CanSat 2022
Critical Design Review (CDR)
Outline
Version 3.0

Team Descendere #1022

Presentation Outline

Team Organization

Team Leader
Kittipon Amornprasertkij

Faculty Advisor
Joshua Staubs, Ph.D.

Mechanics
[Descent Control Design, Mechanical Subsystem]

- **Leader** Nuchit Vichitkijja
  - Kittipon Amornprasertkij

Programming
[Communication & Data, Flight Software Design, Ground Control Subsystem]

- **Leader** Krissada Singhakachain
  - Thasvarit Krueklai
  - Arkkhanirut Pandej

Electronics
[Sensor Subsystem, Electrical Power System]

- **Leader** Suvijak Piyanopharoj
  - Pitiphoom Achapramote
  - Krin Kaweewongsonthorn
  - Shinakrit Laokittichai

Acronyms
(1 / 3)

Acronyms	Definition
ABS	Acrylonitrile Butadiene Styrene
CAD	Computer Aided Design
CDH	Communication and Data Handling
CDR	Critical Design Review
CI	Communication Interface
COTS	Commercial-Off-The-Shelf
DC	Descent Control
DIPS	Dual in-line package
EEPROM	Electronically Erasable Programmable Read-Only Memory
EPS	Electrical Power Subsystem
FRR	Flight Readiness Review
FSW	Flight Software
G	Gravitational acceleration

Acronyms	Definition
GB	Gigabyte
GCS	Ground Control System
GHz	Gigahertz
GNSS	Global Navigation Satellite System
GPIO	General Purpose Input/Output
GPS	Global Positioning System
GS	Ground Station
GUI	Graphical User Interface
Hz	Hertz
I^2C	Inter-Integrated Circuit
LED	Light Emitting Diode
Li-ion	Lithium Ion
MCU	Microcontroller Unit
MHz	Megahertz

Acronyms
(2 / 3)

Acronyms	Definition
MB/s	Megabit per second
N	Newton
PC	Polycarbonate
PCB	Printed Circuit Board
PDR	Preliminary Design Review
PETG	Polyethylene Terephthalate Glycol
PFR	Post Flight Review
PLA-LW	Polylactic Acid-Lightweight
RAM	Random-Access Memory
RC	Radio Communication
RP-SMA	Reverse Polarity Sub-Miniature Version A
RTC	Real time clock
SD	Secure Digital
SPI	Serial Peripheral Interface

Acronyms	Definition
SS	Sensor Subsystem Design
TP	Tethered Payload
TX	Transmit
UART	Universal Asynchronous Receiver-Transmitter
USB	Universal Serial Bus
V	Volt
W.h	Watt-Hour
csv	Comma-Separated Values
dB	Decibel
dBi	Decibels relative to Isotropic
dBm	Decibel milliwatt
fps	Frames per second
g	gram
hPa	Hectopascal

Acronyms
(3 / 3)

Acronyms	Definition
kB	Kilobyte
kg	kilogram
m	Meter
m/s	meter per Second
m/s^2	meters per Second squared
m^3	Meter cubed
mA	milliampere
mA▪H	milliampere-Hour
rpm	Rounds Per Minute
s	Seconds
t	Time
v	Velocity
°	Degrees
°C	Degree Celsius
µA	microampere
µF	microfarad

Verification Methods

Acronyms	Definition
A	Analysis
D	Demonstration
I	Inspection
T	Test

System Overview

Kittipon Amornprasertkij

Mission Summary (1/2)

Mission Objectives

To design a CanSat that consists of a container and a tethered payload which meets these conditions:

- The payload shall be attached to the container with a 10 meter long tether.
- The CanSat shall be launched to an altitude ranging from 670 meters to 725 meters above the launch site and deployed near apogee.
- The CanSat must survive the forces incurring at launch and deployment.
- Once the CanSat is deployed from the rocket, the CanSat shall descend using a parachute at a rate of 15 m/s.
- At 400 meters, the CanSat shall deploy a larger parachute to reduce the descent rate to 5 m/s.
- At 300 meters, the CanSat shall release a tethered payload to a distance of 10 meters in 20 seconds. During that time, the payload shall maintain the orientation of a video camera with a resolution of 640x480 30 frames per second pointing in the south direction. The video camera shall be pointed 45 degree downward to assure terrain is in the video.
- The tethered payload shall transmit all of its telemetry to a container.
- The container shall relay the telemetry from the payload with a rate of 4 Hz and transmit to the ground station with a rate of 1 Hz and use the team number plus 5000 as NETID until it lands .

Mission Summary (2/2)

Bonus Objectives

- As the container is releasing the payload, the container shall contain a video camera with a resolution of 640x480 @30 frames per second and start recording to show the descent of the payload. All videos are to be recorded and recovered when the CanSat is retrieved from the field.

Summary of Changes Since PDR (1/3)

Subsystem	Changes	Rationales
Sensor Design	Bonus camera is changed from **Raspberry pi camera v2.1** to **Adafruit 3202 Mini Spy Camera.**	To reduce weight and space
	Container GPS is changed from **MAX-M8Q** to **ATGM336H.**	To reduce weight and space
	Hall effect magnetic sensor (revolution counter) is added	To measure the deployed distance of the payload
Descent Control	**Fins** are removed.	Fins are not efficient in roll axis
	The second parachute slot is **enlarged.**	To prevent the lid from bending upwards
	The second parachute color is changed from **fluorescent pink** to **fluorescent orange.**	Fluorescent pink is not available in our country.
CDH	Container and payload memory are changed from **SanDisk Ultra 16 GB** to **SanDisk Extreme PRO 32 GB.**	To reserve more memory space in case any received data exceeds 16 GB
	Bonus camera memory is changed from **SanDisk Extreme PRO 64 GB** to **SanDisk Extreme PRO 32 GB.**	There is no need to use a 64 GB microSD card since the new bonus camera has lower resolution.

