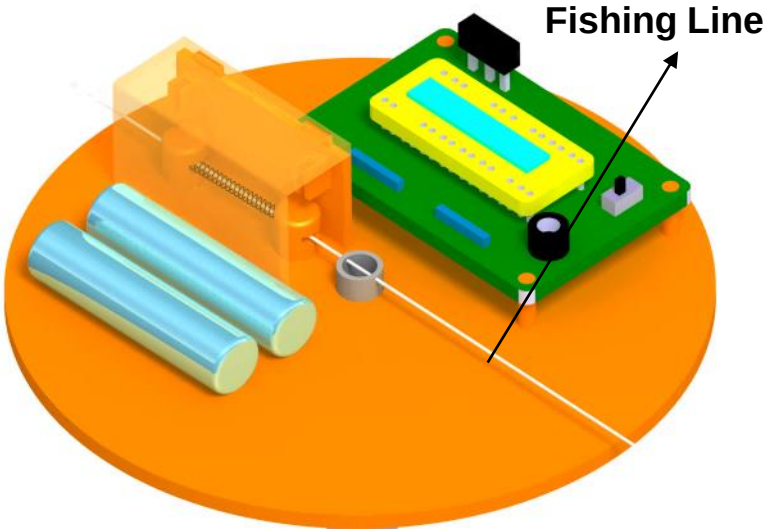


- Auto-gyro mechanism exists on the payload to provide required lift and drag. (BR-10)

Payload Mechanical Layout of Components (8/9)

Container Attachment Points



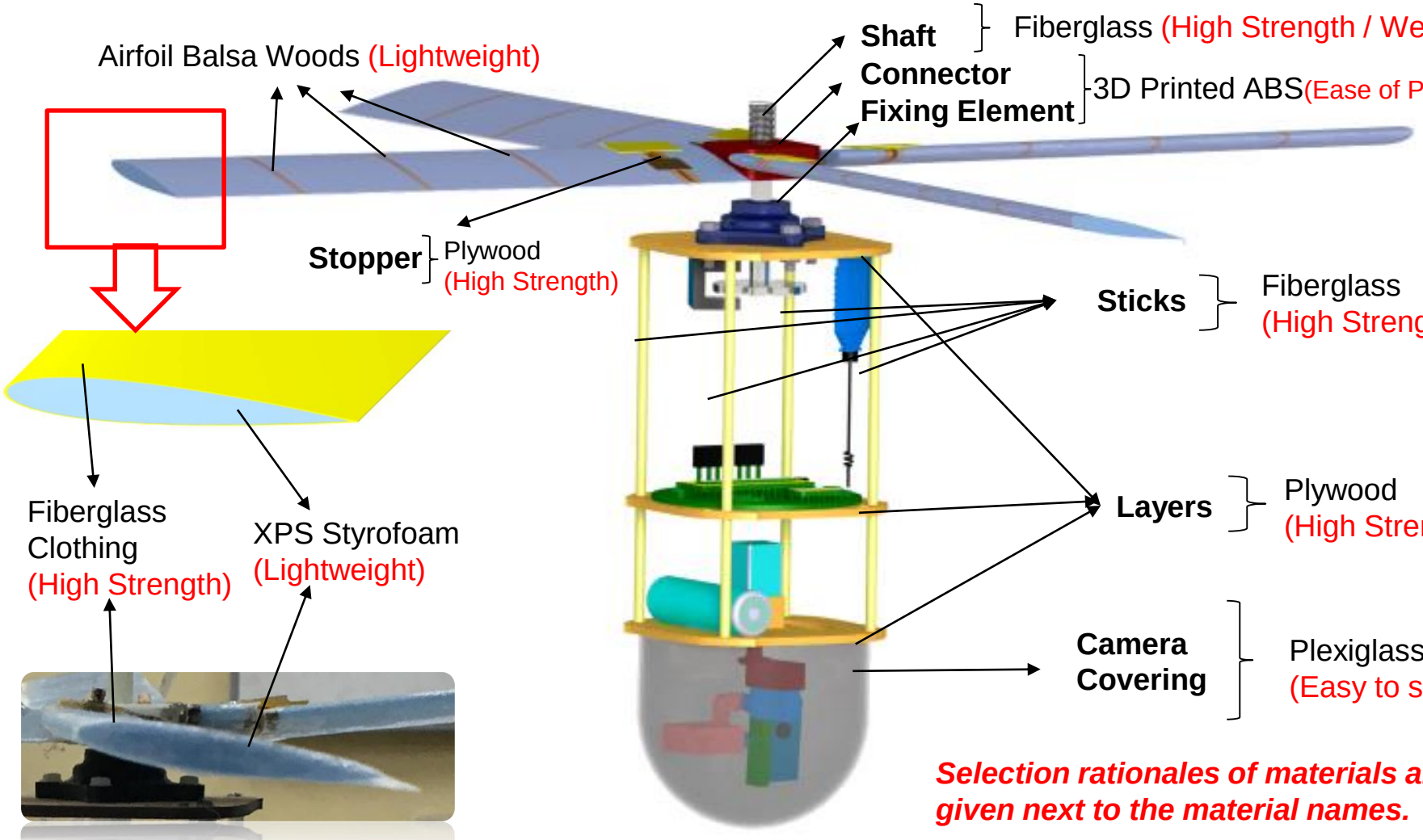


- When payload is mounted in container, system is fixed by tying fishing line.

- The fishing line passes through the holes on the payload's shaft and the container. When the payload is mounted in the container, system is fixed by tying fishing line.

Payload Mechanical Layout of Components (9/9)

Structural Material Selections



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

Container Mechanical Layout of Components (1/7)

Container Structure

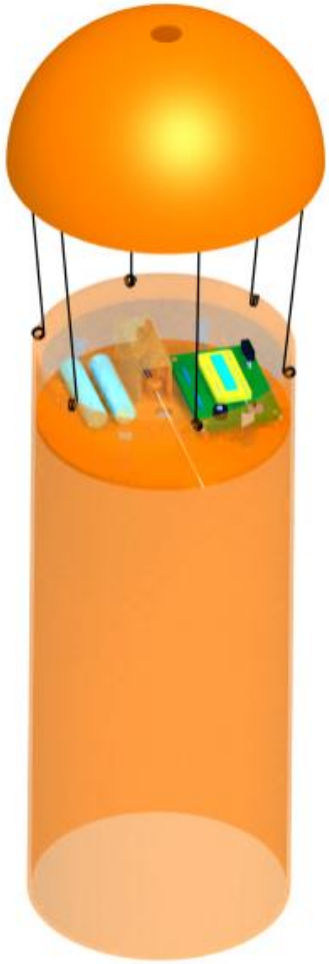
Structure on Different Phases of Flight

Before CanSat is released from rocket.

After CanSat is released from rocket.

Container Mechanical Layout of Components (2/7)

Container Structure

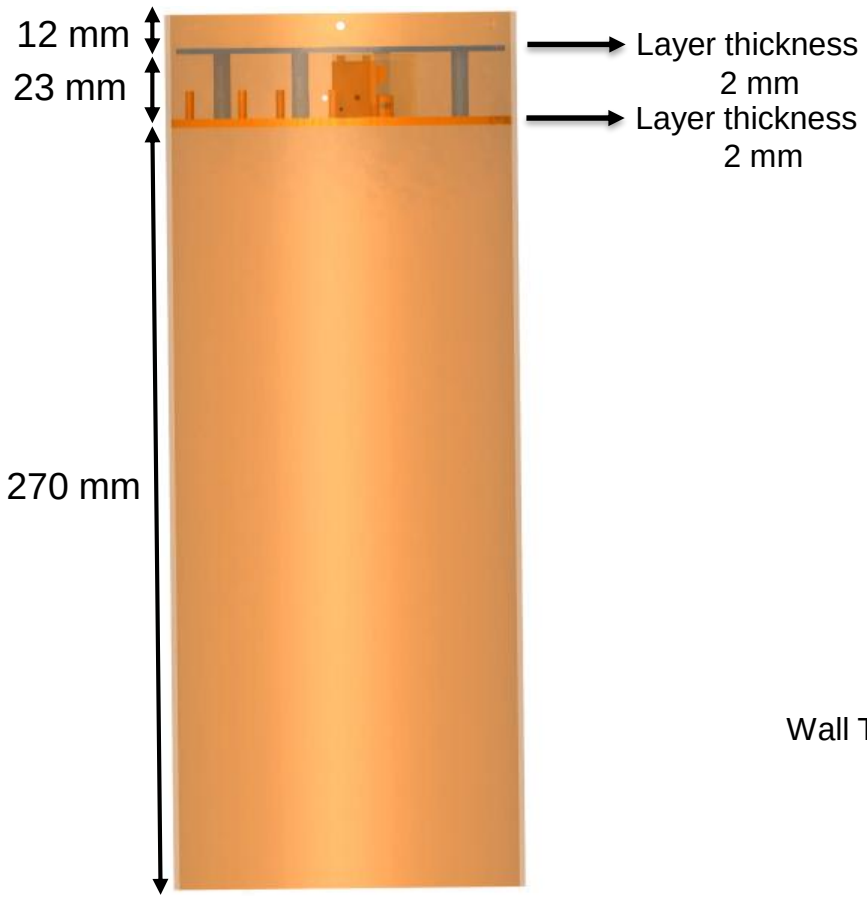


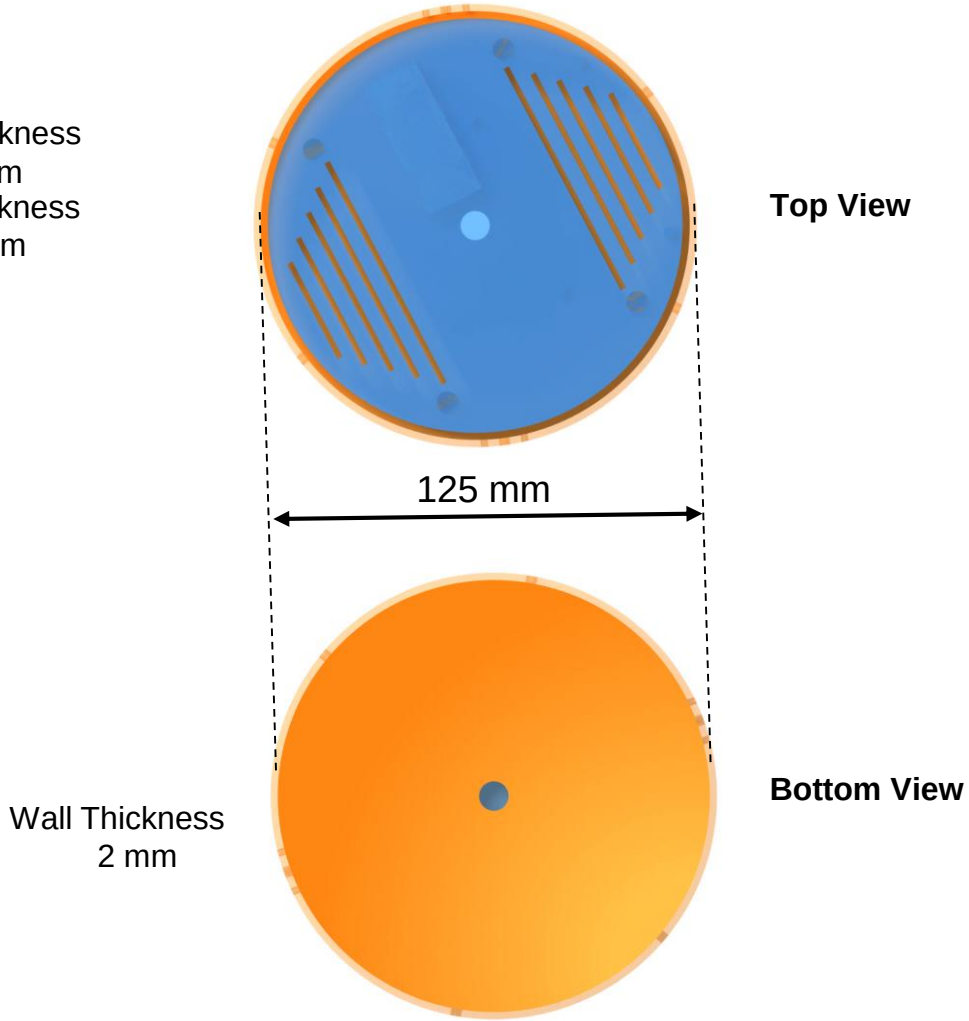
- Cylindrical shape prevents payload to stuck inside the rocket.
- Bottom of container is designed to be as big volume as possible.
- There is a top layer separating parachute from electronic parts.
- An intermediate layer separates payload volume from container electronics.
- There are electronics and 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.

Container Mechanical Layout of Components (3/7)

Container Structure

Dimensions

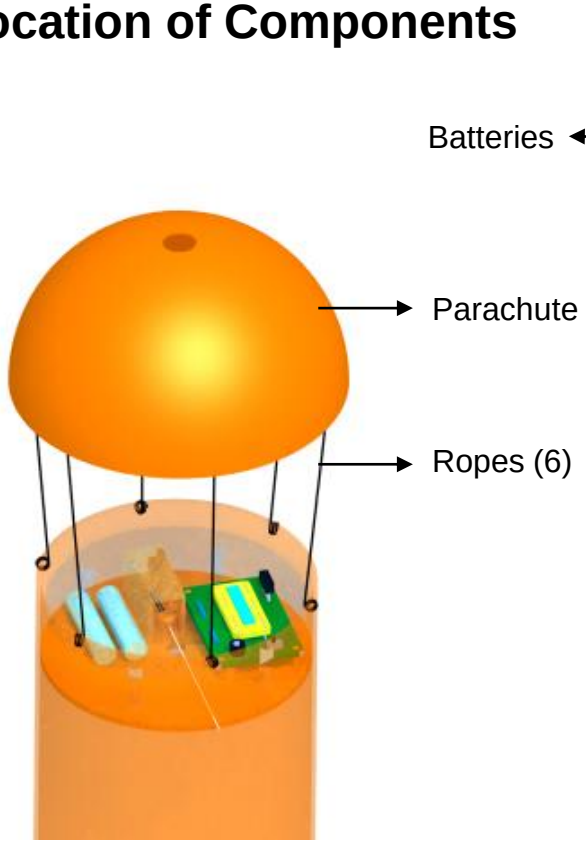


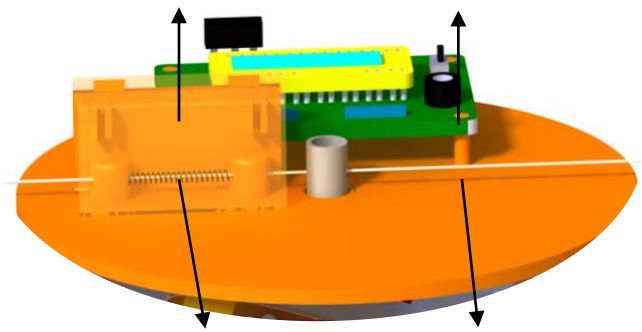


Container Mechanical Layout of Components (4/7)

Container Structure

Location of Components

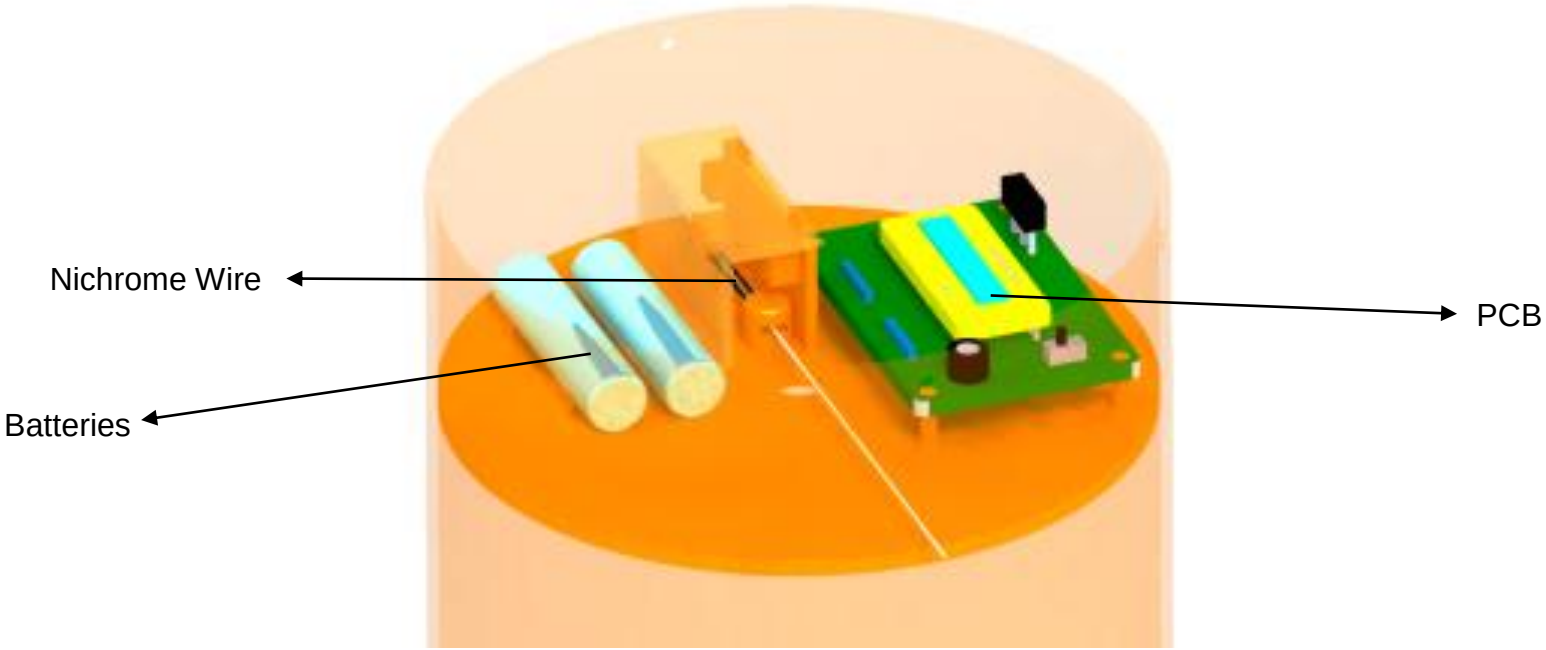




Container Mechanical Layout of Components (5/7)

Electrical Components

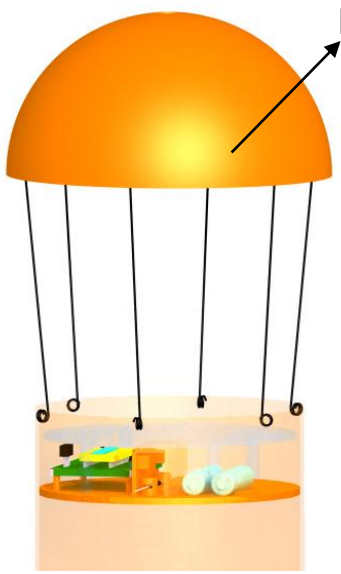
- The PCB is placed on the top of the container and fixed to plate.
- The battery is placed on the top.
- There is a nichrome wire at the payload release mechanism.



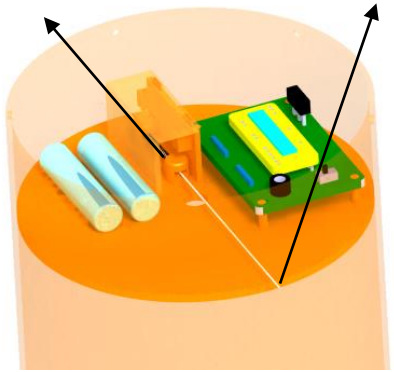
Container Mechanical Layout of Components (6/7)

Major Mechanical Parts

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



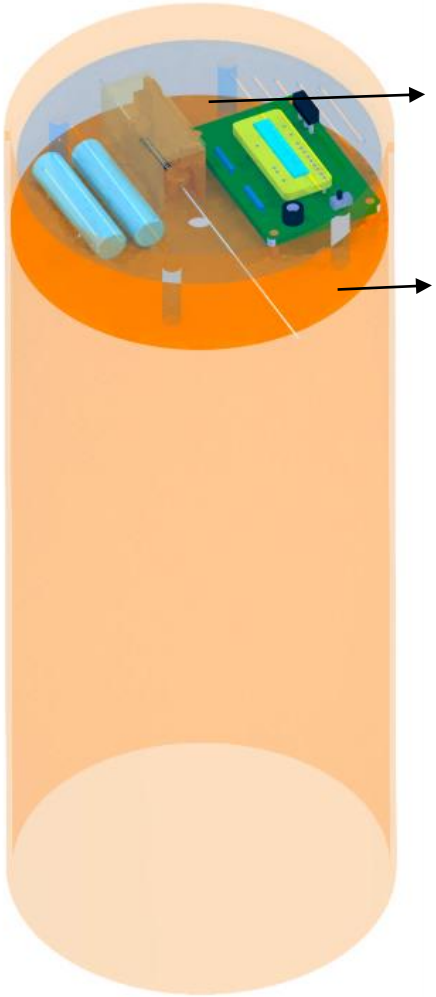
Parachute mechanism provides passive descent. When CanSat is deployed, parachute opens freely to limit container's velocity.