Summary of Changes Since PDR (2 / 3)

Subsystem	Changes	Rationales
Electrical Power	Container battery is changed from **SONY CTC5D** to **Vapcell 16650 M20.**	To reduce weight
	Payload battery is changed from **UltraFire TR16340** to **Vapcell 18350 F14.**	The old battery cannot supply power for 2 hours (according to the test).
Flight Software	Apogee detection is triggered when altitude reaches **510 m and/or altitude starts to decrease.**	To prevent mission failure when rocket does not reach expected apogee
Ground Control System	**Ground station PCB** is added.	To allow the merging of data between the GS and CanSat which can tell where the CanSat is relative to the GS.
	Data are exported to external files to be read and **displayed by Google Earth.**	The test showed significant performance drop during re-render of the internal map.

Summary of Changes Since PDR
(3 / 3)

Subsystem	Changes	Rationales
Mechanical Design	Container structural material is changed from **ABS** to **PLA-LW/PC**	PLA-LW is lighter, PC can carry lots of load
	Ceramic fiber is added to the container surface	To apply thermal insulation
	Container PCB's shape is changed from **Semi-circular** to **Capsule**	To lower the weight
	Payload battery is moved from **the bottom** to **the top**	To allow easy removal
	Camera gimbal structural material is changed from **PETG** to **PC**	To improve impact strength
	The deployment system is split into two repeated phases **(variable velocity)**	Deploying the payload with constant velocity cannot be done with brake system.
	Revolution counter is added	To measure the deployed distance of payload
	Acrylic foam tape is added to the brake.	To increase the friction between the tether and brake

System Concept of Operations
(1 / 3)

Pre-Launch	Launch and Descent Operations	Post-Launch recovery and Data Reduction
Flight day planning	Rocket is launched into the atmosphere	Recovery crews find the location of the CanSat via GPS and buzzer sound
Arrival at competition area	[670-725 m] CanSat is ejected from the rocket	Inspect the damage
Team Briefing	[700 – 400 m] CanSat descends with the first parachute with the rate of 15 m/s	Data Analysis
Set-up GCS, Operations Check	[400 m] The second parachute is deployed, reducing the descent rate to 5 m/s	PFR Preparation
FRR	[300 m] The tethered payload is released to the distance of 10 m in 20 s. The camera pointed 45 degrees up from the ground in the south direction.	PFR Presentation
Load CanSat into the rocket	[0 m] CanSat reaches the ground; data transmission is stopped; the buzzer is activated.	

System Concept of Operations
(2 / 3)

Team members; roles and responsibilities

Mission Control Officer
Kittipon Amornprasertkij

Informs flight coordinator when the team and CanSat are ready for the flight.

CanSat Preparation and Assembly Crews

Prepare, assemble, set-up, and load the CanSat into the rocket

- Nuchit Vichitkijja
- Suvijak Piyanopharoj
- Krin Kaweewongsonthorn

Recovery Crew

Search for the CanSat, inspect the CanSat for any damage

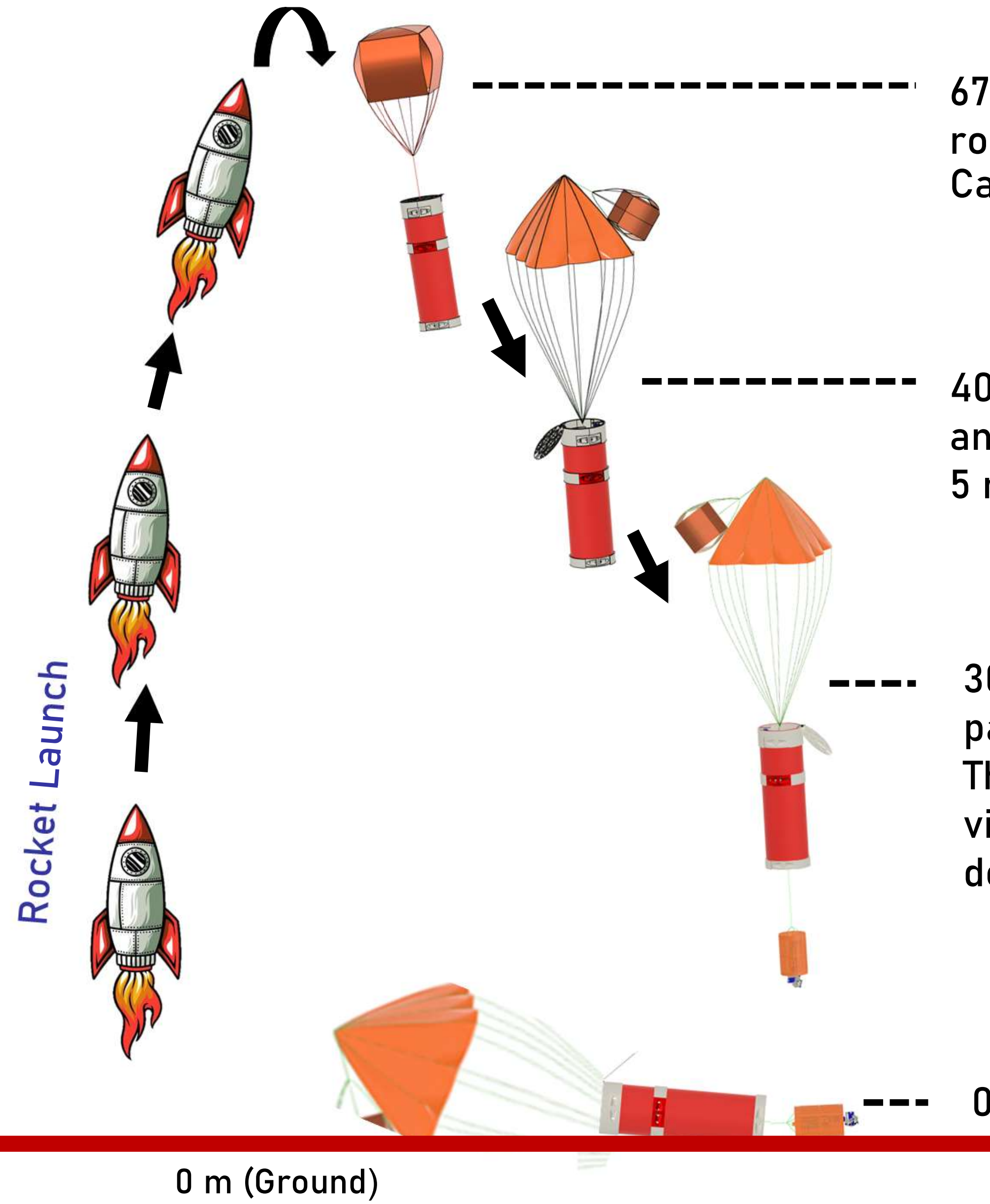
- Thasvarit Krueklai
- Pitiphoom Achapramote
- Shinakrit Laokittichai

Ground Station Crew

Monitor the GS for telemetry reception, Point antenna

- Krissada Singhakachain
- Arkkhanirut Pandej

System Concept of Operations (3 / 3)



670-725 m - CanSat is deployed from rocket. With the first parachute, the CanSat descends at a rate of 15 m/s.

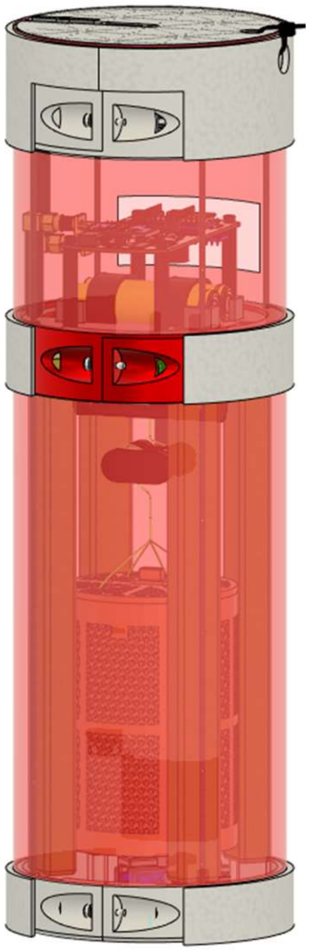
400 m - Second parachute will be deployed and the descent rate will be reduced to 5 m/s.

300 m - CanSat releases a tethered payload to a distance of 10 m in 20 s. The payload maintains the orientation of a video camera pointing 45 degrees downward in south direction.

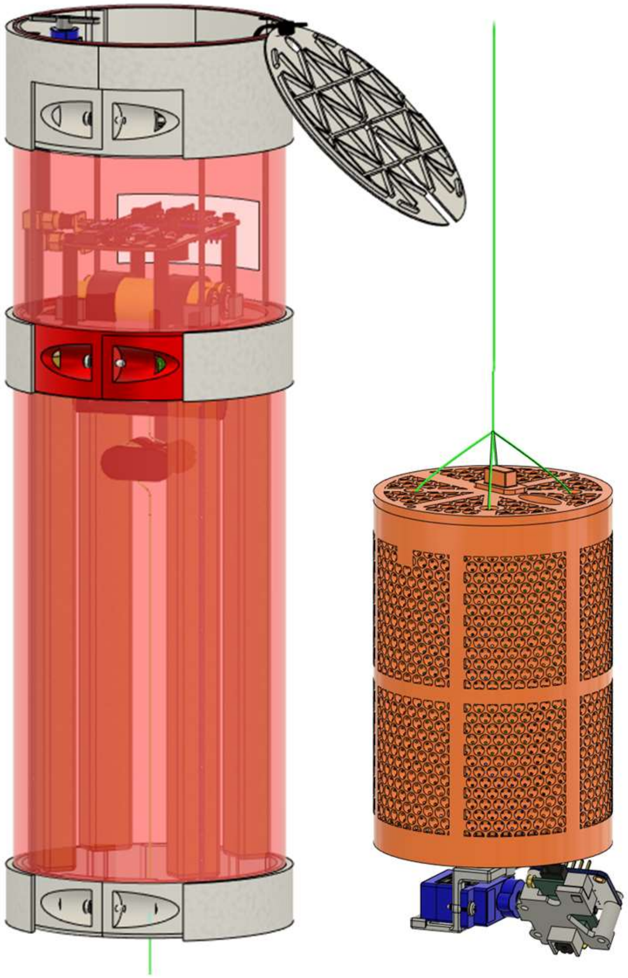
0 m - CanSat landed, ready for recovery.

Payload Physical Layout (1/6)