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

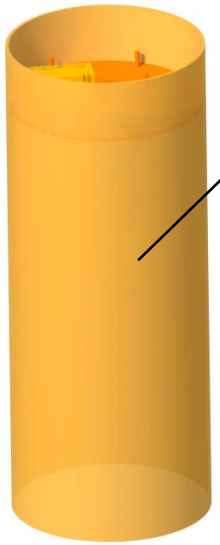
Container Mechanical Layout of Components (7/7)

Structural Material Selections



Top Layer } Balsa Wood

Intermediate Layer } Plywood

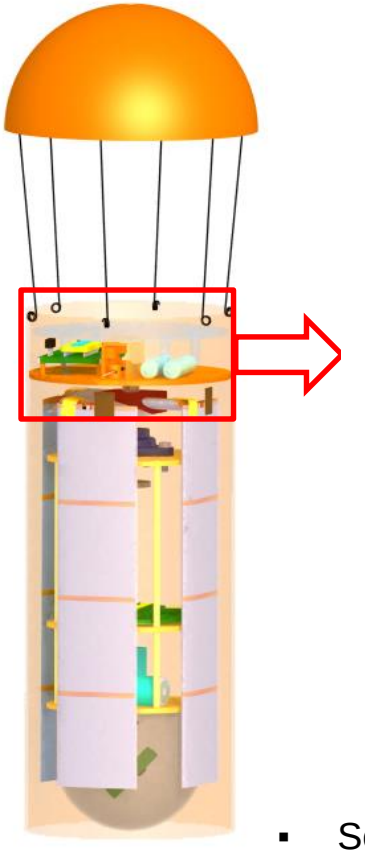


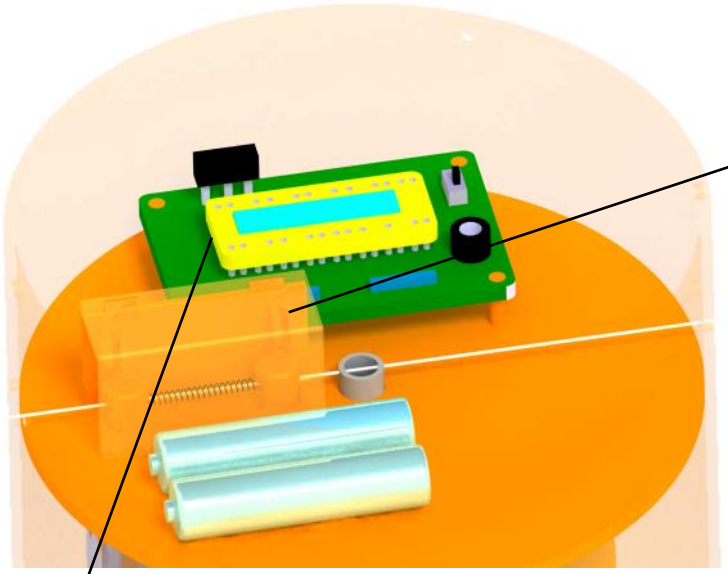
Container Main Body } Fiberglass

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 wood is used because of its lightweight.

Payload Release Mechanism (1/3)

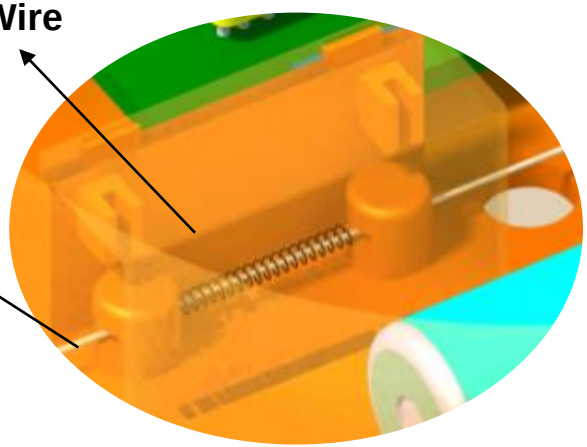




- Releasing mechanism is covered by a structure to prevent fatal failures which can be caused by heat. ***(BR-19)***

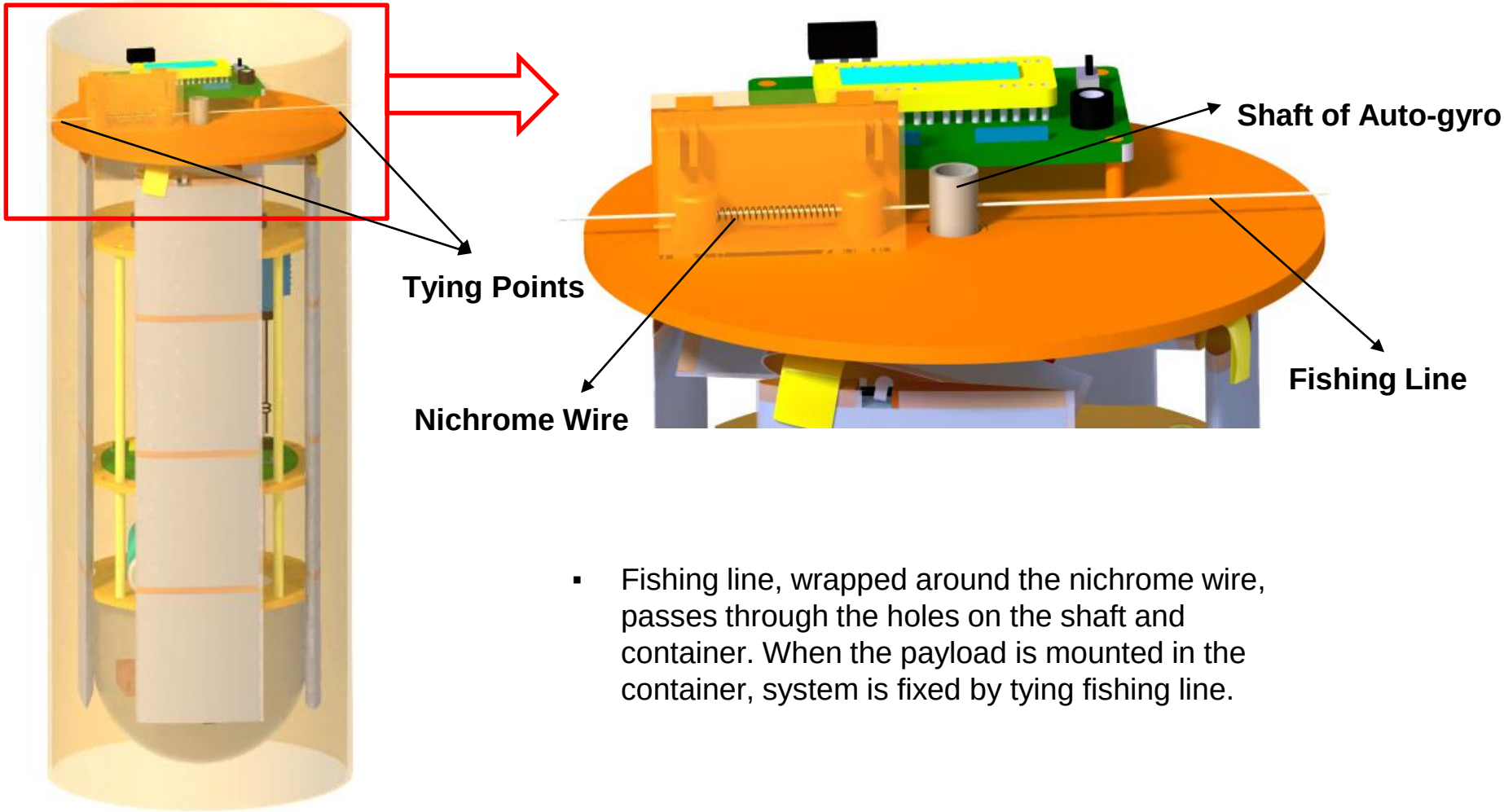
Nichrome Wire

Fishing Line



- Separation is realized by electronics on container.

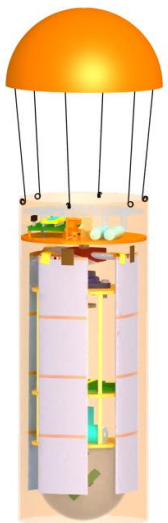
Payload Release Mechanism (2/3)



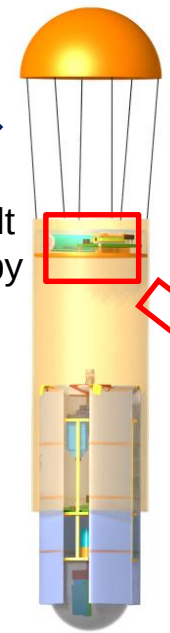
- Fishing line, wrapped around the nichrome wire, passes through the holes on the shaft and container. When the payload is mounted in the container, system is fixed by tying fishing line.

Payload Release Mechanism (3/3)

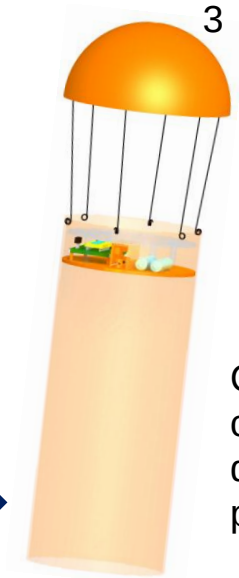
1



2

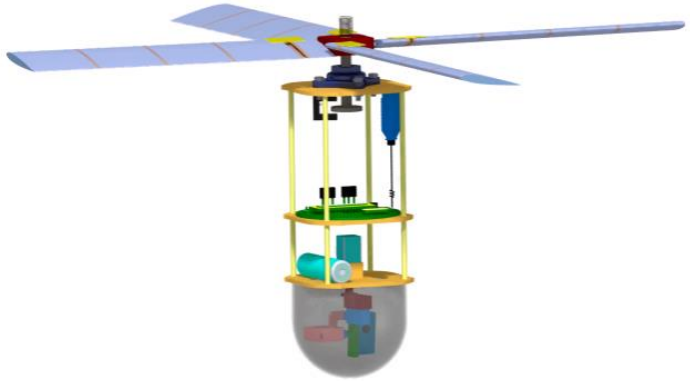


3



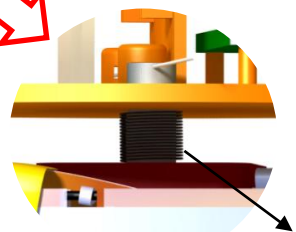
Container continues to descend passively.

4



- Payload starts to descend with auto-gyro mechanism.

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

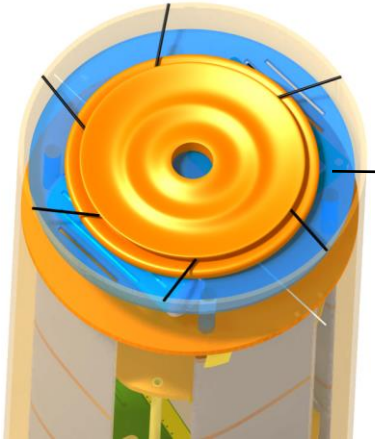


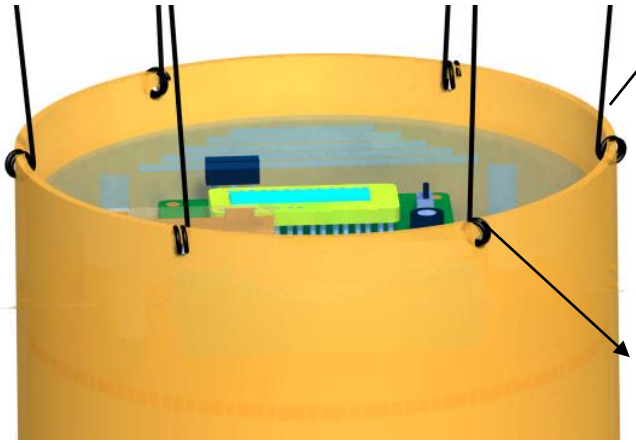
Spring

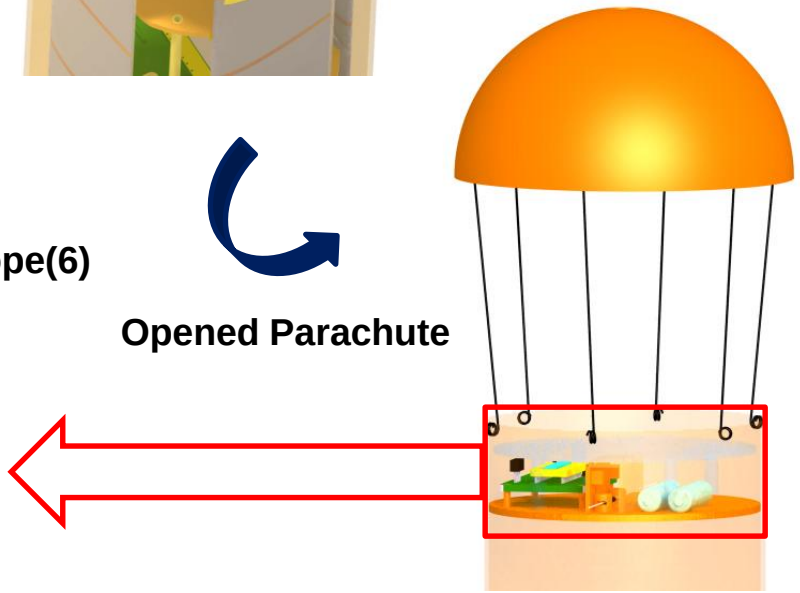
- The payload is released and separation carries out.
- The spring facilitates separation by releasing spring potential energy.

Container Parachute Release Mechanism (1/2)

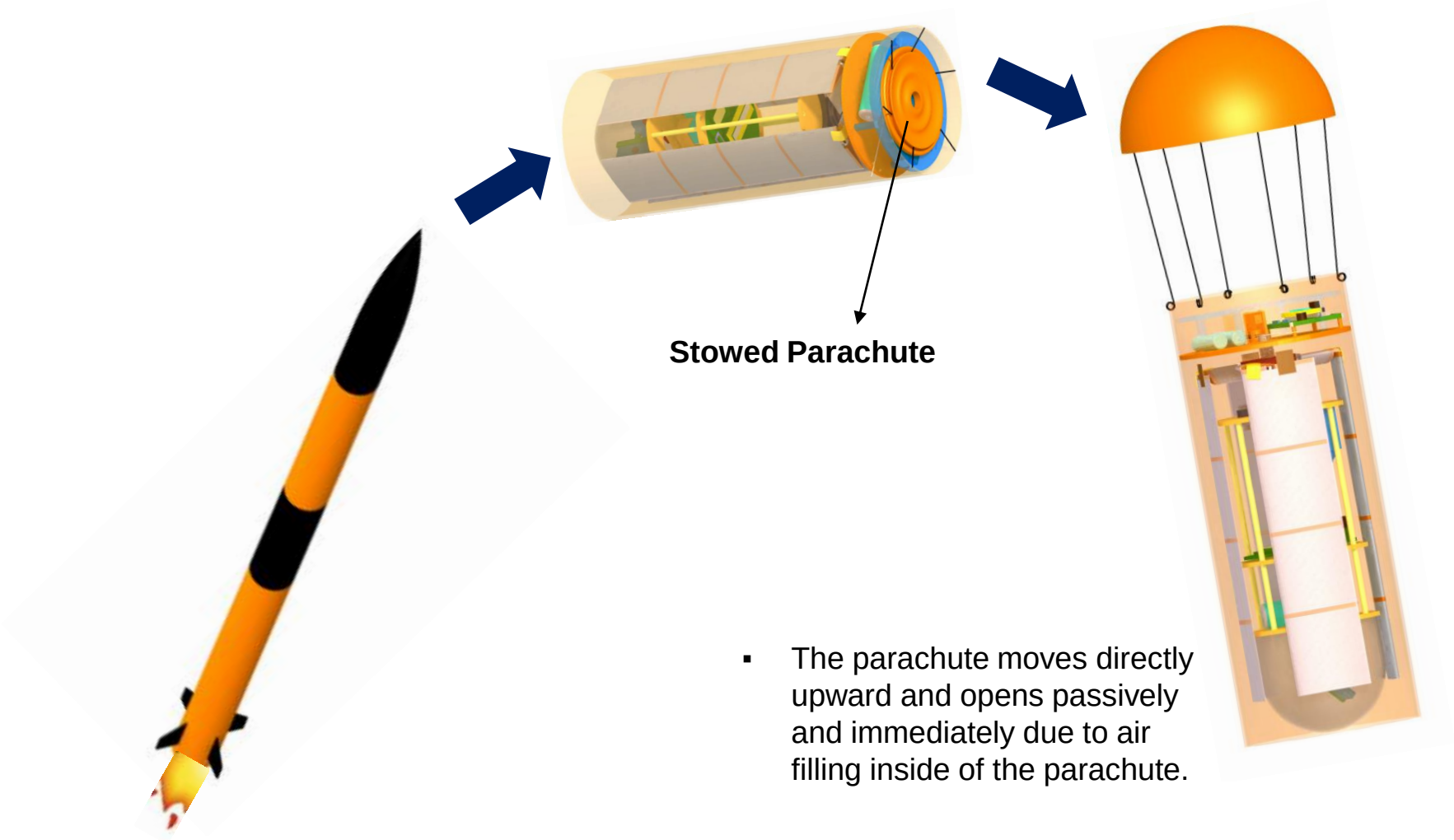
- A passive landing control system which is parachute will be assembled to container.
- Parachute ropes attached to the container's holes will be knotted.
- The parachute is located on the top of the container and stowed freely.
- When CanSat deploys from rocket, stowed parachute is freed to open.
-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

Structure Survivability (1/2)

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 a servo motor 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.

Structure Survivability (2/2)

Acceleration and Shock Force Requirements and Testing

- Acceleration and shock force tests were evaluated with drop test. The CanSat structure epoxy-reinforced was released in 3 meter. The results showed that the electronic components remained stationary and did not disperse.

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	6	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
Stopper Apparatus	6	M	-

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	62.5	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	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**

Our total mass meets the competition requirements.

<u>Correction Methods</u>

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

CDH Overview

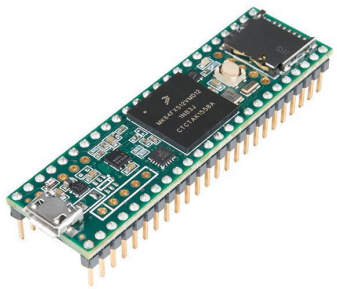
- **Payload:**

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**.

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

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

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



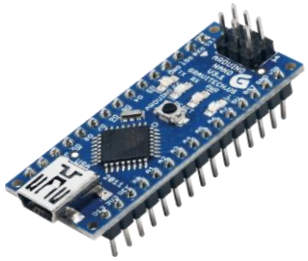
- **Container:**

Arduino Nano: *A processor* is used to control the release mechanism and process the sensor data.

Sandisk Ultra 16GB: *A memory card* is used to store altitude data of the container.

BMP180: *A pressure sensor* is used to measure the altitude of the container.

IRL 540: *N channel mosfet* is used to activate the release mechanism.



CDH Changes Since PDR

- **The container processor Teensy 3.2 has been changed to Arduino Nano. Container circuit is supplied by 7.2V two serial batteries because separation mechanism necessitate high voltage. Therefore, Teensy 3.2 is required a step-down regulator due to its power supply range which is 3.6V to 6.2V, but Arduino has convenient power supply range which is 7V to 12V, and is not required an external voltage regulator.**

CDH Requirements (1/3)

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	✓		✓	

CDH Requirements (2/3)

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	✓		✓	

CDH Requirements (3/3)

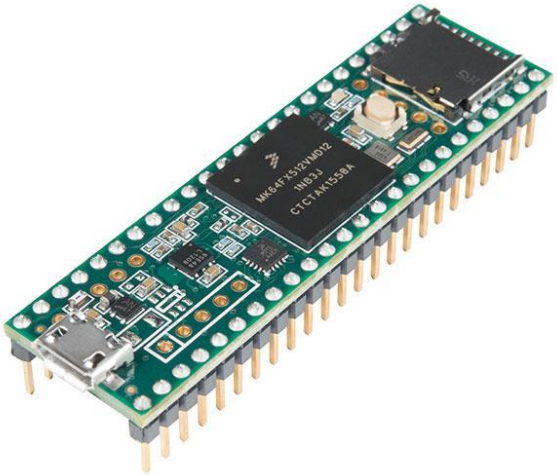
ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
CDH-14	The container shall measure altitude using an air pressure sensor.	Additional	-	-	Very High	✓		✓	
CDH-15	The container processor shall store altitude data into a memory card.	Additional	-	-	Very High	✓		✓	
CDH-16	The container shall release the payload at 450 meters +/- 10 meters.	CReq	BR-9	DCS-5 MS-8	Very High	✓		✓	
CDH-17	All structures shall be built to survive 15 Gs of launch acceleration.	CReq	BR-14	SS-2 MS-10	Very High	✓	✓	✓	
CDH-18	All structures shall be built to survive 30 Gs of shock	CReq	BR-15	SS-3 MS-10 DCS-6	Very High	✓	✓	✓	

Payload Processor & Memory Selection (1/3)

Model	Processor Speed	I/O Pins [Number]	Data Interfaces [Number]	Memory	Power Consumption	Boot Time	Bus Width
Teensy 3.5	120 MHz	Analog In[25] PWM [20] Digital[14]	I^2C [3] SPI [3] UART [6]	Flash - 512 KB SRAM - 256 KB EEPROM - 4 KB	0.225 Wh	3 s	32-bit

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.
- According to our experiences in the past, Teensy 3.5 is suitable.



Payload Processor & Memory 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	**I²C**	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 4.2mm	**Mass**	4.8 g
Processor Speed	120 Mhz	**Boot Time**	3 s
Bus Width	32-bit	**Power Consumption**	0.225 Wh

Payload Processor & Memory Selection (3/3)

Model	Memory	Interface	Data Transfer Rate
SanDisk Ultra 16GB SD Card	16 GB	SPI	80 MB/s

Selected Memory: SanDisk Ultra 16 GB SD Card

- Affordable cost.
- High data transfer rate.
- SPI interface is more stable than I²C interface.
- Easy pluggable and removable structure.

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

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.

Payload Antenna Selection (1/2)

Model	Connection Type	Frequency	Direction	Gain	Impedance	Beam Width Horizontal /Vertical	VSWR(Max)
TL-ANT2405CL	RP-SMA	2.4 GHz	Omni-directional	5 dBi	50 Ohms	360° / 32°	1.92:1

Selected Antenna: TL-ANT2405CL

- Satisfies payload requirements.
- Provides sufficient gain and vertical beam width.
- According to our experiences in the past TL-ANT2405CL is suitable for desired communication.