CanSat



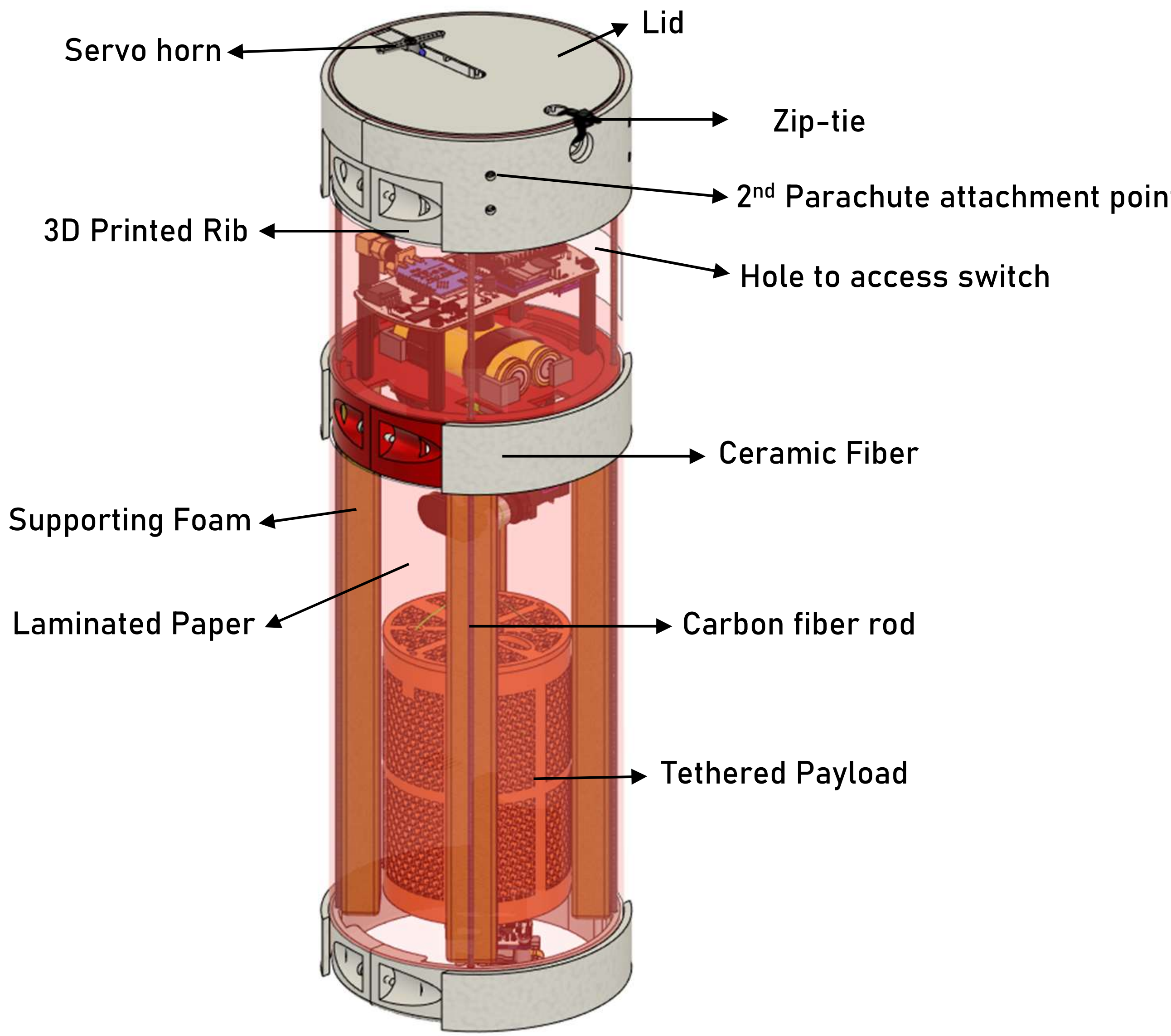
Launch Configuration



Deployed Configuration

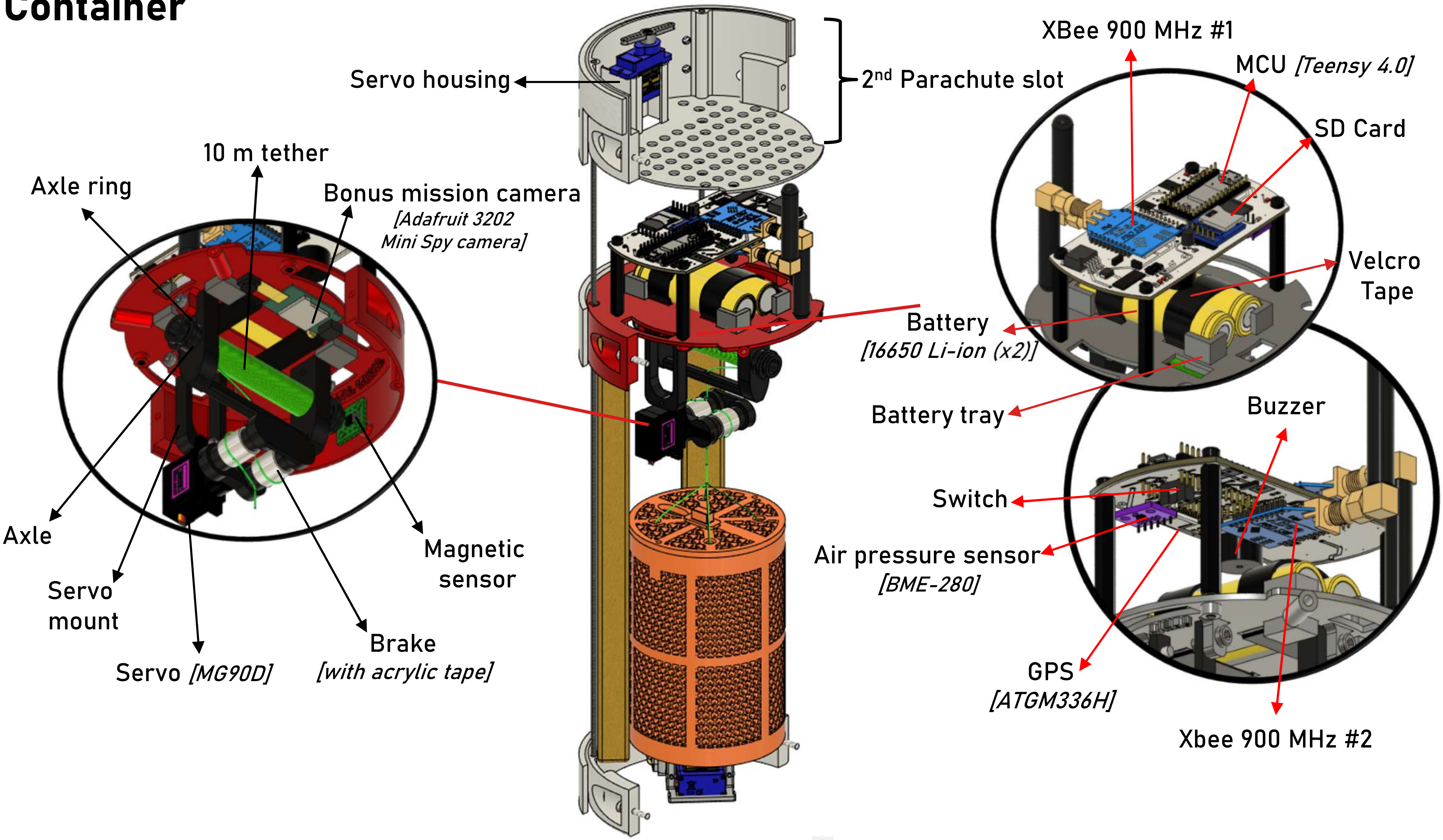
Payload Physical Layout
(2 / 6)

Container

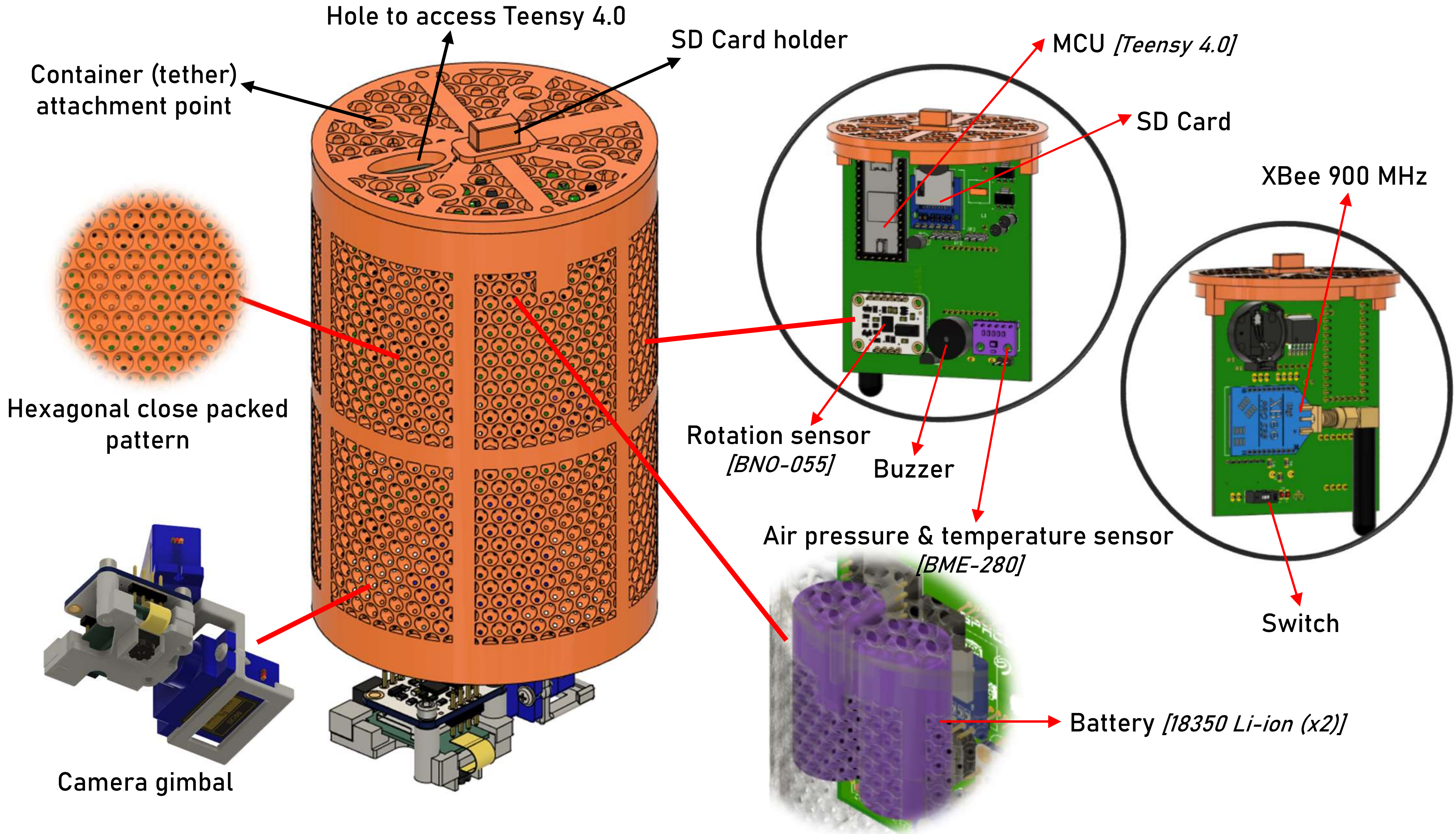


Payload Physical Layout
(3 / 6)