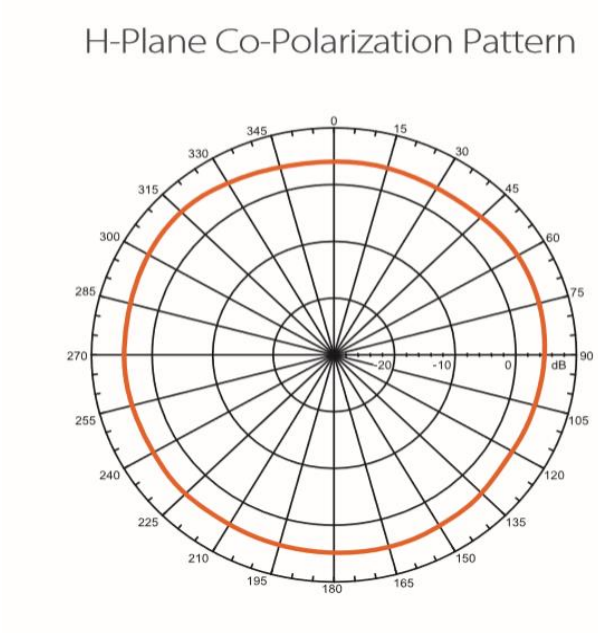
Mass & Size:

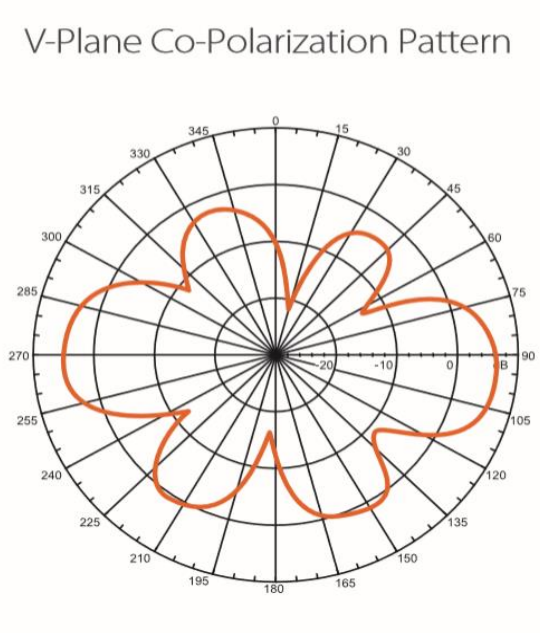
- Mass of the antenna is 14 grams which is lightweight when the performance and payload requirements are considered.
- Dimensions are 160 mm x 12 mm x 12 mm.
- Dimensions satisfies payload requirements from the compact design to fit in the payload.

Payload Antenna Selection (2/2)

Performance:

- Maximum Voltage Standing Wave Ratio (VSWR) value is 1.92:1. This value increases the performance importantly such as 90.1% of power is transmitted to the antenna while 9.9% is reflected.
- Sufficient polarization rates:
  - ➢ Horizontal Polarization Beam Width: 360°
  - ➢ Vertical Polarization Beam Width: 32°





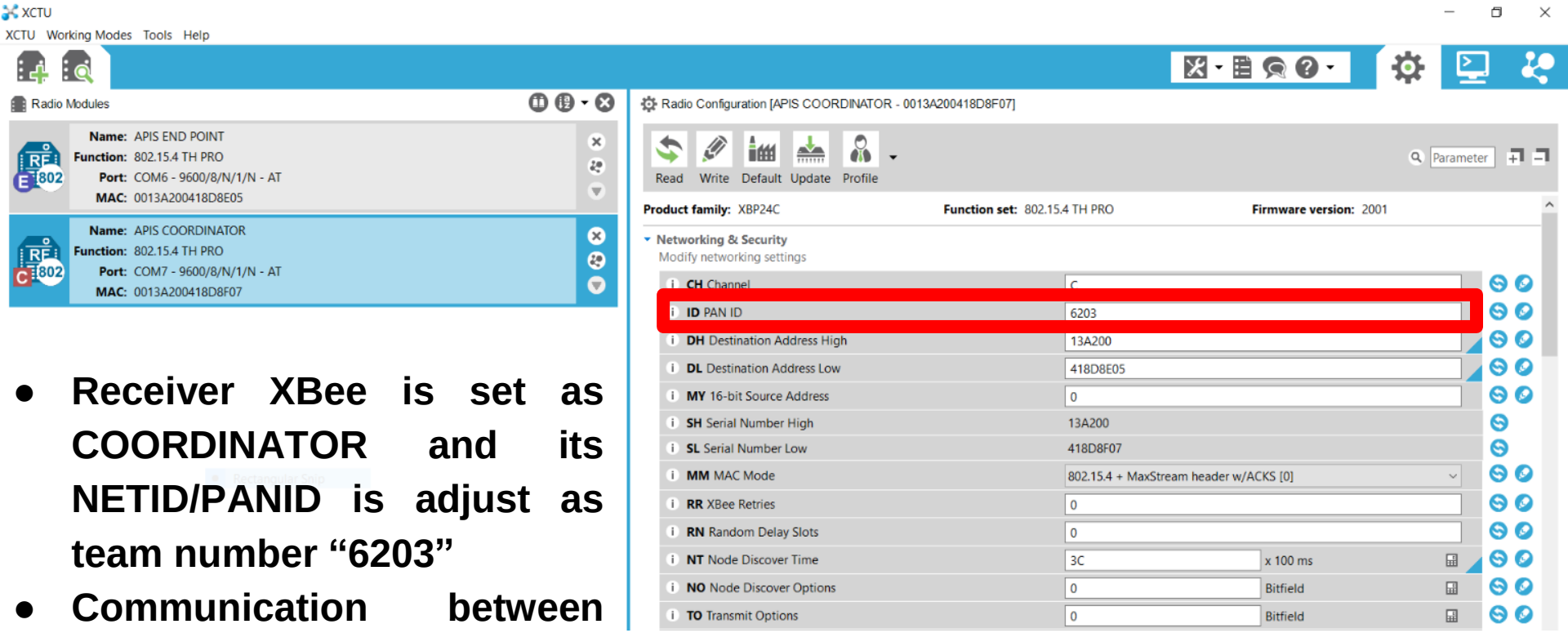
Payload Radio Configuration (1/3)

- **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)
- **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.
- **Frequency:** 2.4GHz
- **Transmit Power:** 63 mW (+18 dBm)

Payload Radio Configuration (2/3)

- **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.*

Payload Radio Configuration (3/3)



- **Receiver XBee is set as COORDINATOR and its NETID/PANID is adjust as team number "6203"**
- **Communication between both XBees are successfully achieved.**

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:

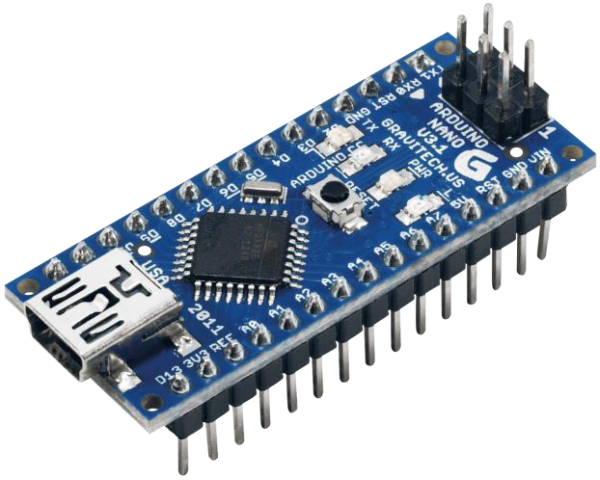
There will be a bonus direction data of the camera. This data shows the direction of the camera relative to Earth's magnetic north.

Container Processor & Memory Selection (1/3)

Model	Processor Speed	I/O Pins [Number]	Interface [Number]	Memory	Power Consumption	Boot Time	Bus Width
Arduino Nano	16 MHz	Digital [14] Analog In [8]	UART [2] I2C [2] SPI [4]	EEPROM - 1KB Flash - 32KB SRAM - 2KB	0.222 Wh	6.6 s	8 bit

Selected Processor : Arduino Nano

- Sufficient program and appropriate memory area for flight software.
- Sufficient processor speed for container circuit.
- Easy to program.
- Has acceptable dimensions for the circuit of the container.
- Works smoothly by high supply voltages.



Container Processor & Memory Selection (2/3)

- **The properties of Arduino Nano are given below:**

Operating Voltage (Logic Level)	5 V	**Analog Input**	8
Supply Voltage (Limits)	7-12 V	**I^2C**	2
Number of I/O Pins	22	**SPI**	4
PWM	6	**UART**	2
Flash Memory	32 KB	**Price**	8.99 $
Dimensions	18mm x 45 mm	**Mass**	5 g
Processor speed	16 MHz	**Boot Time**	6.6 s
Bus Width	8 bit	**Power Consumption**	0.222 Wh

Container Processor & Memory Selection (3/3)

Model	Memory	Interface	Data Transfer Rate	Type
SanDisk Ultra 16 GB SD Card	16 GB	SPI	80 MB/s	Flash

Selected Memory: SanDisk Ultra 16 GB SD Card

- Affordable cost.
- High data transfer rate.
- SPI interface is more stable than I²C interface.
- Easy pluggable and removable structure.

Electrical Power Subsystem Design

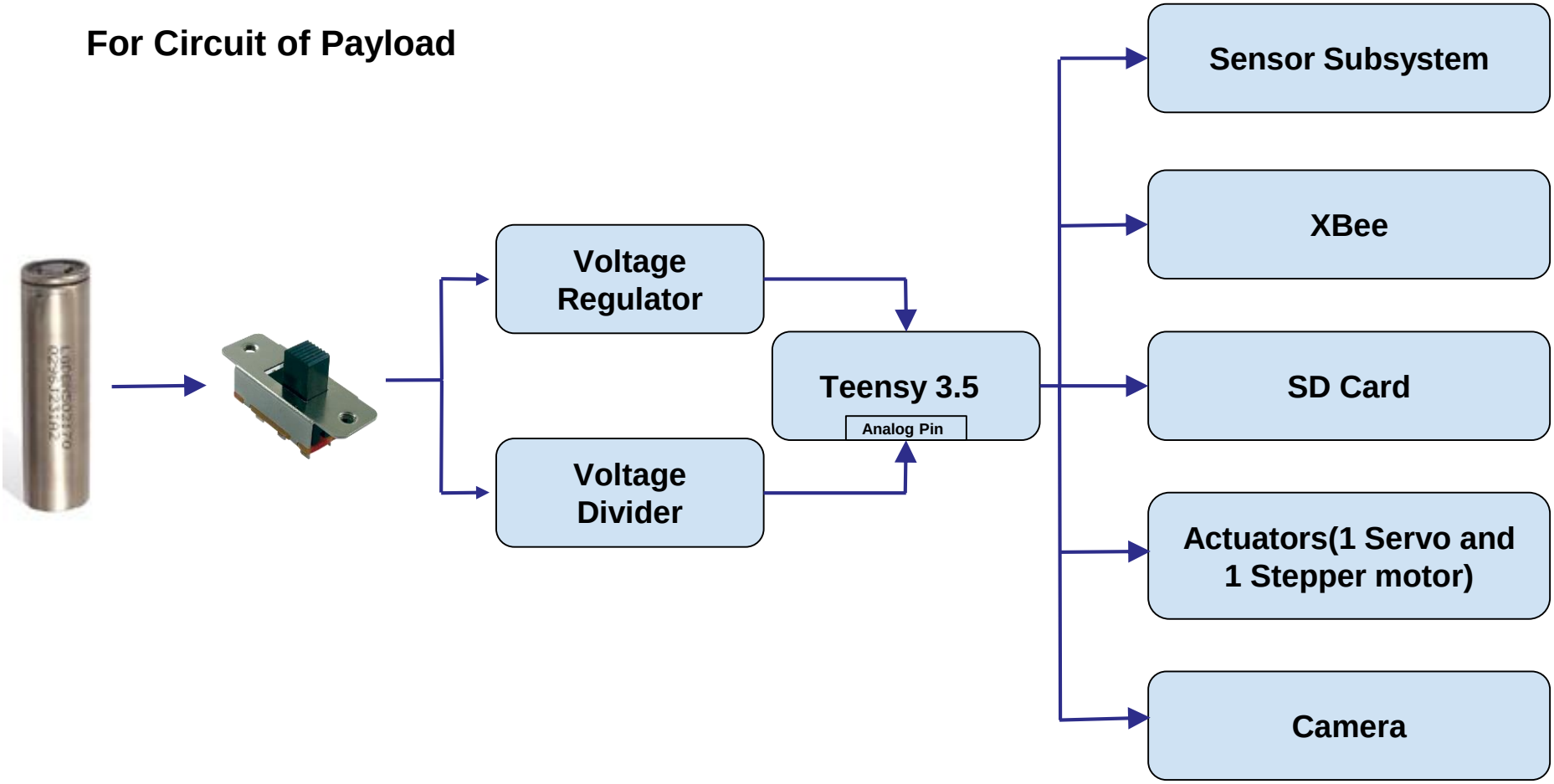
Buse COP

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

x2 →

→ **Arduino Nano** → **SD Card**, **Sensor Subsystem**, **Release Mechanism** → **Mosfet**

EPS Changes Since PDR

- In the payload circuit, one servo is removed from the camera stabilizer and Adafruit BNO055 is decided to use as pitch/roll sensor rather than MPU6050. As a result, payload power budget calculations and payload electrical diagrams are updated.

- In the container circuit, Arduino Nano is selected as microcontroller instead of Teensy 3.2, a 5V step up regulator is removed because of the microcontroller changing and OEM16340 battery is changed with Orion 10440 two serial batteries due to high voltage requirements for separation mechanism.

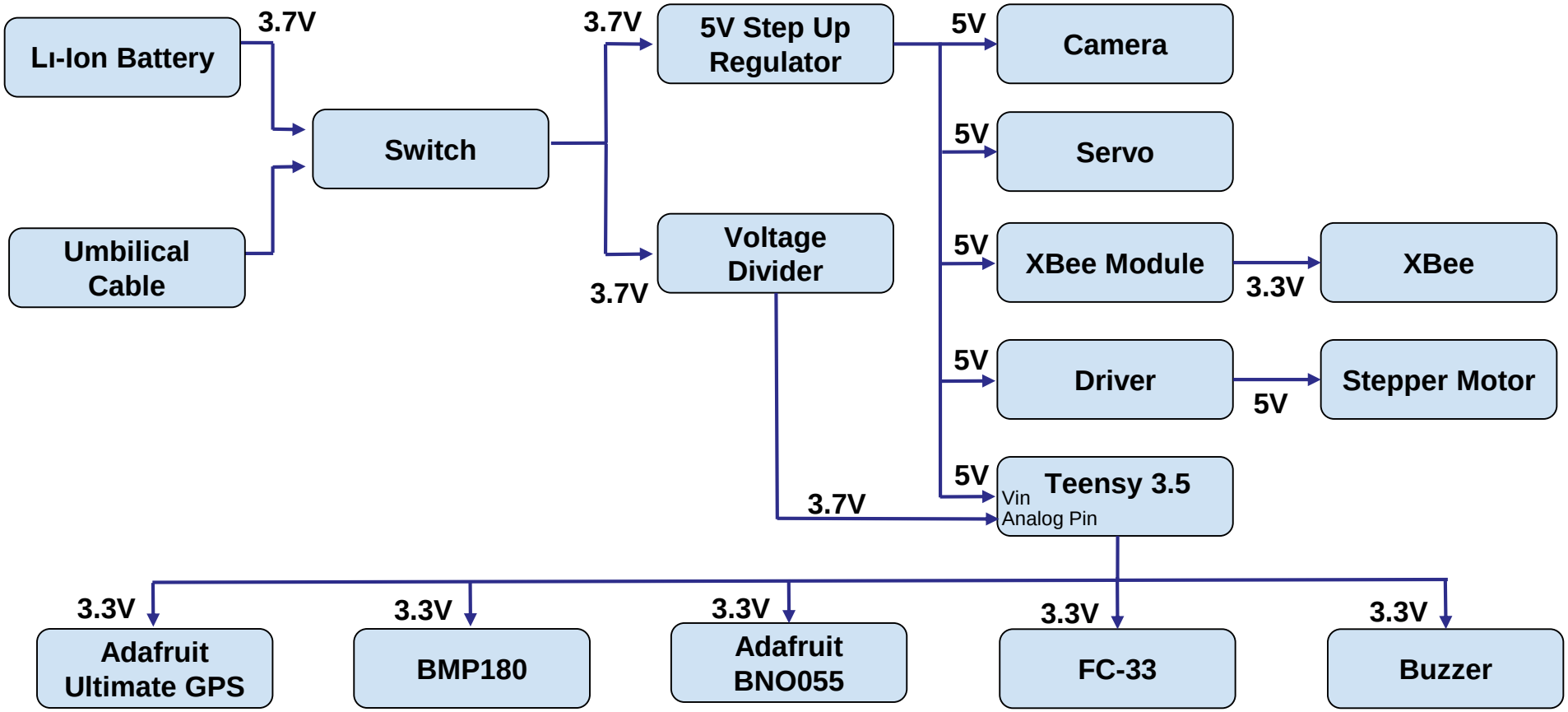
EPS Requirements (1/2)

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		✓		✓

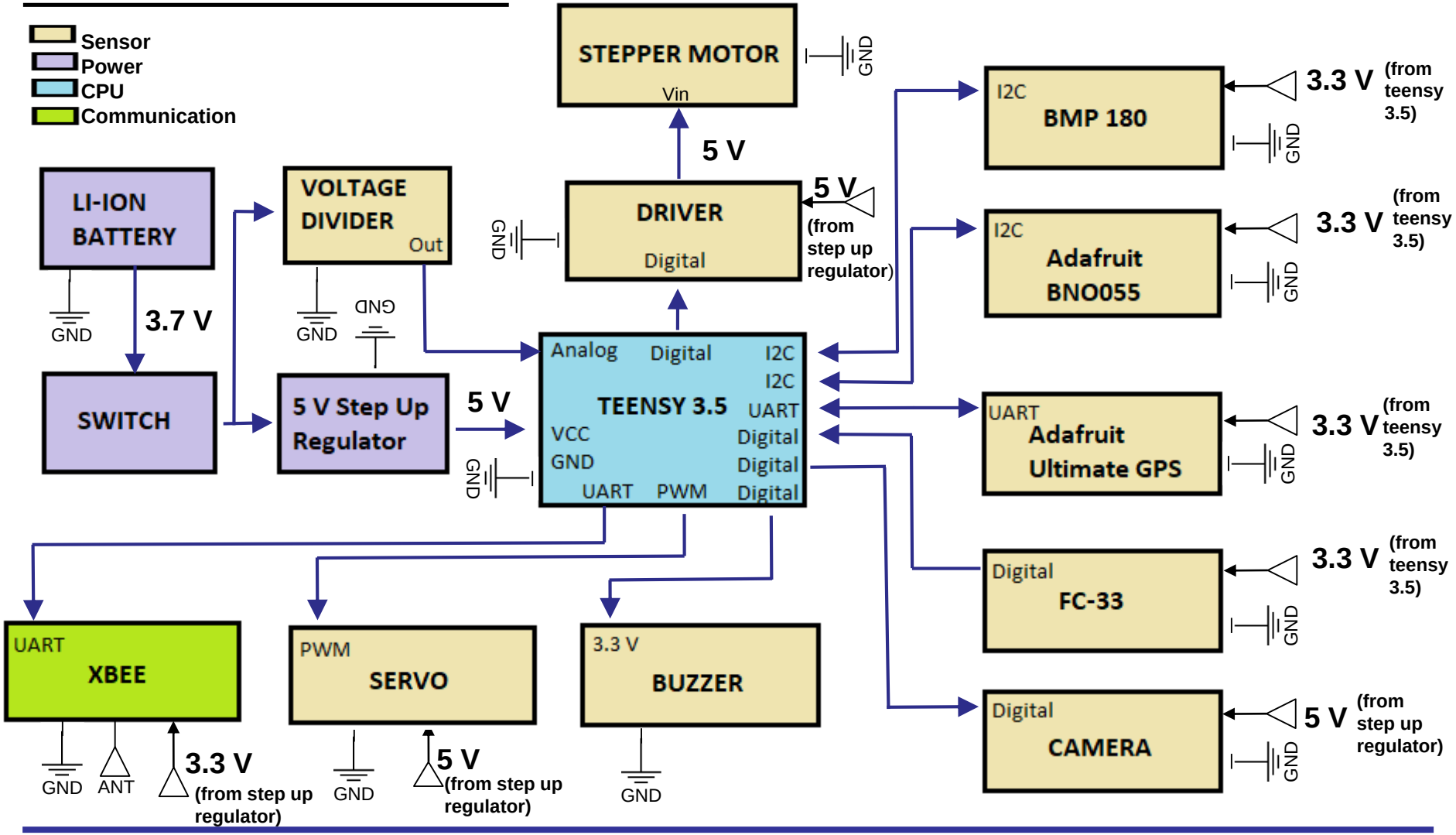
Payload Electrical Block Diagram (1/2)



- 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 Source

PROPERTIES OF LG M50 21700

Type	Lı-Ion
Number of Cells	1
Voltage	3.7 V
Current Capacity	5000 mAh
Instant Maximum Current Generation	7.3 A
Energy	18.2 Wh
Mass	68.2 g
Configuration	Series

Our final selection is LG M50 21700.

- This battery is selected due to enough voltage, energy and lightweight.
- High current capacity meets 2 hours operation with system.
- Current that battery can generate is appropriate to actuate all electronic components simultaneously.