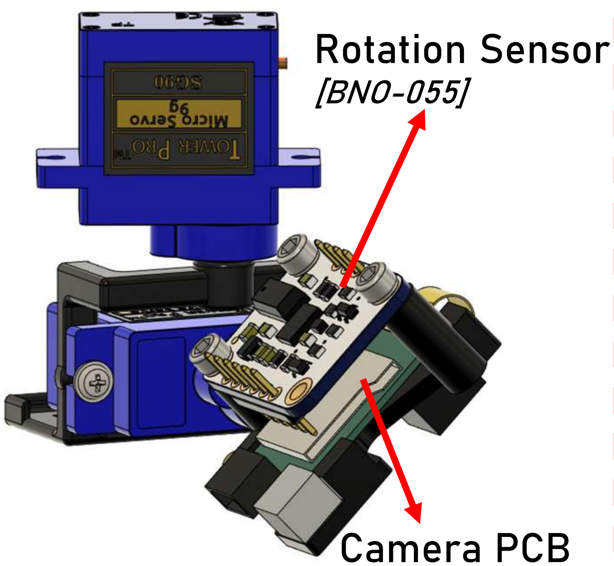
Container

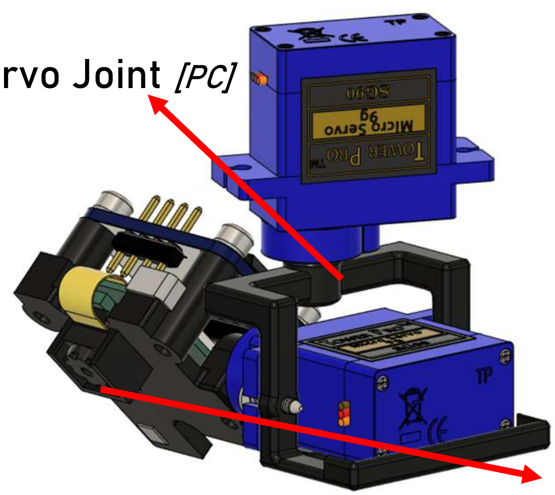


Tethered Payload

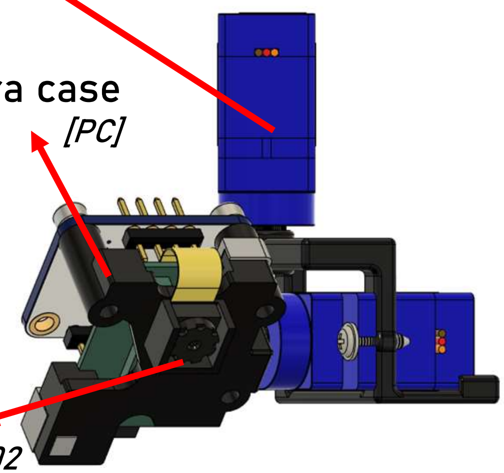


Camera Gimbal





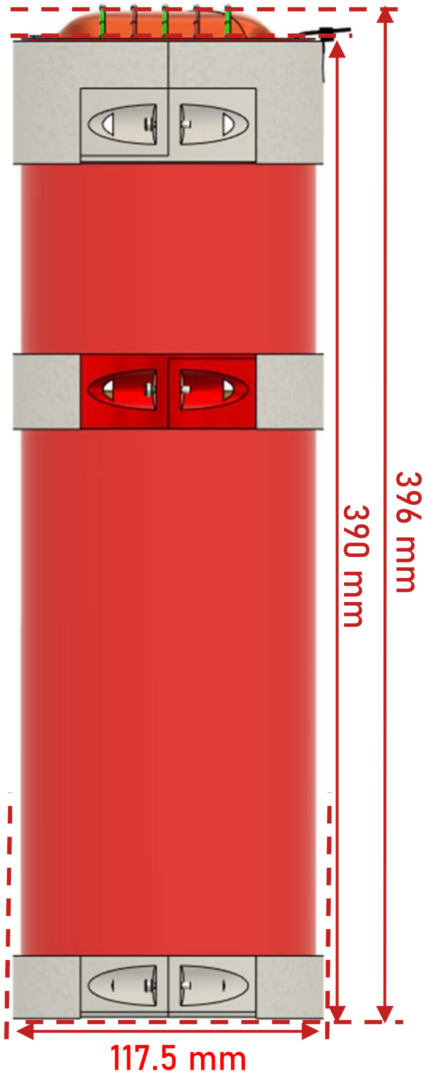
Front view



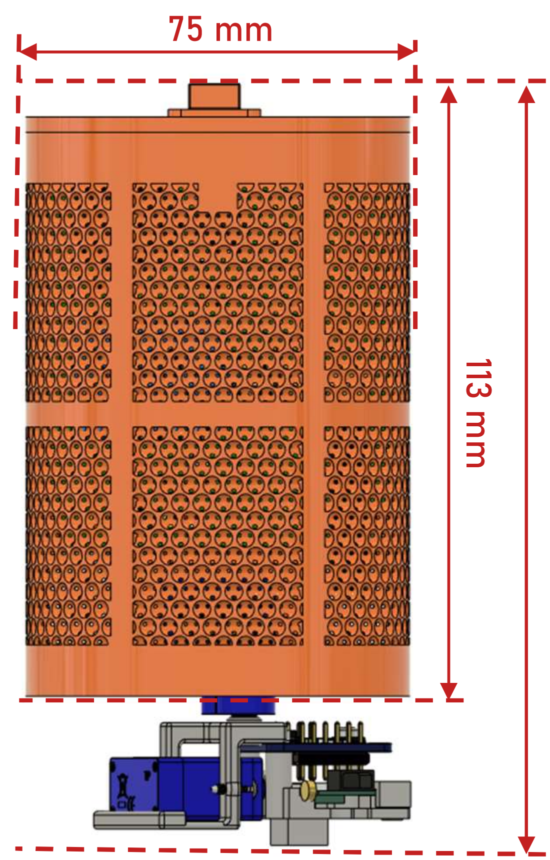
Side view

Payload Physical Layout
(6 / 6)

Dimension



Container Dimension



Tethered Payload Dimension

Launch Vehicle Compatibility

Container Dimension

• Height	-	390	mm
• Height with stowed parachute	-	396	mm
• Diameter	-	117.5	mm

Tethered Payload Dimension

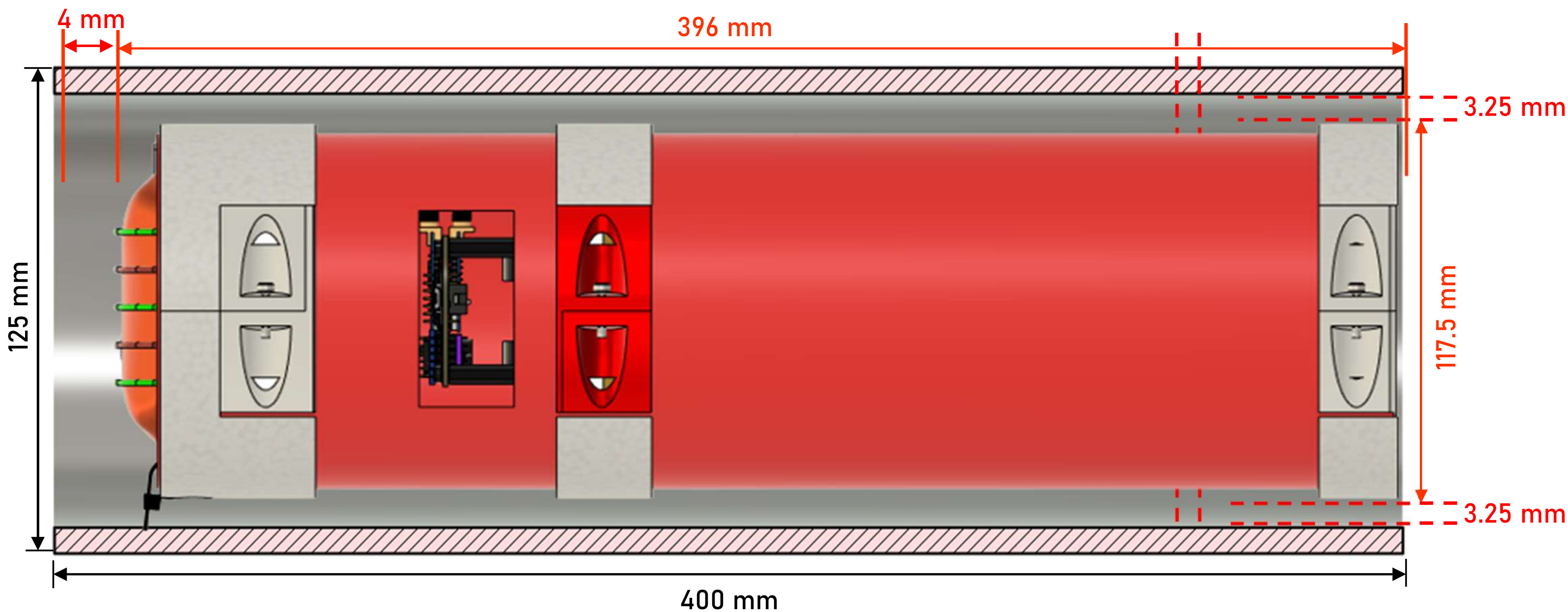
• Height (Gimbal Included)	-	142.10	mm
• Diameter	-	75	mm

Rocket Payload Section Dimension

• Height	-	400	mm
• Diameter	-	125	mm

Clearance

• Height gap	-	4	mm
• Diameter gap	-	3.25	mm



Sensor Subsystem Design

Suvijak Piyanopharoj

Sensor Subsystem Overview

NO	Sensor types	Sensor models	Purposes	Sections
1.	Air Pressure Sensor	BME-280	To measure air pressure for altitude calculation	TP and Container
2.	Air Temperature Sensor	BME-280	To measure air temperature	TP and Container
3.	Battery Voltage Sensor	Teensy Analog Pin	To measure Battery Voltage of TP and container	TP and Container
4.	Rotation Sensor	BNO-055	To measure rotational motion	TP
5.	Camera	Adafruit 3202 Mini Spy Camera	Recording video during the mission process	TP
6.	GPS	ATGM336H	To track container position	Container
7.	Bonus Camera	Adafruit 3202 Mini Spy Camera	To record video for bonus mission	Container
8.	Revolution Counter Sensor	HX3144UA	To measure the deployed distance of payload	Container

Sensor Changes Since PDR

Section	PDR	CDR	Rationale
Bonus Camera	Raspberry pi camera v2.1	Adafruit 3202 Mini Spy Camera	• Take up less space. • Significantly reduce weight.
Container GPS	MAX-M8Q	ATGM336H	• To reduce the weight • More affordable in our country
Container Revolution Counter Sensor	-	HX3144UA	• To measure the deployed distance of payload

Adafruit 3202
Mini Spy Camera
(Bonus Camera)

ATGM336H (Container GPS)

HX3144UA
(Container Revolution
Counter Sensor)

Container Air Pressure Sensor Summary

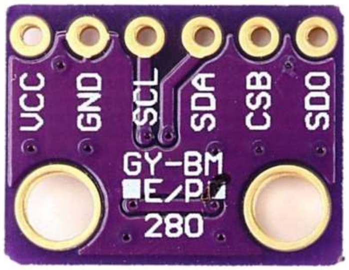
Sensor Model	CI (s)	Operation Range (hPa)	Accuracy (hPa)	Size (mm)	Mass (g)	Supply Voltage	Current (µA)	Cost ($)
BME-280	I²C, SPI	300.00~1100.00	±1.00	15.5 x 11.5 x 3.0	1.0	3.3 V (Module)	3.6	3.25

Data Processing

```
BME280 bme280;
bme280.init();
float a = bme280.calcAltitude(bme280.getPressure());
Altitude = float(a - refAltitude);
```

Data Format

$$Float = x.xx\ (Pa)$$



Equation

Hypsometric Equation

$$h = \frac{(R) \times (T + 274.15)}{g}$$

$h = Elevation\ of\ Measured\ Data$
$R = Specific\ Gas\ Constant\ for\ Dry\ Air$
$T = Current\ Temperature$
$g = Gravitational\ Acceleration$

Container GPS Sensor Summary

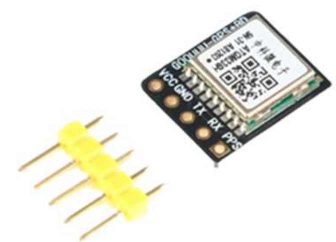
Sensor Model	CI (s)	Accuracy (m)	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
ATGM336H	UART	±2.50	15.7 x 13.1	4.4 g (With Antenna)	3.3 V, 5.0 V (Module)	25	11

Data Processing

```
TinyGPSPlus gps;

gps.encode(Serial2.read());
Latitude = gps.location.lat();
Longitude = gps.location.lng();

sprintf(gpsTime, "%02d:%02d:%02d",
gps.time.hour(), gps.time.minute(),
gps.time.second());

gpsAltitude = gps.altitude.meters();
gpsSatellite = gps.satellites.value();
```

Data Format

$$Float = x.xx$$
$$int = x$$



Container Voltage Sensor Summary

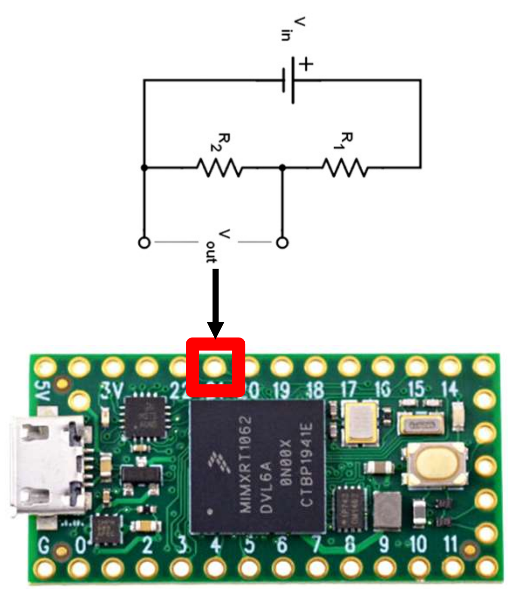
Sensor Model	CI (s)	Range (V)	Accuracy (V)	Mass (g)	Sensitivity or Resolution	Cost ($)
Teensy 4.0 Analog Pin	Analog	0.00~3.30	±0.1%	<1	0.05 V	0

Data Processing

```
#define R1_Ohm 2000.0
#define R2_Ohm 1250.0

float apparentVoltage = analogRead(21) * 3.3 / 1023.0;
Voltage = apparentVoltage * ((R1_Ohm + R2_Ohm) / R2_Ohm);
```

Data Format

$$Float = x.xx\ (V)$$



Equation

<u>*Voltage Divider Equation*</u>

$$V_{out} = V_{in} \times \left(\frac{R_2}{R_1 + R_2}\right)$$

$V_{in} = Input\ Voltage$
$V_{out} = Output\ Voltage$
$R_1 = 2{,}000\ \Omega$
$R_2 = 1{,}250\ \Omega$