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
Servo	5	300	1.5	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
Adafruit BNO055	3.3	12.3	0.04059	0.04059	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)
1251.305 mA	1251.305 mA x 2 h = **2502.61 mAh**	5.9296 W	5.9296 W x 2 h = **11.8592 Wh = 11859.2 mWh**

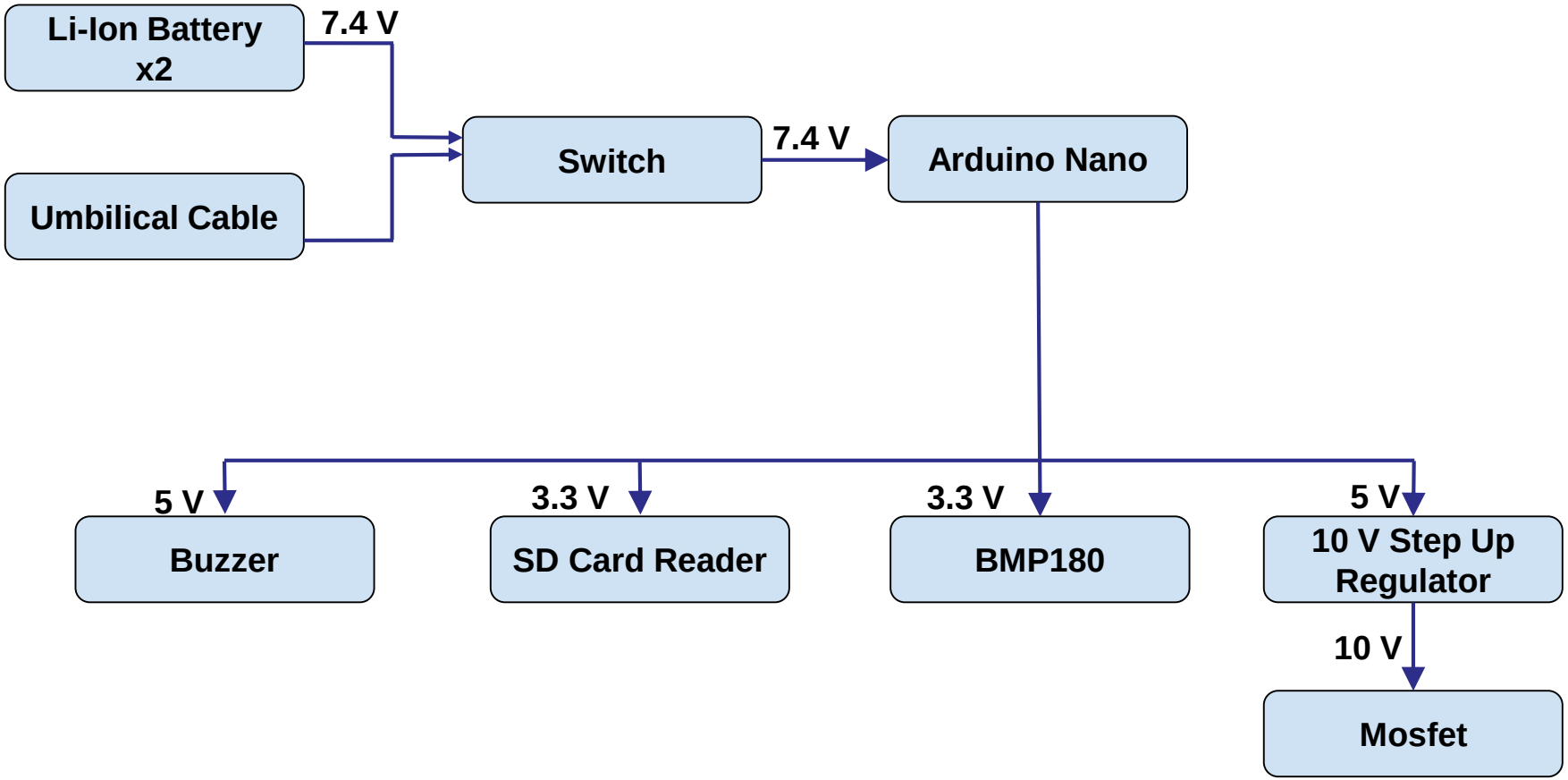
Payload Power Budget (3/3)

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)
2497.39 mAh	**6.3408 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.**

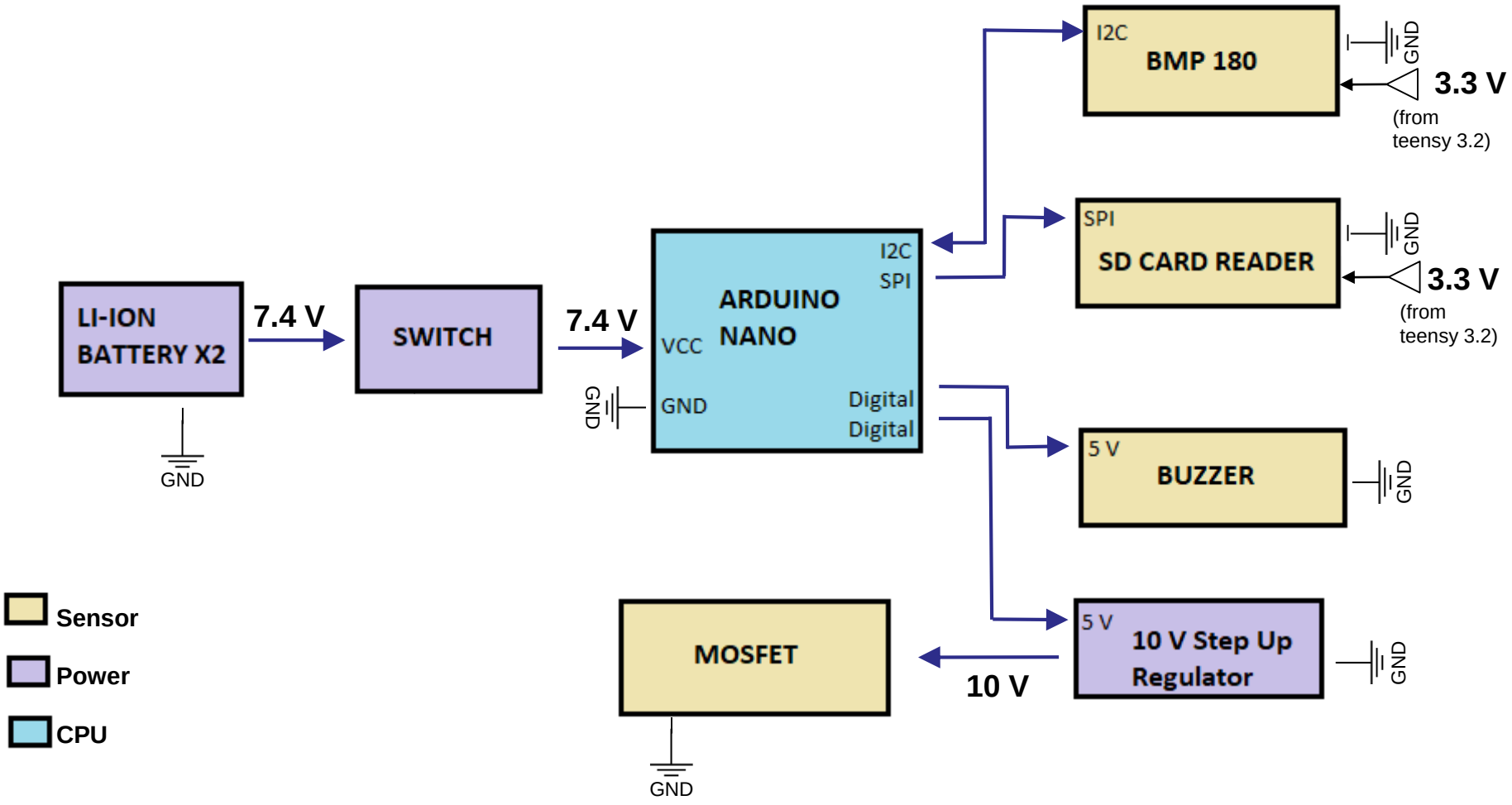
Container Electrical Block Diagram (1/2)



- 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.
- Arduino Nano 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 Source

PROPERTIES OF ORION 10440

Type	Lı-Ion
Number of Cells	2
Voltage (for one)	3.7 V
Current Capacity (for one)	600 mAh
Instant Maximum Current Generation (for one)	1.4 A
Energy (for one)	2.22 Wh
Mass (for one)	9 g
Configuration	Series

Our final selection is ORION 10440.

- This battery is selected due to enough voltage, energy and lightweight.
- Sufficient current capacity meets 2 hours operation with system.
- Current that batteries can generate is appropriate to activate release mechanism.

Container Power Budget (1/2)

Component	Voltage (V)	Current (mA)	Power (W)	Power Consumption (Wh) (W x 1h)	Duty Cycle (%)	Source
Arduino Nano	7.4	30	0.222	0.222	100	Datasheet
BMP180	3.3	0.005	0.0000165	0.0000165	100	Datasheet
Mosfet (IRL540)	10	90	0.9	0.9	5	Estimate
SD Card Reader	3.3	150	0.495	0.495	100	Datasheet/ Estimate
Buzzer	5	25	0.125	0.125	100	Datasheet

Total Current	Total Current Consumed (for two hours)	Total Power	Total Power Consumed (for two hours)
295.005 mA	295.005 mA x 2 h = **590.01 mAh**	1.742 W	1.742 W x 2 h = **3.484 Wh = 3484 mWh**

Container Power Budget (2/2)

Available Total Current Capacity (for two hours)	Available Total Power Capacity (for two hours)
600 mAh	4.44 Wh

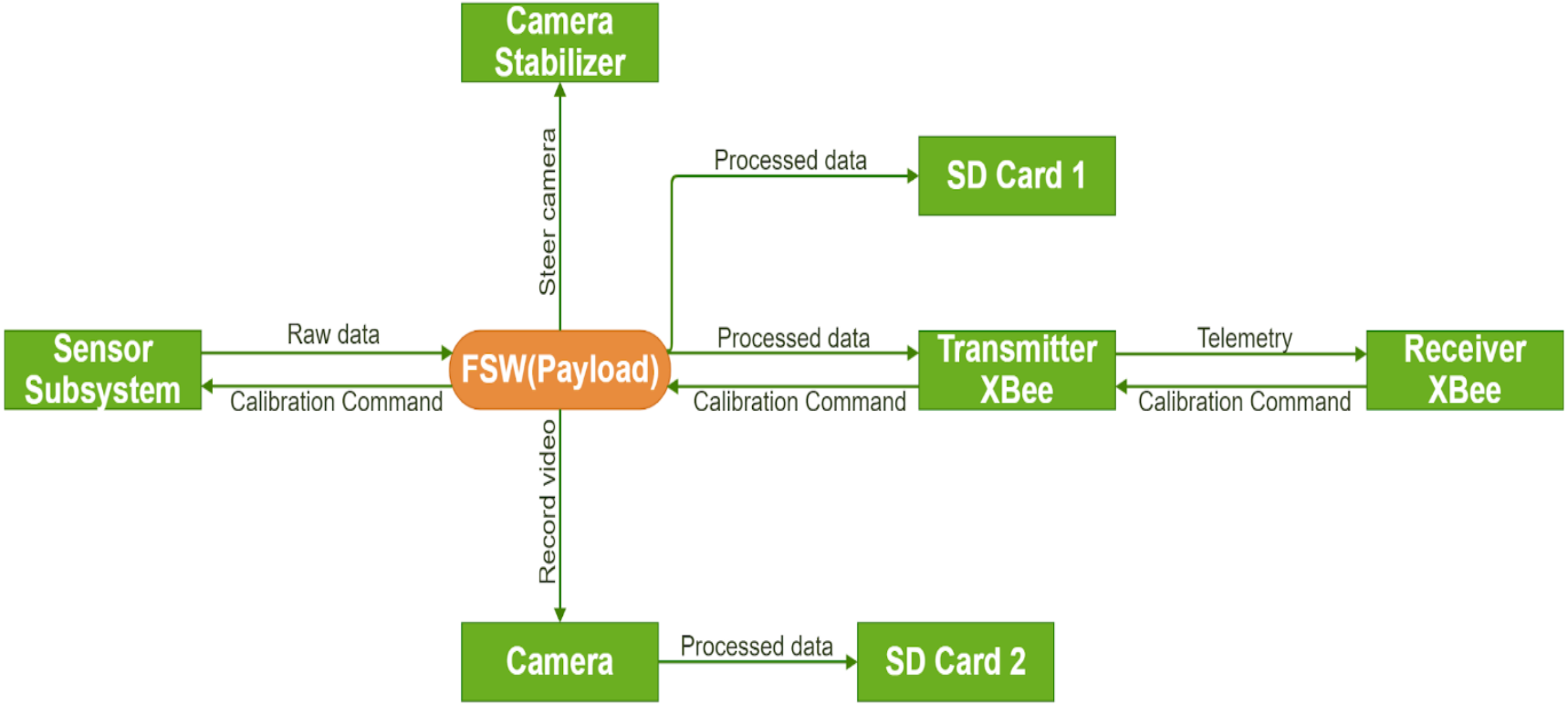
Margin of Current Consumption (for two hours)	Margin of Power Consumption (for two hours)
9.99 mAh	**0.956 Wh**

- **Double Orion 10440 batteries will be used as power source.**
- **Selected batteries are capable of providing power to the container for at least two hours.**

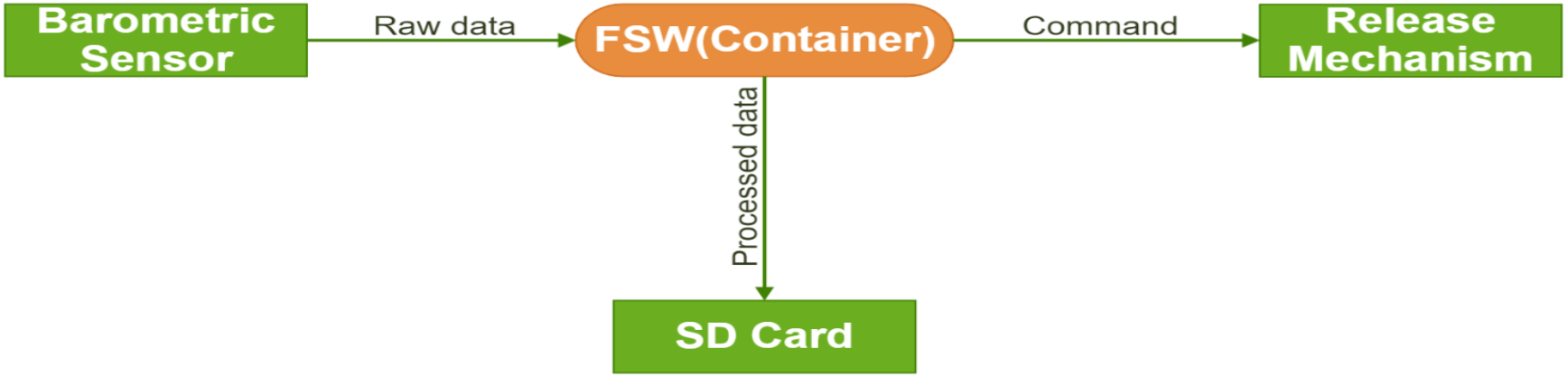
Flight Software (FSW) Design

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 Changes Since PDR

- Payload software development plan is extended to Late April because of the sensor changes causing library changes.

- Container software development plan is completed on time.

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)

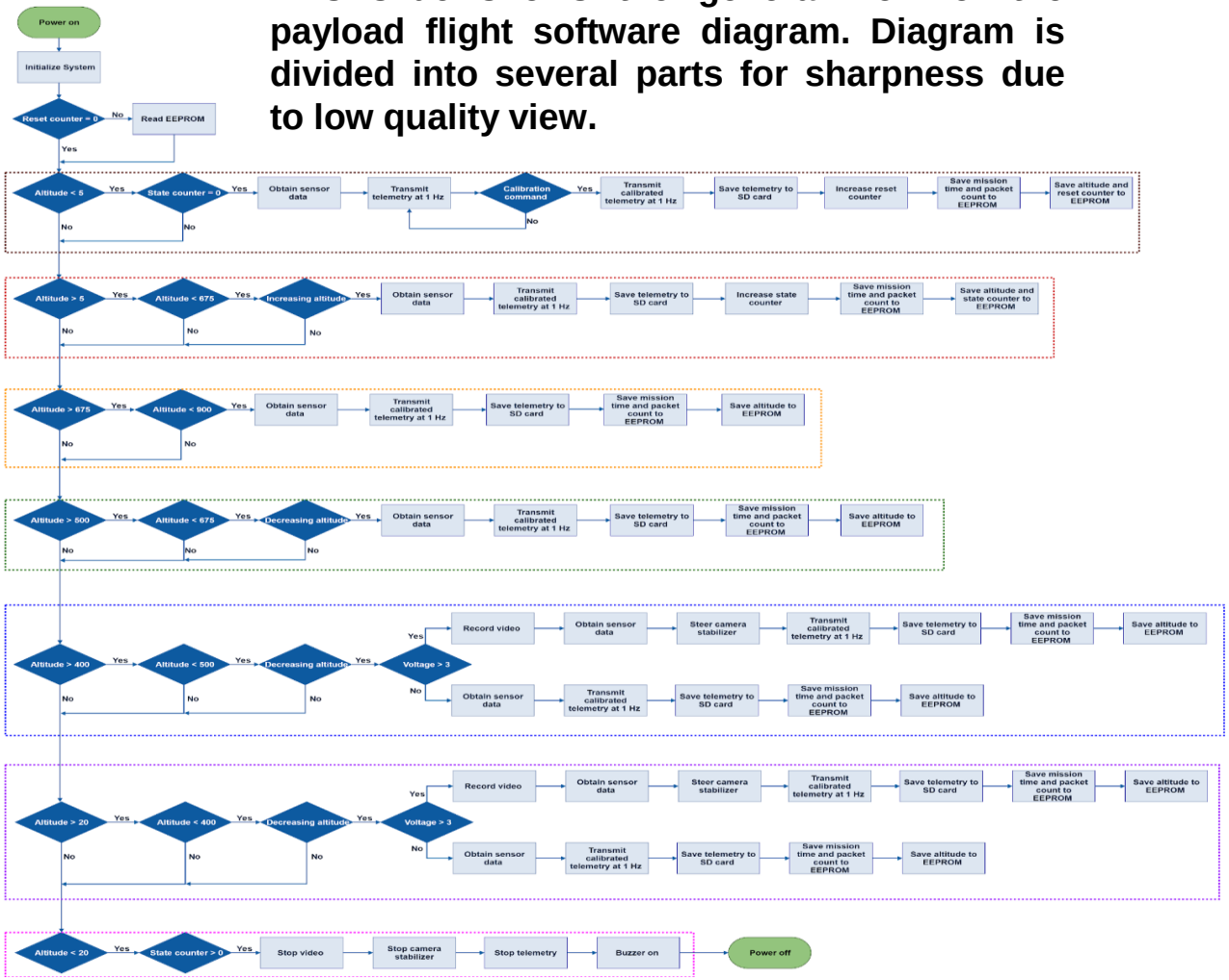
ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
FSW-7	The probe shall transmit all sensor data in the telemetry	CReq	BR-26		Very High	✓		✓	
FSW-8	The ground station shall be able to command the science vehicle to calibrate barometric altitude, and roll and pitch angles to zero as 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 CanSat 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

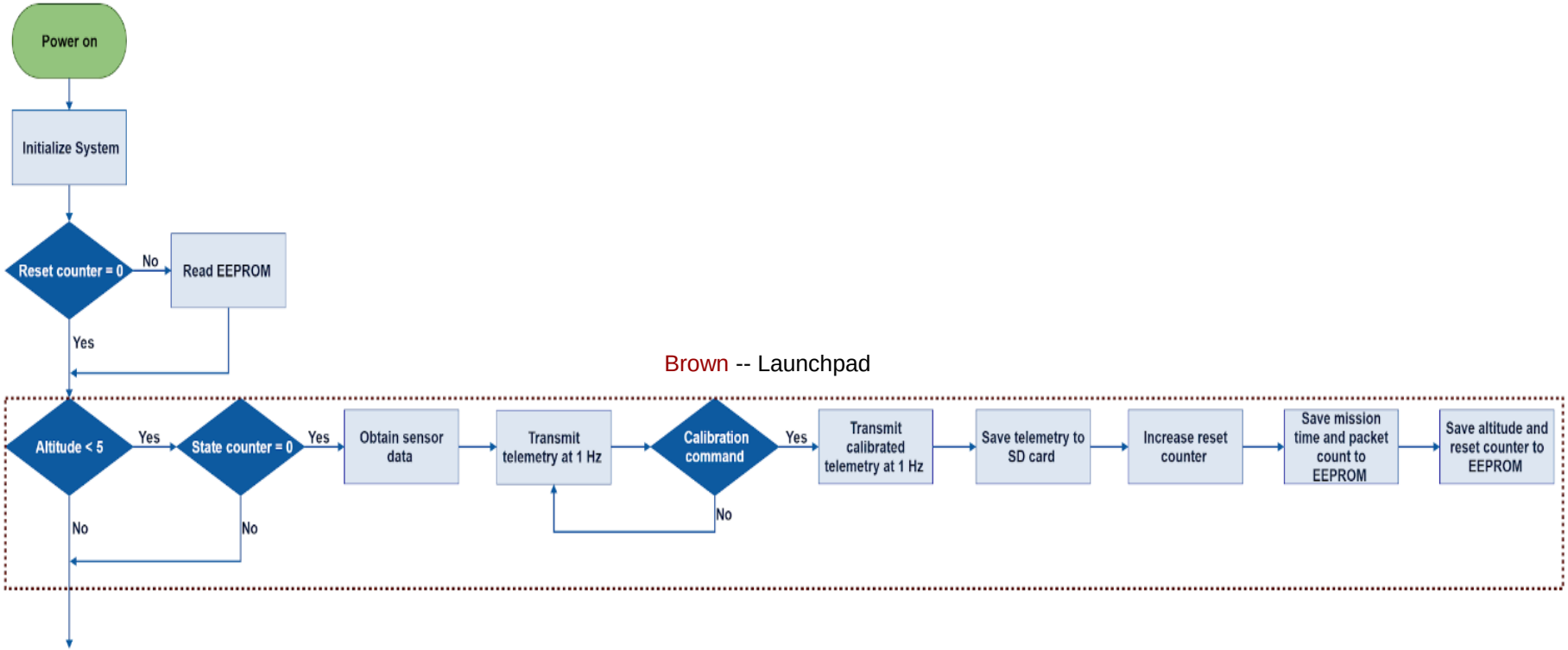
Green -- Descent

Navy Blue -- Separation

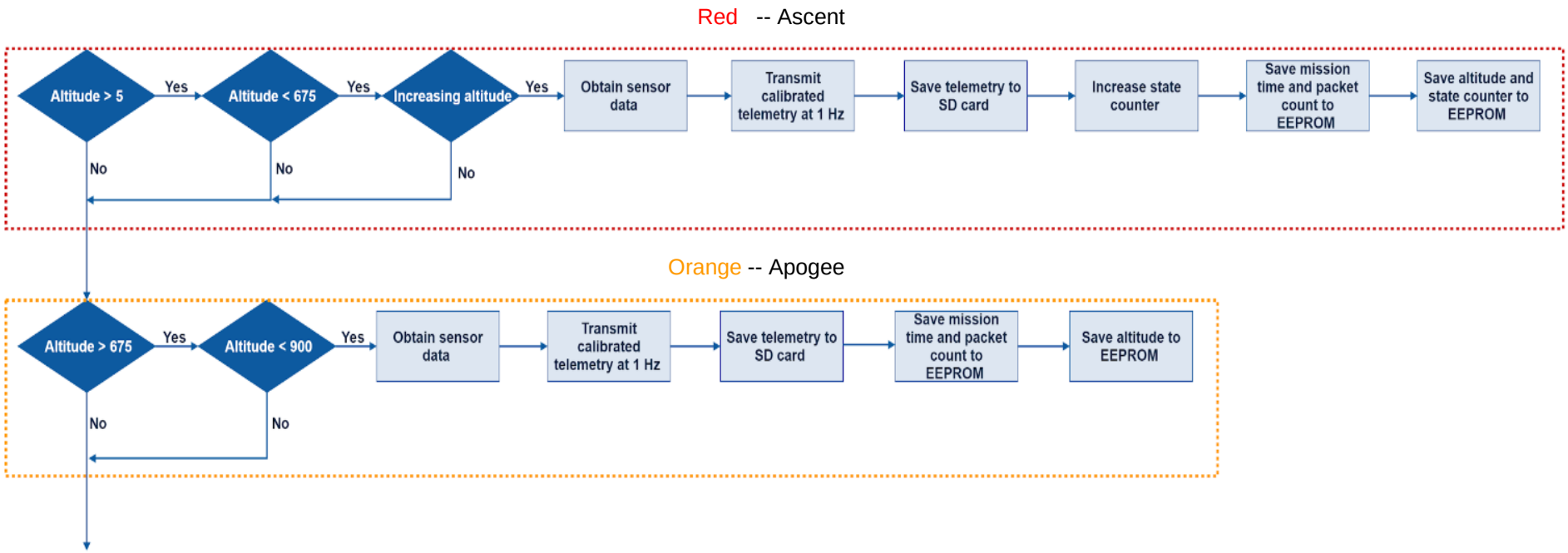
Purple -- Descent after separation

Pink -- Landing

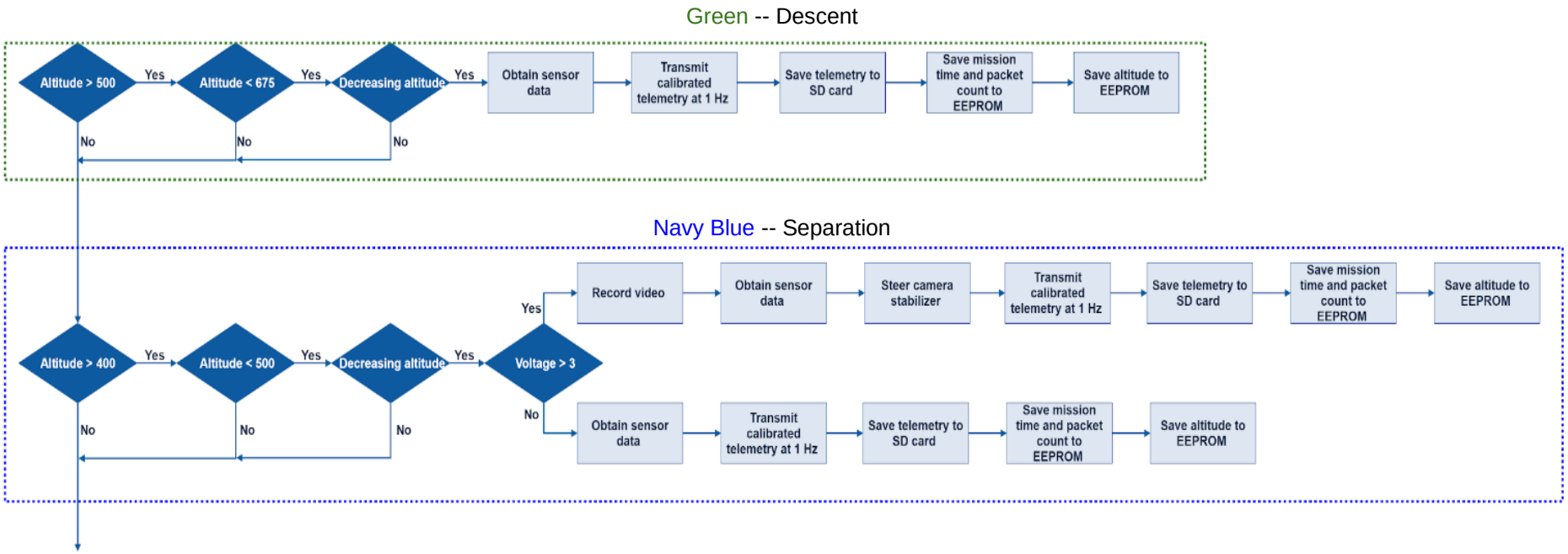
Payload CanSat FSW State Diagram (2/6)



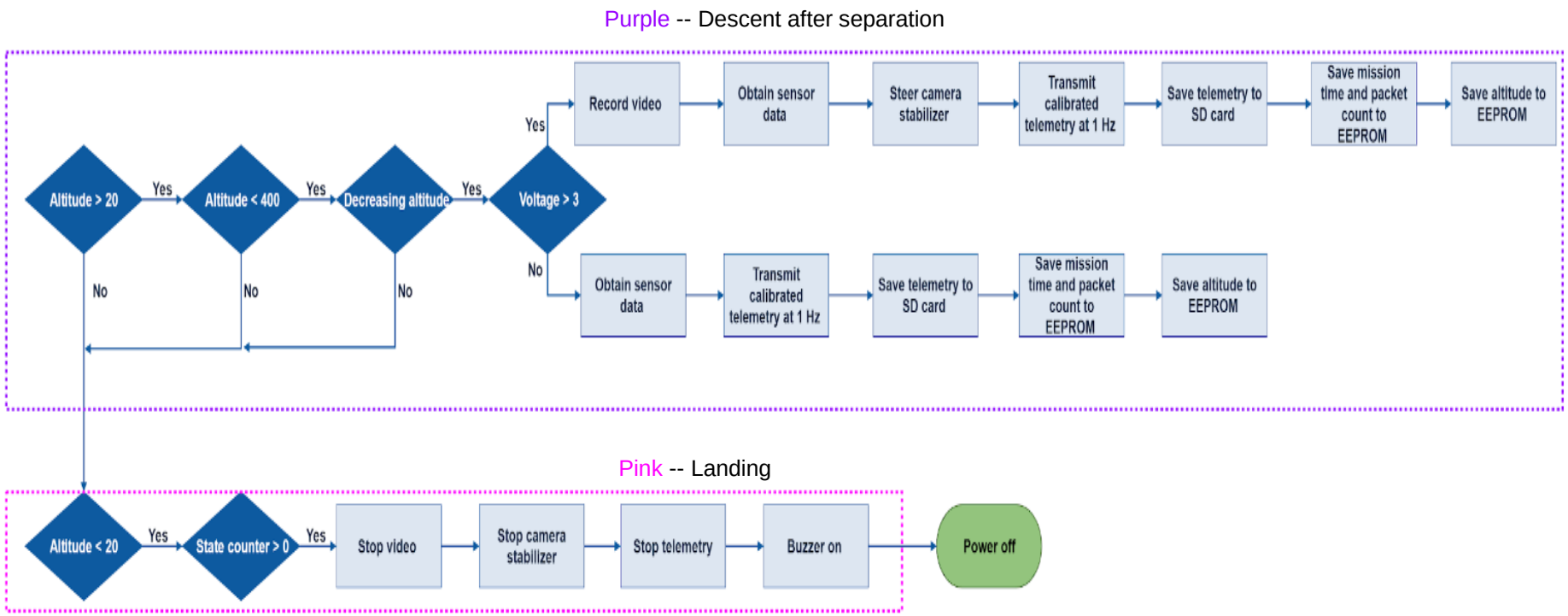
Payload CanSat FSW State Diagram (3/6)



Payload CanSat FSW State Diagram (4/6)



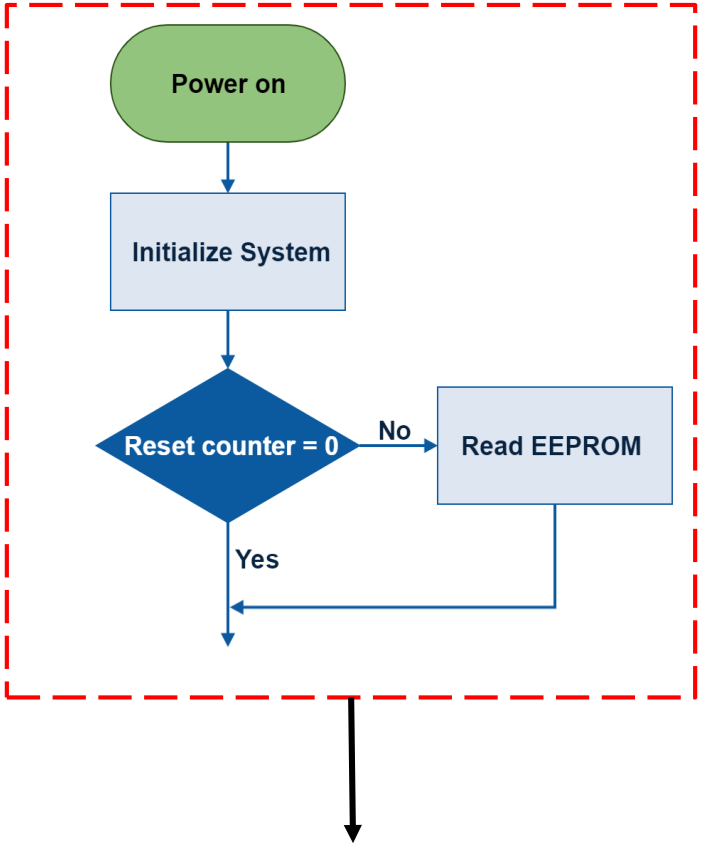
Payload CanSat FSW State Diagram (5/6)



Payload CanSat FSW State Diagram (6/6)

Payload FSW State Recovery

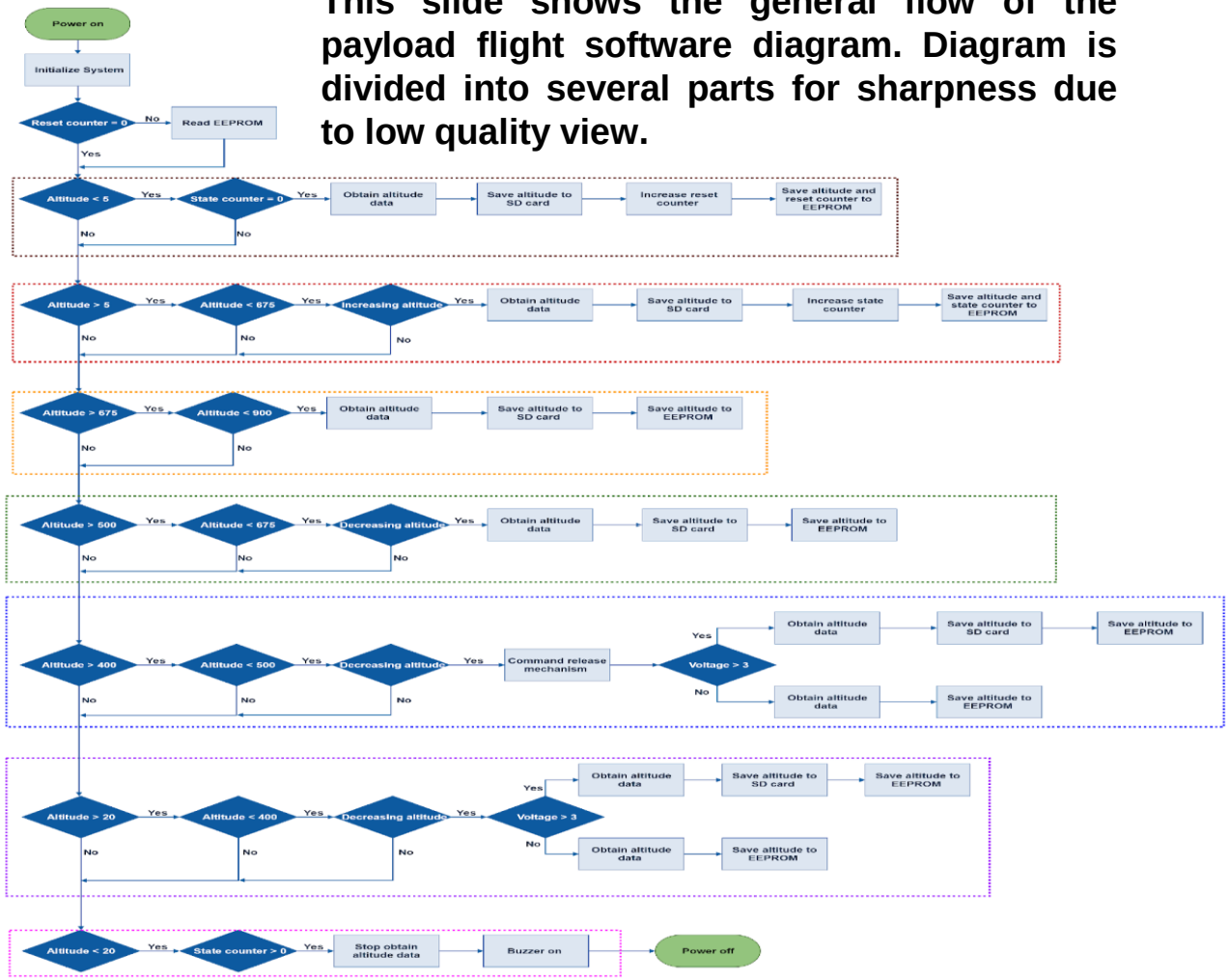
- Altitude data, reset counter and state counter variables will be used to recover FSW state if processor resets. Reset counter is an integer variable which helps to determine reset situation, and state counter is an integer variable which helps to determine software states.
- Reset reasons may be high temperatures affecting directly to the microprocessor, high current exceeding limits of input and output pins of the microprocessor, and flight software which closes to flash memory limit of the 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 the 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 CanSat 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

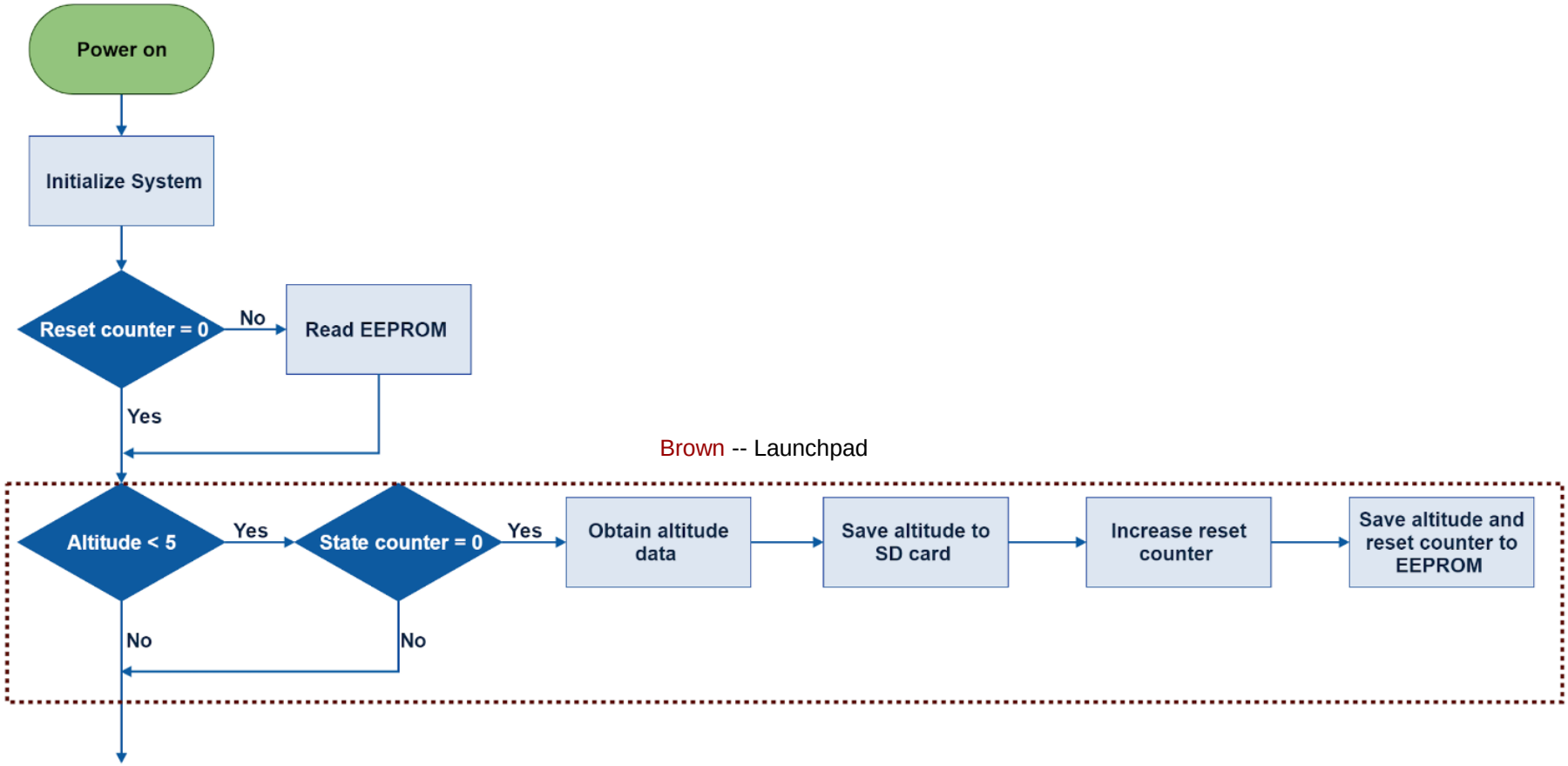
Green -- Descent

Navy Blue -- Separation

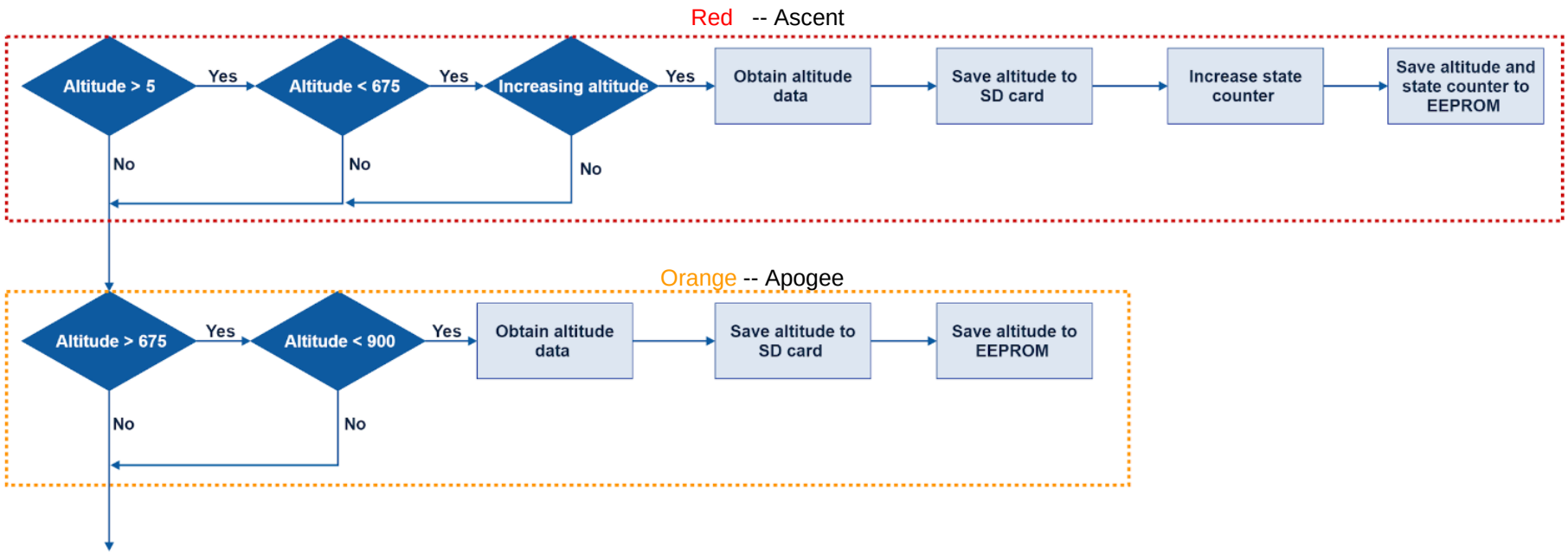
Purple -- Descent after separation

Pink -- Landing

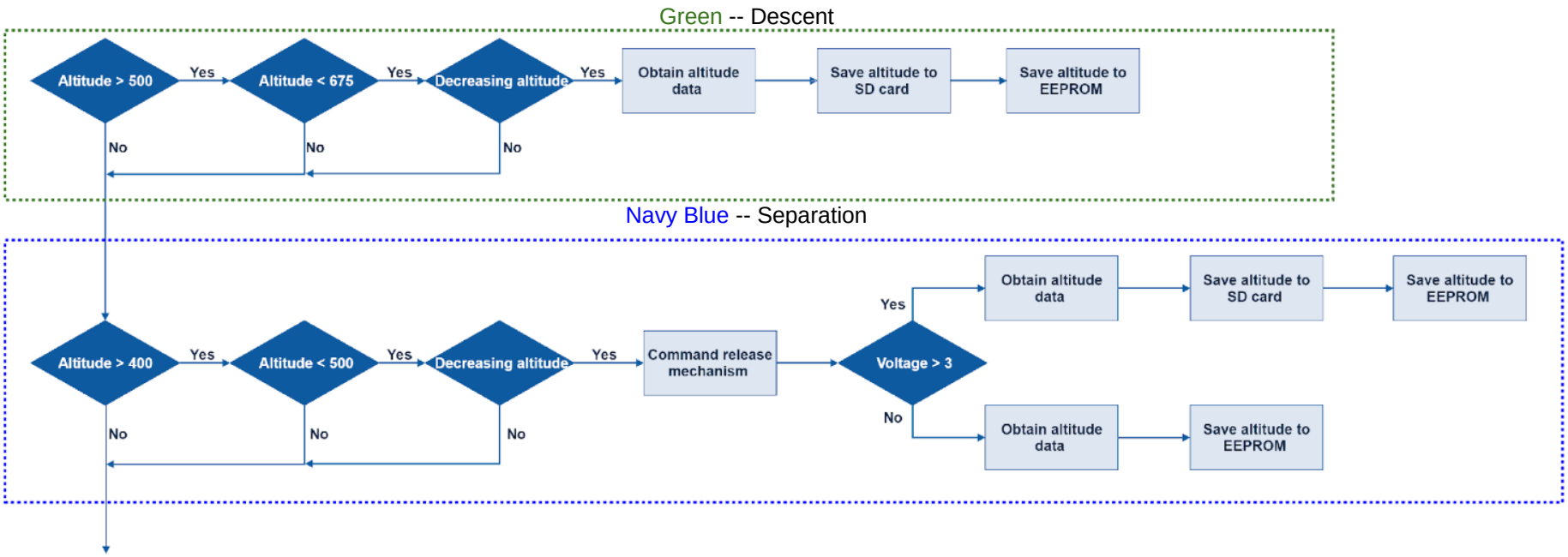
Container CanSat FSW State Diagram (2/6)



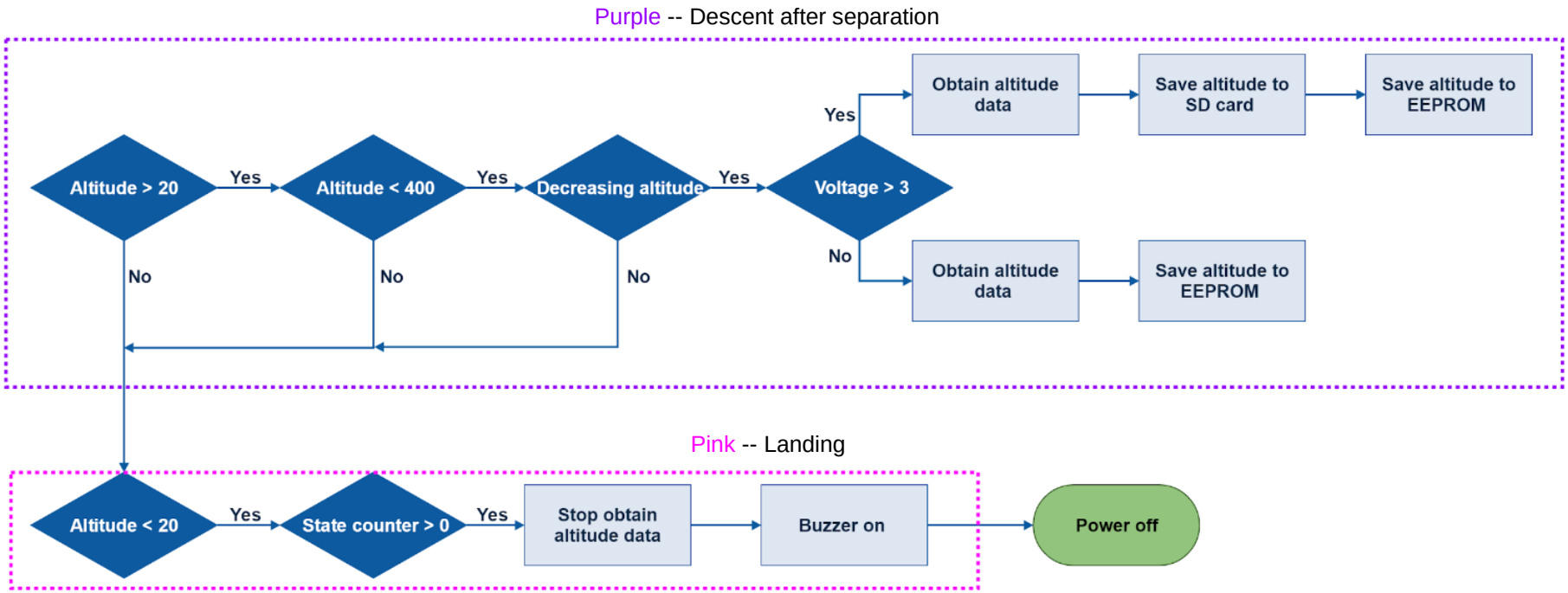
Container CanSat FSW State Diagram (3/6)



Container CanSat FSW State Diagram (4/6)



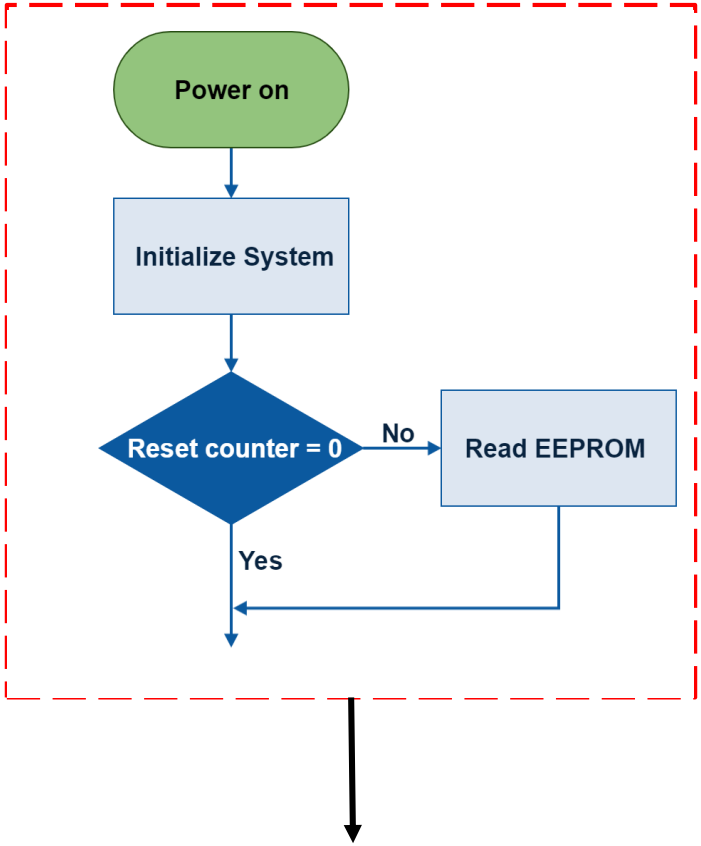
Container CanSat FSW State Diagram (5/6)



Container CanSat FSW State Diagram (6/6)

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 the microprocessor, high current exceeding limits of input and output pins of the microprocessor, and flight software which closes to flash memory limit of the 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 (1/5)

- **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 camera stabilizer on breadboard, so reaction time and rotation speed of the motors with respect to changing angles is determined.
  - ➢ A prototype circuit of the container is formed on a breadboard by using a barometric sensor and a 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 (2/5)

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.	Completed	Late February
Recording video by using camera and storing the video to SD Card.	Completed	Early March
Magnetometer data analysis and calibration for bonus objective.	Completed	Mid March
Coding of servo and stepper motors for camera stabilizer with respect to varying gyroscope and magnetometer data.	In progress	Early April
PCB and software compatibility test.	Not started	Mid April
Testing camera stabilizer by bringing all components together.	Not started	Late April
Wireless communication test with ground station at the 1 km range.	Not started	Late April

Software Development Plan (3/5)

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.	Completed	Late February
MOSFET logic signal efficiency test to melt the fishing line for separation mechanism.	Completed	Early March
PCB and software compatibility test.	Completed	Mid March

Software Development Plan (4/5)

- **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

Software Development Plan (5/5)

Progress since PDR:

Payload Software Development Plan Updates :

- Pitch/Roll sensor is changed after PDR, so programming of calibration command is postponed. As a result, payload software development plan is extended to Late April.
- Calibration command is programmed with new Pitch/Roll sensor which is Adafruit BNO055.
- Video recording after separation algorithm is developed, and recorded video is stored on SD Card.
- Magnetometer on the BNO055 is calibrated, and magnetic heading calculation algorithm is developed.

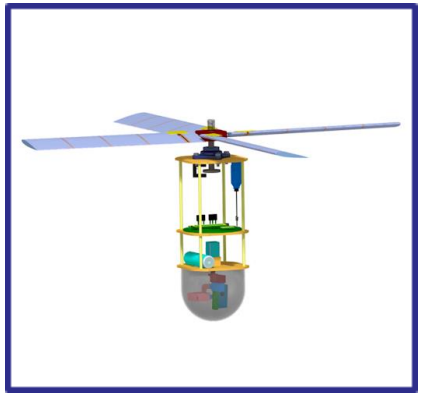
Container Software Development Plan Updates:

- Container software development plan is completed successfully without any delay.
- Algorithm of separation mechanism is developed and programmed for 450 meters.
- Fishing line which holds together CanSat before separation is melted by MOSFET in few seconds at the given altitude.
- Components of the container are soldered to PCB, and flight software and PCB are worked together without any problem.

Ground Control System (GCS) Design

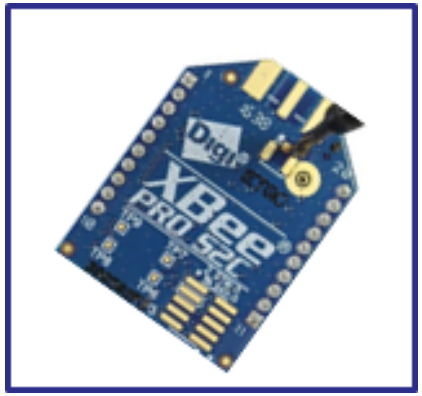
Resul DAGDANOV

GCS Overview



PAYLOAD

UART



XBEE

Data transmission via Xbee Pro S2C

HAND-HELD ANTENNA

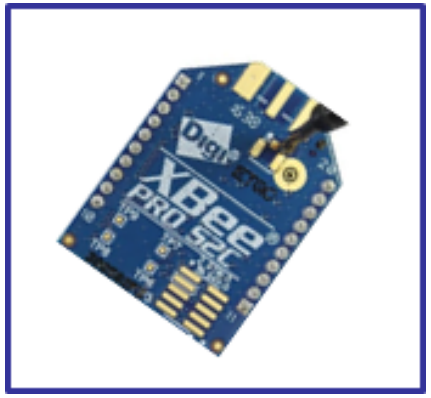
N Type to RP-SMA Converter

GROUND STATION LAPTOP

Connected to serial port via USB

XBEE ADAPTER

Connected to GCS via Xbee Adapter



XBEE MODULE

GCS Changes Since PDR

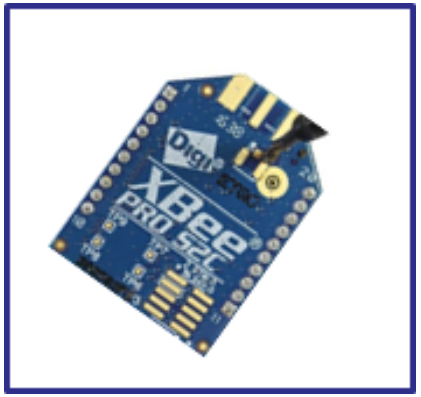
- There is no change in Ground Control Station since PDR.

GCS Requirements

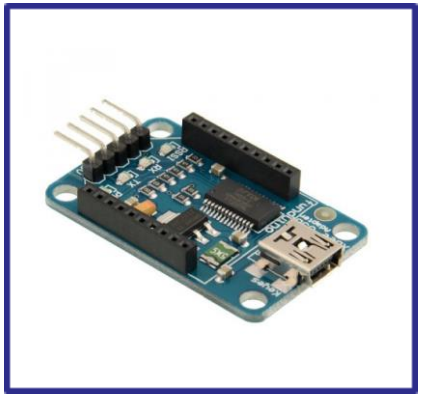
ID	Requirement	Rationale	Parent	Children	Priority	VM			
						A	I	T	D
GCS-1	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.	CReq	BR-29	-	Very High	✓		✓	
GCS-2	Each team shall develop their own ground station.	CReq	BR-35	-	Very High	✓			
GCS-3	All 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 Software (1/3)

Telemetry Display Prototypes:

<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 Software Design:

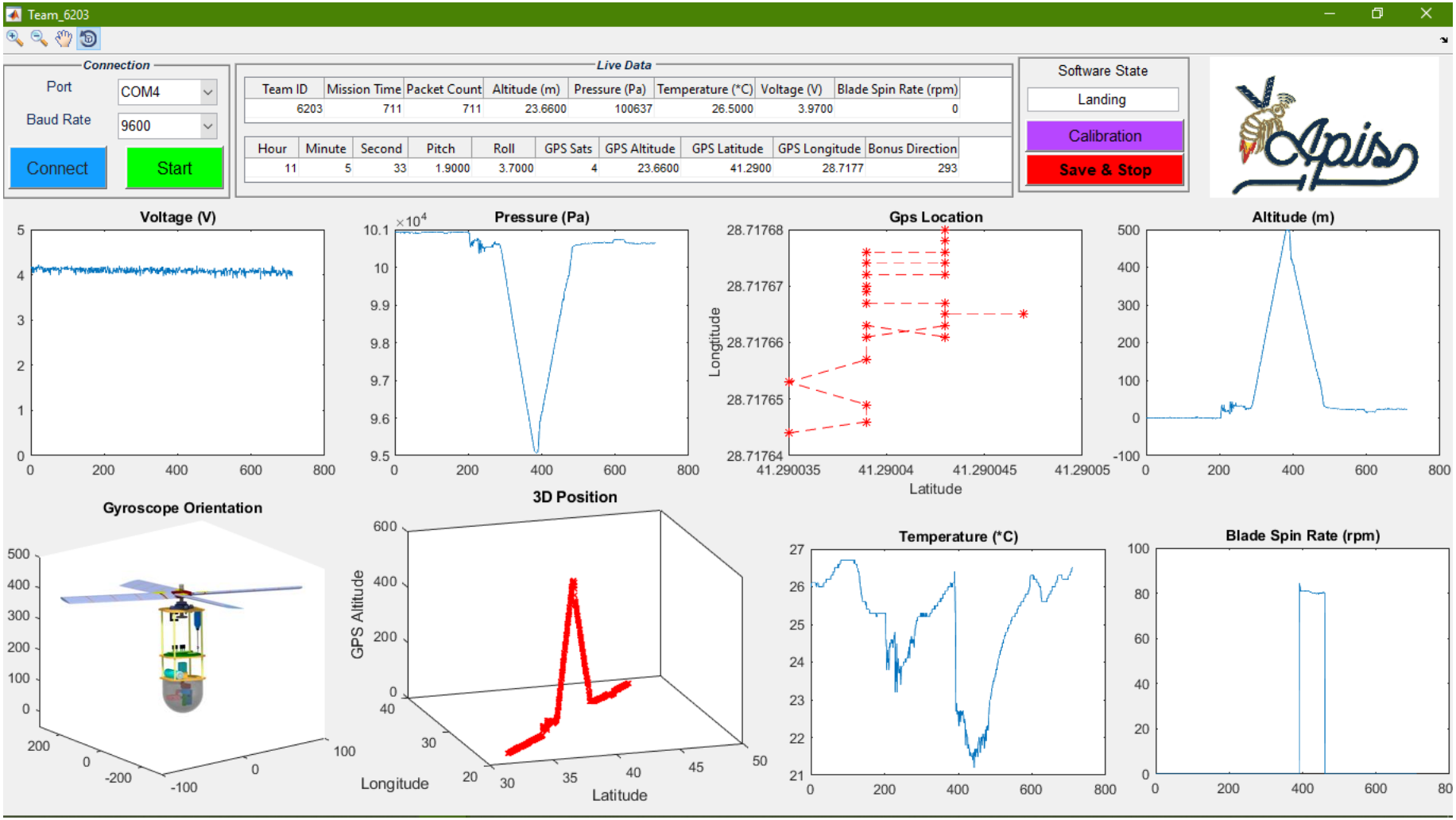
- Ground station software will be designed with Matlab GUI Package.
- Received telemetry data will be recorded in a .csv file right after being read throughout the ground station Xbee Module.
- This received data will then be displayed on the real time plots.
- Telemetry is verified by making a comparison between data saved to SD card and data saved to computer in .csv format.
- Real time plots will be labeled with engineering units.
- All real time telemetry data will be shown on the ground station software.

Commercial off the shelf (COTS) software packages:

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

GCS Software (2/3)

Telemetry Data Recording and 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.

Command Software and Interfaces:

- Command software and plotting interfaces are designed in Matlab GUI Package and programmed in MATLAB.

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”

Progress since PDR:

- The backup ground control station software is designed with Python programming language
- Command interfaces are upgraded on the GCS software.

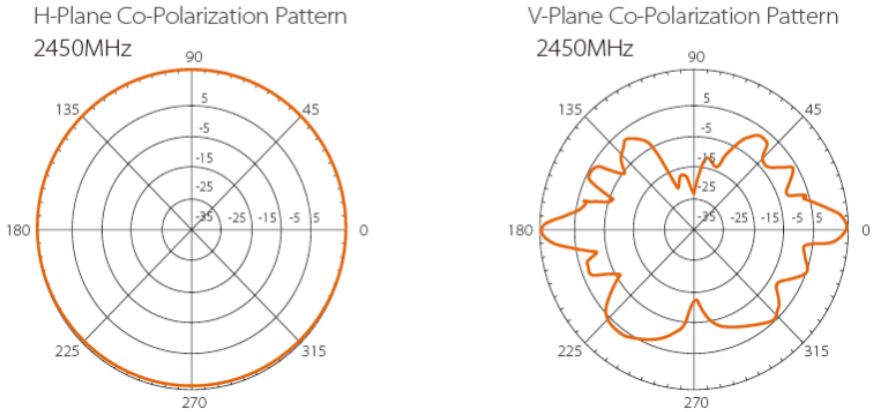
GCS Antenna (1/5)

Model	Connection Type	Frequency	Direction	Gain	Price
TP-LINK TL-ANT2415D	N-Female	2.4 Ghz	Omni - Directional	15 dBi	$ 66

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.

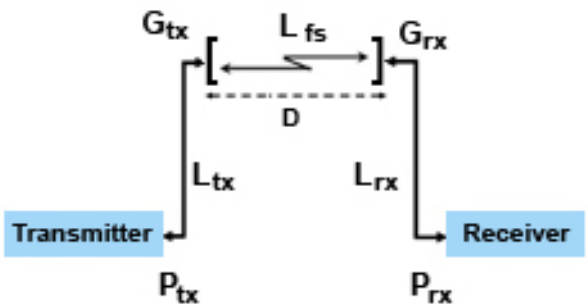
Radiation Patterns:



GCS Antenna (2/5)

Radio Link Budget Formula:

$$P_{RX} = P_{TX} + G_{TX} + G_{RX} - L_{TX} - L_{FS} - L_P - L_{RX}$$



Where,

P_{RX} = Received Power (dBm)

P_{TX} = Transmitter Power Output (dBm)

G_{TX} = Transmitter Antenna Gain (dBi)

G_{RX} = Receiver Antenna Gain (dBi)

L_{TX} = Losses Associated with Transmitter (cable, connectors, etc.) (dB)

L_{FS} = Free-Space Losses (dB)

L_P = Miscellaneous Signal Propagation Losses (polarization misalignment, etc.) (dB)

L_{RX} = Losses Associated with Receiver (cable, connectors, etc.) (dB)

Distance Link Predictions and Margins

- Transmitter Output Power: 18 dBm.
- Miscellaneous Power Loss: 5 dBm (estimated).
- Receiver Antenna Gain: 15 dBi
- Transmitter Antenna Gain: 5 dBi
- Xbee Receiver Sensitivity: -101 dBm.

- **Maximum predicted link distance: 3 km**

- FSPL(Free Space Path Loss) is calculated as **89.59** dB for d = 3000 meters and f = 2.4GHz.

- P_{out} is calculated as **-76.59 dBm > -101 dBm**, so our margin is approximately -24.41 dBm which is very sufficient.

GCS Antenna (4/5)

GCS Antenna (5/5)

Model	Type	Mass	Material	Price
Hand Held	Hand held	~ 0.25 kg	3D Printed ABS	$ 6

Antenna Compliance with hand-held requirement:

- Since the selected antenna is a long thin cylindrical structure, it is suitable for the antenna carry apparatus we designed. In addition, the low weight of the antenna makes it suitable for carrying by hand.

Advantages of using Hand Held Design:

- Cost effective.
- Easy to use.
- Lightweight.
- Very small.
- Easily operated.
- Control and stabilization of the antenna with hand held design is a lot easier.
- Manufacturing of hand held design will be made by 3D printer.

CanSat Integration and Test

Özen HALİÇ

CanSat Integration and Test Overview (1/2)

Subsystem Level Testing Plans

- Sensors are tested on Breadboard individually and then, accuracy of data is controlled.
- CDH is tested on PCB with sensors connected to microcontroller and communication between them is observed.
- Voltage and current are measured by multimeter for EPS.
- Telemetry transmissions are controlled with X-CTU software in radio communication.
- Pitch,roll and altitude data calibration is achieved by sending a byte from ground station to payload FSW.
- Autorotation of blades and unfolding mechanism are tested by dropping payload from 18 meters.
- Parachute will be observed whether it can carry some weight in air by dropping from drone.

Integrated Level Functional Testing Plans

- Attached blades to the payload is dropped from 18 meters, it is observed the blades are starting to rotate.
- Parachute attached to the container is dropped from 18 meters, the velocity change and the rope's endurance are observed.
- Xbees are tested to see they can communicate with each other with X-CTU software.
- Antenna will be tested in different ranges to prevent any signal losses.

CanSat Integration and Test Overview (2/2)

- Latexes and hinges are controlled whether they can provide sufficient reaction to move blades to the initial position by hand.
- Spring will be tested to see it creates enough force to deploy payload from container. If it cannot produce needed force, the spring will be changed in terms of length, diameter or spring pitch.
- Camera stabilizer will be tested by changing the direction of the system and it will be observed the camera's reaction to the movements.
- Altitude sensor and nichrome wire is controlled to work in cooperation on Breadboard.
- It will be tested whether the payload is capable of deploy from container and it is not stuck anywhere inside of the container. After the payload put inside the container, the container will be turned to vertically and the deployment will be observed.

Environmental Testing Plans

- Drop test will be done by connecting a 61 cm non-stretching cord to the parachute and it will be observed parachute is still functional.
- Thermal test will be done in special machine located at university laboratory heating machine to 60ºC.
- Vibration test will also be done at university laboratory in a special machine with the use of accelerometer.

Subsystem Level Testing Plan (1/2)

Sensors

- All sensors are tested on the breadboard.
- It is verified that sensors are functioning properly and the data is accurate.
- After that, the system combined of entire sensors are checked.

CDH

- CDH system is tested on breadboard and on PCB.
- It is ensured that each sensor communicates with microcontroller correctly.
- Transmission speed are tested in Arduino IDE by changing the baud rate and asking from program to write how much data it can send in 1 second.

EPS

- It will be looked on PCB whether there is current leakage by multimeter.
- Calculated voltage and current level are satisfied by the measured values read on multimeter.

Communication

- Xbee configurations and signal level tests are actualized with X-CTU software.
- Telemetry transmission with XBees is tested in distance 500m.

Subsystem Level Testing Plan (2/2)

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.
- Pitch,roll and altitude data calibration is tested by sending a byte from ground station to payload.

Mechanisms

- Verify that unfolding mechanism has enough strength in the air when its position is changing from close to open.
- Autorotation of the blades is tested as dropping payload from different altitudes to see whether blades are beginning to rotate itself
- Release mechanism is tested with FSW. Altitude values simulated and release observed.

Descent Control

- Parachute will be tested by dropping it from different altitudes with drone.
- Tensile strength of ropes that are going to be attached to container will be tested by hand force.
- Separation from container will be tested with drone.

Integrated Level Functional Test Plan (1/2)

Descent Testing

- Blades are connected to the payload and without the unfolding mechanism, the payload released from 18 meters. The payload was kept its stability during the descent.
- Rotation of the blades will be tested by releasing payload in 450 meters from drone.
- Container with parachute tested to make sure that the parachute can carry and slow down the container's velocity.

Mechanisms Testing

- *Release Trigger will be tested by attaching nichrome wire to fishing line and powering them on breadboard.*
- Also, the altitude sensor will be added to breadboard.
- With changing the altitude, it will be satisfied the nichrome wire burning.
- *Survivability of mechanical parts is tested by drop tests and loading tests.*
- Opening mechanism of blades will be tested by hand force. Blades will be continuously closed and opened to see that latexes and hinges work smoothly.
- Camera Stabilizer System will be tested by changing the payload direction to see the camera looks the same spot.
- Spring will be tested to see if it creates enough force to deploy payload from container.
- After these tests are completed, we will try it as a whole system releasing CanSat with drone from 700 meters.

Integrated Level Functional Test Plan (2/2)

Communications Testing

- The ground station software is tested by plotting the telemetries coming from sensors second by second.
- Telemetry is verified by making a comparison between data saved to SD card and data saved to computer in .csv format.
- 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.
- Antennas will be tested within the different ranges to make sure data transfer is smooth.

Deployment Testing

- Container with parachute dropped from 18 meters to see that the ropes can carry the container. *(Container Parachute Release Test)*
- Then, the container with parachute will be released from 450m with drone to make sure parachute can land container safely.
- Release Trigger that is mentioned in mechanisms is also tested in 700 meters by releasing CanSat from drone.
- It will be observed the payload is capable of releasing from the container without any latency in operation.
- Also, it will be observed during the test the payload released from the container smoothly.

Environmental Test Plan (1/2)

Drop Test

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

Thermal Test

- Thermal tests are done at university laboratory to see whether mechanical and electronic components can withstand at extreme temperatures.
- Maintain the test conditions for two hours.
- Verify that the CanSat is still functional.
- Check out that both epoxy joints and materials can endure 60ºC temperature.

Environmental Test Plan (2/2)

Vibration Test

- Structural integrity, CanSat strength and fatigue will be determined with vibration test.
- Mount the CanSat to the machine.
- The sander adjusted to its max. power.
- After the power up, sander is turned off during 5 seconds of periods.
- Repeat the process for 4 more times.
- Check out if accelerometer data is still being collected.

Fit Check

- Dimensions are verified by using sensitive equipments.
- Diameter of CanSat is verified by using a laser-cutted plate with hole in the middle which the hole's diameter equal to competition requirement (125mm).
- Height is verified by using a ruler.

Test Procedures Descriptions (1/6)

Test Procedures	Test Description	Requirements	Pass/Fail Criteria	Pass/Fail
Sensors Subsystem Test	Sensors are tested at different temperatures for long time periods to see how accurate sensors are.	SS-1, SS-6,7,8,9,10,11	Incoming data must be accurate, continuous and stable.	✓
(CDH) Serial Communication Test	Microcontrollers baud rate is to be fixed at 9600 and all data is to sent in string format.	CDH-1 CDH-2 CDH-7	If string formatted data is sent without interruption and in the desired order, test is successful.	✓
(CDH) RTC Time Keeping Test	RTC is started-stopped continuously and RTC data is recorded.	CDH-4	Despite the forced resets RTC must keep the time and continue from where it reset.	✓
(FSW) Release Mechanism Algorithm Test	CanSat is thrown from rooftop of 18 meters.	FSW-1 FSW-4	Nichrome wire must be triggered to release the payload.	✓

Test Procedures Descriptions (2/6)

Test Procedures	Test Description	Requirements	Pass/Fail Criteria	Pass/Fail
(EPS) Battery Test	Battery is connected to PCB and voltmeter is connected in parallel	EPS-1 EPS-5	Read voltage must be 3.7 Volts as calculated.	✓
(EPS) Voltage and Current Leakage Test	Voltmeter is connected at the not power connected points.	-	Read voltage must be zero at these neutral points.	✓
Wireless Communication Test	Flight controller is connected to Xbee and data transfer is started.	CDH-4	Despite the forced resets RTC must keep the time and continue from where it reset.	✓
Servo Motor Calibration Test	Servo motor rotation is calibrated with flight algorithm code.	FSW-18	Motor must rotate 90deg. as the command turn(90) sent.	✓
Stepper Motor Test	Stepper motor has to work in cooperation with servo.	FSW-18	Changing camera direction to same spot while the payload falls.	✓

Test Procedures Descriptions (3/6)

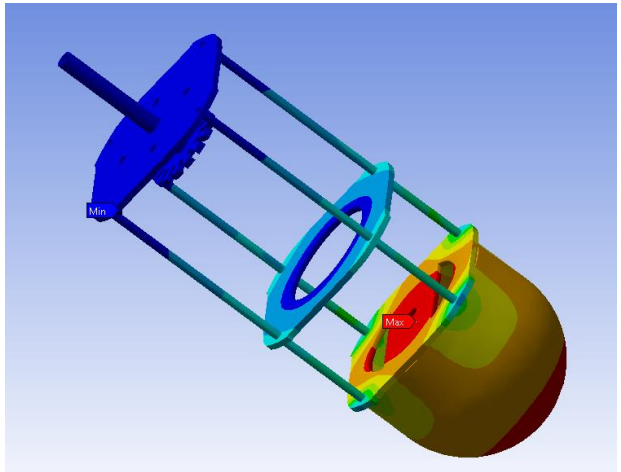
Test Procedures	Test Description	Requirements	Pass/Fail Criteria	Pass/Fail
Payload Deployment Test	CanSat will be dropped several times to make sure payload is safely deployed.	DCS-1	Blades should not stuck in container and the deployment has to be smooth.	✓
Spring Test	Spring is exposed to varying forces for 10 minutes.	DCS-1	Spring must not show deformation and produce enough force for payload deployment.	✓
Parachute Release Test	Parachute release will be tested by drop tests from the drone.	DCS-5 MS-3	Parachute must be released smoothly.	Not tested yet
Tumble Test	CanSat will simulate flight.	-	CanSat must not tumble.	✓
Autorotation Test	Payload will be dropped to see the auto-gyro system is working.	DCS-2	Blades must start to rotate when the separation occurs.	✓

Test Procedures Descriptions (4/6)

Test Procedures	Test Description	Requirements	Pass/Fail Criteria	Pass/Fail
BMP180 Pressure Sensor Test	Pressure sensor is kept working at different temperatures and incoming data is recorded.	SS-1 SS-5	Recorded pressure and temperature data must be stable and must not have oscillation.	✓
BNO 055 Gyroscope Test	Gyroscope is kept working for 1 hour and data is recorded both as the sensor is being moved and kept steady.	SS-1 SS-2	If data is stable as the sensor is steady and the data is changing accordingly with the actual movement, test is successful.	✓
BNO 055 Magnetometer Test	Magnetometer is kept for 1 hour and data is recorded both as the sensor is being moved and kept steady.	SS-1 SS-11	If data is stable as the sensor is steady and data is changing accordingly with the actual movement, test is successful.	Not tested yet.

Test Procedures Descriptions (5/6)

Test Procedures	Test Description	Requirements	Pass/Fail Criteria	Pass/Fail
Deformation and Stress Test of CanSat parts	Total deformation of main frame is analyzed by ANSYS 19.2.	SY-14, MS-12, MS-13	Results of analysis must show that main frame will withstand landing impact.	✓
Total Flight Duration Test	CanSat is released from drone and flight time is recorded.	CDH-3	Total flight duration must be close to 85 seconds as calculated.	Not tested yet.



A screenshot captured from main frame deformation test results.

Test Procedures Descriptions (6/6)

Test Procedures	Test Description	Requirements	Pass/Fail Criteria	Pass/Fail
Vibration Test	CanSat is placed on vibration test machine and vibration machine is operated at high frequencies.	SY-12 SY-13	CanSat must survive one piece, undamaged.	✓
Thermal Test	Thermal tests are made at hand made furnace temperatures up to 60 Celcius.	-	All components must withstand undamaged.	✓
Drop Test	The container parachute and attachment point will survive approximately 30 Gs of shock.	SY-12 SY-13 SY-14	Parachute ropes should be attached to container and there should be no damage.	✓
Mass Test	Total mass of the CanSat is measured.	SY-1 MS-1	Total mass must be 500g.	✓
Dimensions Test	Stowed CanSat dimensions are measured with caliper and ruler.	SY-2 MS-2	CanSat dimensions must be less than requirements.	✓

Mission Operations & Analysis

Aykut ÜÇTEPE

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 occurred during travel. • ***GCS and Antenna will be set up.***	• Separation mechanism will be connected 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 powered 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 - İsmail	**GCS officer:** Resul

Overview of Mission Sequence of Events (2/2)

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, the container and the payload will be separated.
- The payload will start autorotation and will decrease its speed between 10 to 15 m/s.
- The container will open parachute after separation.
- The payload will collect telemetry data and transfer to the GCS during descent.

Recovery

- The 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

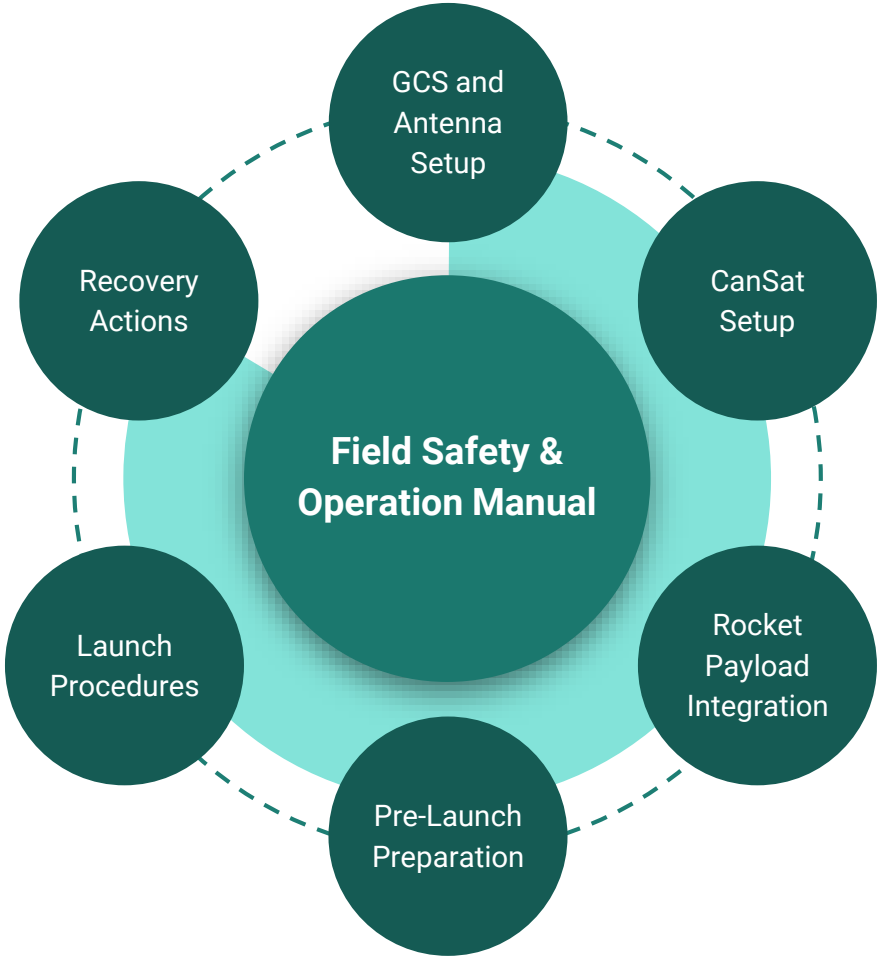
- Transmitted data will be analyzed.
- Damage control will be done.
- Flight data will be delivered to jury.
- Moving on to PFR.

Damage Control:
Sercan - Muhammed

PFR:
İsmail - Altuğ

Field Safety Rules Compliance

- Mission operations manual will consist of 6 sub-topics as indicated in mission guide. Preparing mission guide will help team members to understand safety procedures.
- Indicated manual will also be used in launch rehearsals before competition day.
- Two copies of the Manual in three ring binders will be present at Flight Readiness Review the day before launch.
- The draft of the document is created. It is updated as we progress towards the launch day. ***The document will be finalized in May.***



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)

CanSat Competition 2019
#6203 APIS
***If found, please contact*:**
apisarge@gmail.com
+90-534-395-2519

The label on the left will be on both the container and the payload.

Mission Rehearsal Activities (1/2)

Rehearsed on 03.15.19

Ground System Radio Link Check

- Ground Station and Xbee are communicating as required.
- Communication between Ground Station and Xbee are strong and efficient.
- Telemetry data is taken for controlling accurate data.

Rehearsed on 03.25.19

Powering on/off CanSat

- CanSat is powered on by an external switch.
- System can be rebooted by wireless GCS command.

Will be Rehearsed on May

Launch Configuration Preparations

- Final integration and component placing tests will be done.
- Ground Station will be ready to take data.

Mission Rehearsal Activities (2/2)

Will be Rehearsed on May

Rocket-Payload Assemble

- Final integrated CanSat will be loaded into a imitation rocket frame to detect any possible problems.
- The rocket frame only comprise of a cylinder which have the same dimensions as rocket will be given in the competition area.

Will be Rehearsed on May

Telemetry Processing, Archiving and Analysis

- The final version of the software will be used.
- Telemetry data will be collected and then, stored in SD card and GCS.
- Data will be analyzed at ground Control Station.

Will be Rehearsed on May

Recovery

- Recovery team will be ready.
- The payload and the container will be tracked.
- Landing locations will be found with GPS data.
- Damage control will be done on both the payload and the container.

Requirements Compliance

Sercan SALDAMLI

Requirements Compliance Overview

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

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

➢ **<u>Improvements since PDR</u>**

- Mechanical system is tested via free fall tests.

- Auto-gyro blade opening mechanism and parachute opening mechanism are tested. Both systems worked properly.

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

- Electronic systems are integrated. Telemetry is sent to ground station.

- Strength of latexes and hinges in blade opening mechanism are tested with various scenarios.

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

- Payload separation test is done.

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.92-93-94	*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.25-26	*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.78-79-80	*Completed.*
04	The container shall be a fluorescent color; pink, red or orange.	Comply	p.191	*Completed.*
05	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	p.25-26	*Completed.*
06	The rocket airframe shall not be used as part of the CanSat operations.	Comply	p.25-26	*Completed.*
07	The CanSat shall deploy from the rocket payload section and immediately deploy the container parachute.	Comply	p.88-89	*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.	Comply	p.58	*Tested with free fall test.*
09	The container shall release the payload at 450 meters +/- 10 meters.	Comply	p.85-86-87	*Tested with our FSW.*
10	The science payload shall descend using an auto-gyro/passive helicopter recovery descent control system.	Comply	p.17	*Completed.*
11	The descent rate of the science payload after being released from the container shall be 10 to 15 meters/second.	Comply	p.60-61-62	*Tested with free fall test.*
12	All descent control device attachment components shall survive 30 Gs of shock.	Comply	p.177	*Tested with free fall test.*
13	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Comply	p.90	*Completed.*
14	All structures shall be built to survive 15 Gs of launch acceleration.	Comply	p.179	*Tested with free fall test.*

Requirements Compliance (3/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
15	All structures shall be built to survive 30 Gs of shock.	Comply	p.179	*Tested with free fall test.*
16	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	p.90	*Completed.*
17	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	p.177	*Tested with free fall test.*
18	Mechanisms shall not use pyrotechnics or chemicals.	Comply	p.85-86-87	*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.85-86-87	*Nichrome wire mechanism is enclosured with a protective layer.*
20	The science payload shall measure altitude using an air pressure sensor.	Comply	p.33	*Tested with our FSW.*
21	The science payload shall provide position using GPS.	Comply	p.35	*Tested with our FSW.*

Requirements Compliance (4/9)

ID	Requirement	Compliance	Demonstrator	Comments & Notes
22	The science payload shall measure its battery voltage.	Comply	p.36	*Tested with our FSW.*
23	The science payload shall measure outside temperature.	Comply	p.34	*Tested with our FSW.*
24	The science payload shall measure the spin rate of the auto-gyro blades relative to the science vehicle.	Comply	p.38	*Tested with our FSW.*
25	The science payload shall measure pitch and roll.	Comply	p.37	*Tested with our FSW.*
26	The probe shall transmit all sensor data in the telemetry.	Comply	p.110-111-112	*Completed.*
27	The Parachute shall be fluorescent Pink or Orange.	Comply	p.191	*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.	Comply	p.166	*Completed.*
29	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.	Comply	p.166	*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.110	*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.107	*Completed.*
32	XBEE radios shall have their NETID/PANID set to their team number.	Comply	p.109	*Completed.*
33	XBEE radios shall not use broadcast mode.	Comply	p.112	*Completed.*
34	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Comply	p.210	*Completed.*
35	Each team shall develop their own ground station.	Comply	p.165	*Completed.*
36	All telemetry shall be displayed in real time during descent.	Comply	p.165	*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.164	*Completed.*
38	Teams shall plot each telemetry data field in real time during flight.	Comply	p.165	*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.163	*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.163	*Completed.*
41	Both the container and probe shall be labeled with team contact information including email address.	Comply	p.191	*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.110	*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.14	*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.14	*Completed.*
47	An audio beacon is required for the probe. It may be powered after landing or operate continuously.	Comply	p.123	*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.125-131	*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.14	*Completed.*
51	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	p.73	*Completed.*
52	The auto-gyro descent control shall not be motorized. It must passively rotate during descent.	Comply	p.60-61	*Completed.*
53	The GPS receiver must use the NMEA 0183 GGA message format.	Comply	p.35	*Completed.*
54	The CANSAT must operate during the environmental tests laid out in Section 3.5.	Comply	p.179-180	*Completed.*
55	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	Comply	p.128-133	*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.	Comply	p.39	*Tested with our flight software, camera is activated at given altitude and camera stabilizer system is worked.*

Management

AYKUT ÜÇTEPE

Status of Procurements (1/2)

Mechanical				
Component	Model	Quantity	Order Date	Status
Payload Main Frame	Fiberglass Stick	1 m	12.10.2018 ~ 3.15.2019	Received
Container Frame	Fiberglass Fabric	1 m2	12.10.2018 ~ 3.15.2019	Received
Payload Blades	Styrofoam	1 m2	12.10.2018 ~ 3.15.201	Received
Payload Blades	Balsa	0,5 m2	12.10.2018 ~ 3.15.2019	Received
Parachute Fabric	30d silicone nylon 66cloth	1 m2	12.10.2018 ~ 3.15.2019	Received
Mechanism	Spring-Bearing	1 m	12.10.2018 ~ 3.15.2019	Received
Payload Layers	Plywood	0,5 m2	12.10.2018 ~ 3.15.2019	Received
Release Mechanism	Nichrome Wire	0,2 m	12.10.2018 ~ 3.15.2019	Received
Other tools	Adhesive,hinge, etc	-	12.10.2018 ~ 3.15.2019	Received

Time interval was given as order date because new materials ordered when the old ones are consumed.

Status of Procurements (2/2)

Electronics				
Component	Model	Quantity	Order Date	Status
Barometer	BMP180	2	10.21.2018	Received
Voltage Regulator	Pololu 5V	1	10.21.2018	Received
Camera	Adafruit Mini Spy	1	10.21.2018	Received
SD Card	SANDISK 16 GB	3	10.21.2018	Received
XBEE	XBEE S2C	2	10.21.2018	Received
XBEE's Adapter	XBEE Explorer Dongle	2	10.21.2018	Received
Antenna (Payload)	2405CL	1	10.21.2018	Received
Antenna (Ground Station)	TL ANT2415D	1	10.21.2018	Received
Microcontroller (Payload)	Teensy 3.5	1	10.21.2018	Received
Microcontroller (Container)	Arduino Nano	1	03.15.2019	Received
GPS	Adafruit Ultimate GPS	1	10.21.2018	Received
BUZZER	BUZZER	1	10.21.2018	Received
MOSFET	IRL 540	1	10.21.2018	Received
IMU	BNO 055	1	03.15.2019	Received
Battery (Container)	Orion 10440	2	03.15.2019	Received
Battery (Payload)	LG M50 21700	1	10.21.2018	Received

CanSat Budget – Hardware (1/3)

Electronics				
Component	Model	Quantity	Unit Price[$]	Total[$]
IMU	BNO 055	1	34,95 (Actual)	34,95
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)	Arduino Nano	1	8,99 (Actual)	8,99
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)	Orion 10440	2	2,00(Actual)	4,00
Battery (Payload)	LG M50 21700	1	9,00 (Actual)	9,00

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	1	18,40 (Actual)	18,40
Stepper Motor	Sanyo Miniature Stepper	1	99,95 (Actual)	99,95
Stepper Motor Driver	DRV8834	1	5,95 (Actual)	5,95
MOSFET	IRL 540	1	1,00 (Actual)	1,00

ELECTRONICS TOTAL:	**$ 384,31**

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	0,2 m	1,00 per m	0,2 (Actual)
Other tools	Adhesive,hinge,bearing etc	-	30,00	30,00 (Estimated)
Blades	Styrofoam	1 m2	3,00 per m2	3,00 (Actual)
Blades	Balsa	0,5 m2	7,50 per m2	3,75 (Actual)

BR34 says: *'Cost of the CanSat shall be under $1000.'*
Our Cansat's total cost of is less than $1000. So our budget meets the requirements.

MECHANICS TOTAL:	**$ 76,95**
OVERALL TOTAL:	**$ 461,26**
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)

GCS 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
Competition Fee	1	100 (Actual)	100

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

CanSat Budget – Other Costs (3/3)

Categories	Cost [$]
Electrical and Mechanical	461,26
Ground Station	140,95
Other Costs	7180
TOTAL	$ 7782,21
MARGIN	$ 711
INCOME	$ **10000**

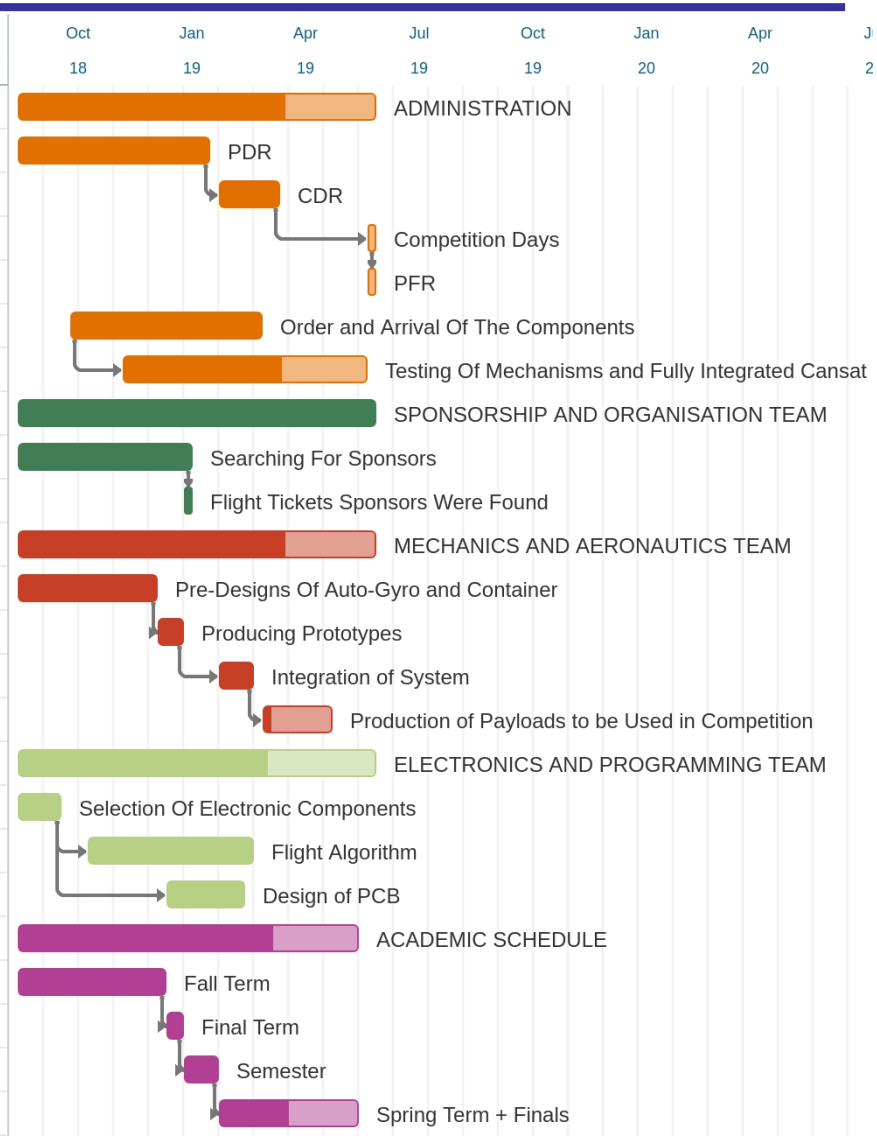
- *Main source of 10000$ income is companies that agreed to finance our team throughout the competition.*

Company	Sponsorship Fee [$]
Turkish Exporters Union	3000
Turkish Aerospace Industry	2000
Aselsan	2000
ISBAK Istanbul IT and Smart City Technologies Inc.	2000
Istanbul Technical University	1000
TOTAL	$ 10000

Program Schedule Overview

Summary

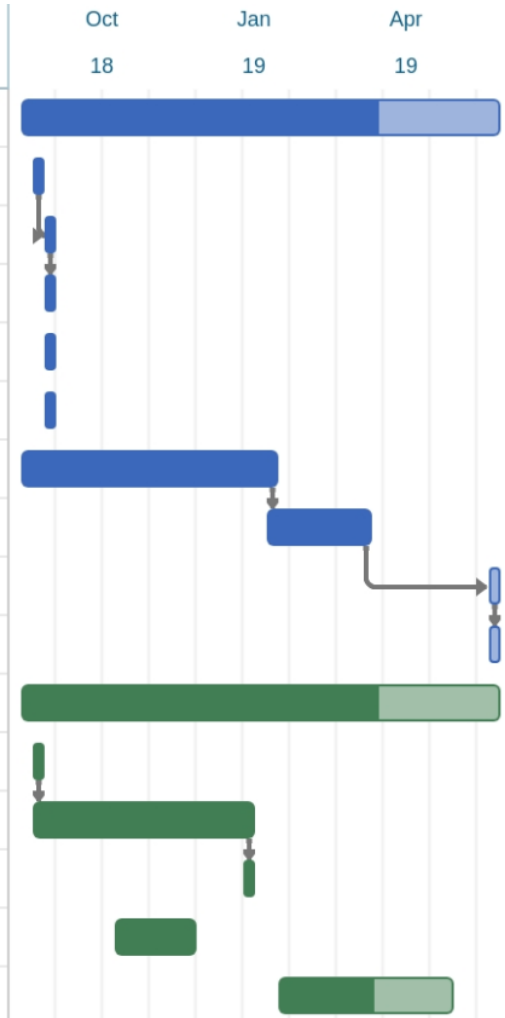
			Assignee	Start Date	Cal. Days	Due Date	Task Prog.
0	AÜ	ADMINISTRATION	Aykut Üçtepe	09/Sep	281d	16/Jun	75%
1	AT	PDR	VU: All Team	09/Sep	146d	01/Feb	100%
2	AT	CDR	VU: All Team	14/Feb	44d	29/Mar	100%
3	AT	Competition Days	VU: All Team	16/Jun	1d	16/Jun	0%
4	AT	PFR	VU: All Team	16/Jun	1d	16/Jun	0%
5	AÜ	Order and Arrival Of The Components	Aykut Üçtepe	21/Oct	148d	17/Mar	100%
6	AT	Testing Of Mechanisms and Fully Integrated Cansat	VU: All Team	01/Dec	188d	06/Jun	65%
7	ZK	SPONSORSHIP AND ORGANISATION TEAM	VU: Zelal Karaca	09/Sep	281d	16/Jun	100%
8	ZK	Searching For Sponsors	VU: Zelal Karaca	09/Sep	132d	18/Jan	100%
9	ZK	Flight Tickets Sponsors Were Found	VU: Zelal Karaca	18/Jan	1d	18/Jan	100%
10	İÖ	MECHANICS AND AERONAUTICS TEAM	VU: İsmail Özcan	09/Sep	281d	16/Jun	75%
11	A	Pre-Designs Of Auto-Gyro and Container	VU: Aykut-İsmail	09/Sep	100d	17/Dec	100%
12	Ö	Producing Prototypes	VU: Özen	30/Dec	9d	07/Jan	100%
13	M	Integration of System	VU: Muhammed	12/Feb	23d	06/Mar	100%
14	AM	Production of Payloads to be Used in Competition	VU: All Mecha…	23/Mar	50d	11/May	10%
15	AE	ELECTRONICS AND PROGRAMMING TEAM	VU: Altuğ Ertan	09/Sep	281d	16/Jun	70%
16	RD	Selection Of Electronic Components	VU: Resul Dag…	09/Sep	24d	02/Oct	100%
17	AE	Flight Algorithm	VU: Altuğ Ertan	02/Nov	127d	08/Mar	100%
18	BC	Design of PCB	VU: Buse Cop	31/Dec	60d	28/Feb	100%
19	AT	ACADEMIC SCHEDULE	VU: All Team	09/Sep	265d	31/May	75%
20	AT	Fall Term	VU: All Team	03/Sep	117d	28/Dec	100%
21	AT	Final Term	VU: All Team	02/Jan	8d	09/Jan	100%
22	AT	Semester	VU: All Team	14/Jan	22d	04/Feb	100%
23	AT	Spring Term + Finals	VU: All Team	15/Feb	106d	31/May	50%



Detailed Program Schedule (1/3)

Detailed Gantt Chart

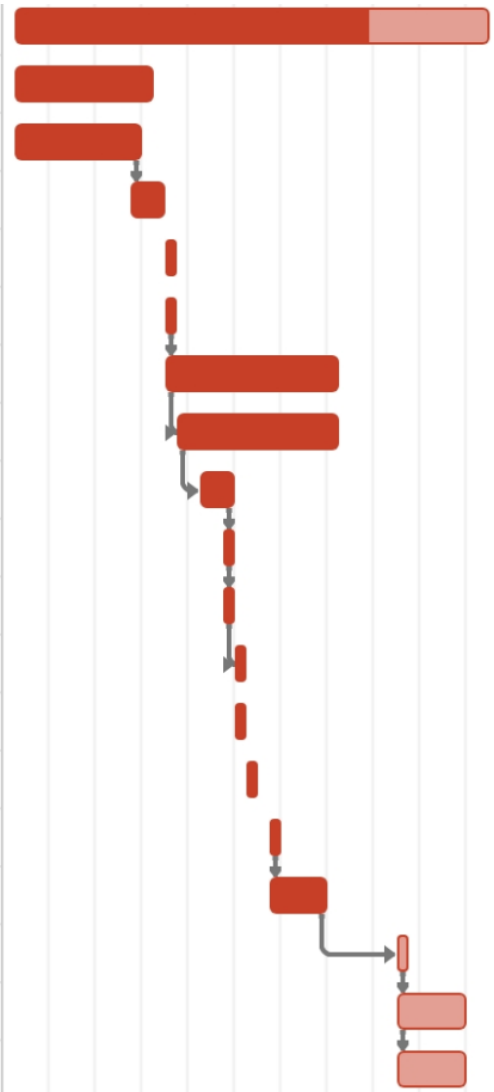
			Assignee	Start Date	Cal. Days	Due Date	Task Prog.
0	AÜ	ADMINISTRATION	Aykut Üçtepe	09/Sep	281d	16/Jun	75%
1	AÜ	Recruiting new team members	Aykut Üçtepe	10/Sep	1d	10/Sep	100%
2	AÜ	The first meeting of this term	Aykut Üçtepe	18/Sep	1d	18/Sep	100%
3	AÜ	Task Sharing	Aykut Üçtepe	18/Sep	1d	18/Sep	100%
4	AÜ	Planning to Team meetings in every Tuesday	Aykut Üçtepe	18/Sep	1d	18/Sep	100%
5	AT	Analyzing PDRs of last year	VU: All Team	17/Sep	2d	18/Sep	100%
6	AT	PDR	VU: All Team	09/Sep	146d	01/Feb	100%
7	AT	CDR	VU: All Team	01/Feb	57d	29/Mar	100%
8	AT	Competition Days	VU: All Team	14/Jun	3d	16/Jun	0%
9	AT	PFR	VU: All Team	16/Jun	1d	16/Jun	0%
10	ZK	SPONSORSHIP AND ORGANISATION TEAM	VU: Zelal Karaca	09/Sep	281d	16/Jun	75%
11	ZK	Created Sponsorship File	VU: Zelal Karaca	16/Sep	1d	16/Sep	100%
12	ZK	Searching For Sponsors	VU: Zelal Karaca	16/Sep	125d	18/Jan	100%
13	ZK	Flight Tickets Sponsors were Found	VU: Zelal Karaca	18/Jan	1d	18/Jan	100%
14	AÜ	Designing Team T-shirts	Aykut Üçtepe	01/Nov	40d	10/Dec	100%
15	AT	Team Members Start To Give Robotic Lessons to …	VU: All Team	10/Feb	94d	14/May	55%



%75 of the total work is completed.

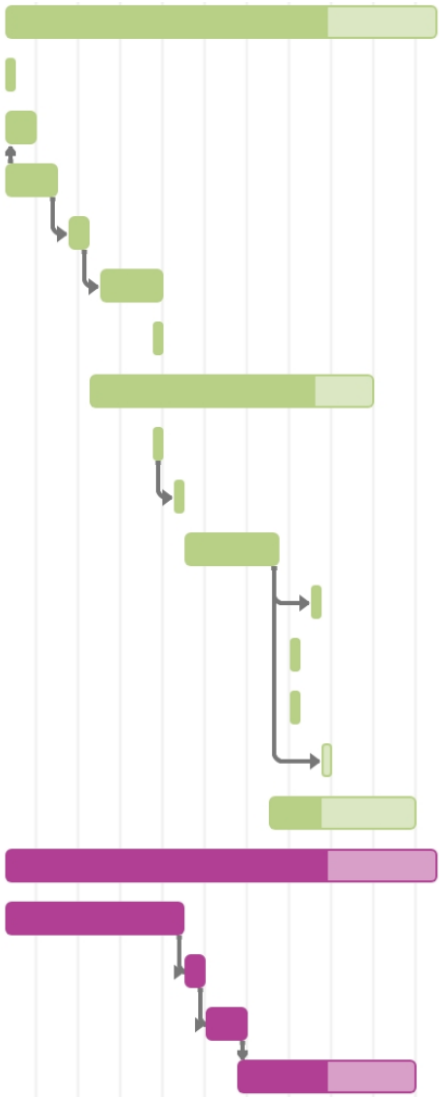
Detailed Program Schedule (2/3)

16	İÖ	MECHANICS AND AERODYNAMICS TEAM	VU: İsmail Özcan	09/Sep	281d	16/Jun	75%
17	S	Payload Structural Design	VU: Sercan-M…	09/Sep	72d	19/Nov	100%
18	AÜ	AutoGyro Blade Design	Aykut Üçtepe	09/Sep	65d	12/Nov	100%
19	ÖH	AutoGyro Blades Folding Mechanism Design	VU: Özen Haliç	12/Nov	21d	02/Dec	100%
20	İÖ	Container Design	VU: İsmail Özcan	04/Dec	1d	04/Dec	100%
21	SS	Material Selection	VU: Sercan Sa…	04/Dec	6d	09/Dec	100%
22	AÜ	Order of Some Materials For Prototypes	Aykut Üçtepe	09/Dec	97d	15/Mar	100%
23	AÜ	Arrival of Mechanic Components	Aykut Üçtepe	11/Dec	97d	17/Mar	100%
24	ÖH	To Produce the First Prototype	VU: Özen Haliç	25/Dec	14d	07/Jan	100%
25	S	AutoGyro Blades Rotation Test	VU: Sercan-M…	11/Jan	1d	11/Jan	100%
26	S	AutoGyro Blades Loading Test	VU: Sercan-Öz…	11/Jan	1d	11/Jan	100%
27	İÖ	Testing Friction of the Roller	VU: İsmail Özcan	16/Jan	1d	16/Jan	100%
28	İÖ	Impact Test of the Structure	VU: İsmail Özcan	15/Jan	1d	15/Jan	100%
29	SS	Impact Test of the Gimball Protection Shield	VU: Sercan Sa…	23/Jan	1d	23/Jan	100%
30	S	Testing the Prototypes	VU: Sercan-Öz…	06/Feb	1d	06/Feb	100%
31	M	Integration Of Parts into the Payload	VU: Muhammed	06/Feb	29d	06/Mar	100%
32	AM	Testing All System via Rocket or Drone	VU: All Mecha…	22/Apr	1d	22/Apr	0%
33	AM	Making Modifications Due to Test Results	VU: All Mecha…	22/Apr	40d	31/May	0%
34	AM	Production Of Cansats to be Used in Competition	VU: All Mecha…	22/Apr	40d	31/May	0%



Detailed Program Schedule (3/3)

35	AE	ELECTRONICS AND PROGRAMMING TEAM	VU: Altuğ Ertan	09/Sep	281d	16/Jun	75%
36	AE	Project Start	VU: Altuğ Ertan	09/Sep	1d	09/Sep	100%
37	RD	Selection of Microcontroller	VU: Resul Dag…	09/Sep	13d	21/Sep	100%
38	RD	Selection of Sensors	VU: Resul Dag…	08/Sep	25d	02/Oct	100%
39	AÜ	Order of Electronic Components	Aykut Üçtepe	20/Oct	3d	22/Oct	100%
40	AÜ	Arrival of Elecronic Components	Aykut Üçtepe	09/Nov	36d	14/Dec	100%
41	RD	Separation system algorithm	VU: Resul Dag…	10/Dec	1d	10/Dec	100%
42	AE	Flight Algorithm	VU: Altuğ Ertan	02/Nov	180d	30/Apr	80%
43	RD	Battery Selection	VU: Resul Dag…	10/Dec	1d	10/Dec	100%
44	AE	Test on the Breadboard	VU: All Electro…	29/Dec	1d	29/Dec	100%
45	BC	Design of PCB	VU: Buse Cop	31/Dec	60d	28/Feb	100%
46	AE	Seperation System Test	VU: All Electro…	25/Mar	1d	25/Mar	100%
47	AÜ	Order of New Selected Electronic Components	Aykut Üçtepe	15/Mar	1d	15/Mar	100%
48	AÜ	Arrival of New Selected Electronic Components	Aykut Üçtepe	17/Mar	1d	17/Mar	100%
49	EA	Xbee Communication Test in Bosphorus	VU: Elif Acar	04/Apr	1d	04/Apr	0%
50	AE	Making Changes and Redesign	VU: All Electro…	25/Feb	96d	31/May	35%
51	AT	ACADEMIC SCHEDULE	VU: All Team	09/Sep	281d	16/Jun	75%
52	AT	Fall Term	VU: All Team	09/Sep	111d	28/Dec	100%
53	AT	Final Term	VU: All Team	02/Jan	8d	09/Jan	100%
54	AT	Semester	VU: All Team	14/Jan	22d	04/Feb	100%
55	AT	Spring Term + Finals	VU: All Team	04/Feb	117d	31/May	50%



Shipping and Transportation

Flight

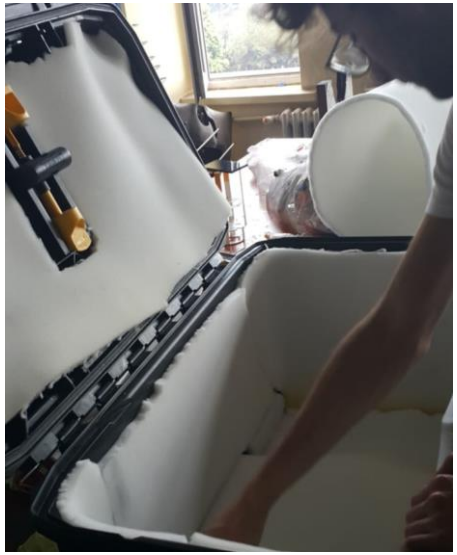
- Selected airline: Turkish Airlines
- Planned arrival to Houston: 11.06.2019

CanSat Hardware

- We have made a sponsorship deal with a cargo company to carry our CanSat from Istanbul to Houston.
- It will be transported inside safe containers.

Tools and Equipment

- The contracted cargo company will carry our antenna mast and assembly, spare part and other arguments.
- They will be transported inside safe bags.



The inner side of the boxes where the Cansat, tools and equipment will be carried is covered with sponge and bubble wrap by our team.

Conclusions

Administration & Finance

Major Accomplishments:

1. Schedule was created.
2. Sponsors for airline tickets, accommodation and car rental were found.
1. PDR was completed
5. CDR was completed
6. Sponsorship deal was made with the cargo company.

Major Unfinished Work:

1. Visas of 5 team members are not approved yet.

Electronics & Programming

Major Accomplishments:

1. Electronic component choosing is almost fully completed.
2. PCB design progress is almost done.

3. Flight Software design progress is almost finalised.

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

2. Majority of tests are done

Major Unfinished Work:

1. The fully finished CanSat needs to be tested with drone.

Conclusion: **The schedules and deadlines have been met.**

Team APIS ARGE is ready to move on to Launch Day and PFR.