Payload Air Pressure Sensor Summary

Sensor Model	CI (s)	Operation Range (hPa)	Accuracy (hPa)	Size (mm)	Mass (g)	Supply Voltage	Current (µA)	Cost ($)
BME-280	I^2C, SPI	300.00~1100.00	±1.00	15.5 x 11.5 x 3.0	1.0	3.3 V (Module)	3.6	3.25

Data Processing

```
#define SEALEVELPRESSURE_HPA 1013.25
Adafruit_BME280 bme;
bme.begin(0x76, &Wire);

altitude = (bme.readAltitude(SEALEVELPRESSURE_HPA)) -
groundAlt;
```

Data Format

$$Float = x.xx\ (Pa)$$

Equation

Hypsometric Equation

$$h = \frac{(R) \times (T + 274.15)}{g}$$

$h =$ *Elevation of Measured Data*
$R =$ *Specific Gas Constant for Dry Air*
$T =$ *Current Temperature*
$g =$ *Gravitational Acceleration*

Payload Air Temperature Sensor Summary

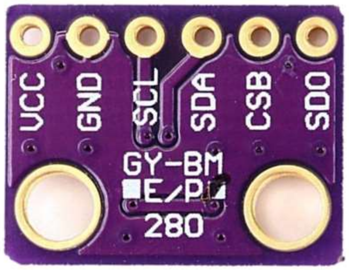
Sensor Model	CI (s)	Operation Range (hPa)	Accuracy (hPa)	Size (mm)	Mass (g)	Supply Voltage	Current (µA)	Cost ($)
BME-280	I^2C, SPI	300.00~1100.00	±1.00	15.5 x 11.5 x 3.0	1.0	3.3 V (Module)	3.6	3.25

Data Processing

```
Adafruit_BME280 bme;
bme.begin(0x76, &Wire);
temp = bme.readTemperature();
```

Data Format

$$Float = x.xx\ (Pa)$$



Equation

Hypsometric Equation

$$h = \frac{(R) \times (T + 274.15)}{g}$$

$h = Elevation\ of\ Measured\ Data$
$R = Specific\ Gas\ Constant\ for\ Dry\ Air$
$T = Current\ Temperature$
$g = Gravitational\ Acceleration$

Payload Voltage Sensor Summary

Sensor Model	CI (s)	Range (V)	Accuracy (V)	Mass (g)	Sensitivity or Resolution	Cost ($)
Teensy 4.0 Analog Pin	Analog	0.00~3.30	±0.1%	<1	0.05 V	0

Data Processing

```
#define R1_Ohm 2000.0F
#define R2_Ohm 1600.0F

float apparentVoltage = analogRead(15) * 3.3 /
1023.0;
Voltage = apparentVoltage * ((R1_Ohm + R2_Ohm) /
R2_Ohm);
```

Data Format

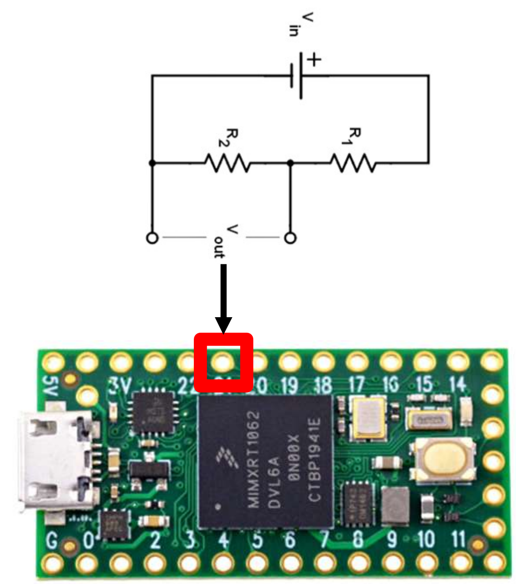
$$Float = x.xx\ (V)$$

Equation

<u>*Voltage Divider Equation*</u>

$$V_{out} = V_{in} \times \left(\frac{R_2}{R_1 + R_2}\right)$$

$V_{in} = Input\ Voltage$
$V_{out} = Output\ Voltage$
$R_1 = 2{,}000\ \Omega$
$R_2 = 1{,}600\ \Omega$



Payload Rotation Control Sensor Summary

Sensor Model	CI (s)	Resolution (degree)	Accuracy (degree)	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
BNO-055	I²C, UART	±1.00	±1.00	5.2 x 3.8 x 1.1	3.0	3.3 V, 5 V (Module)	12.3	34.15

Data Processing

```
Adafruit_BNO055 bnoPcb = Adafruit_BNO055(55, 0x28);
bnoPcb.begin()
bnoPcb.setExtCrystalUse(true);
imu::Vector<3> gyro =
bnoPcb.getVector(Adafruit_BNO055::VECTOR_GYROSCOPE);
gyro_r = gyro.x();
gyro_p = gyro.y();
gyro_y = gyro.z();
imu::Vector<3> accel =
bnoPcb.getVector(Adafruit_BNO055::VECTOR_ACCELEROMETER);
accel_r = accel.x();
accel_p = accel.y();
accel_y = accel.z();
imu::Vector<3> mag =
bnoPcb.getVector(Adafruit_BNO055::VECTOR_MAGNETOMETER);
mag_r = mag.x();
mag_p = mag.y();
mag_y = mag.z();
```

Equation

Method of converting a quaternion to a 3x3 orthogonal rotation matrix

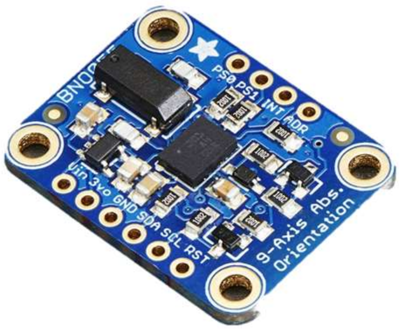
$$(w,x,y,z)$$

$$= \begin{bmatrix} w^2+x^2+y^2+z^2 & 2(xy-wz) & 2(wy+xz) \\ 2(xy+wz) & w^2-x^2+y^2-z^2 & 2(-wx+yz) \\ 2(-wy+xz) & 2(wx+yz) & w^2-x^2-y^2+z^2 \end{bmatrix}$$

$$w = \cos\theta \qquad y = Vy\sin\theta/2$$
$$x = Vx\sin\theta/2 \qquad z = Vz\sin\theta/2$$

Data Format

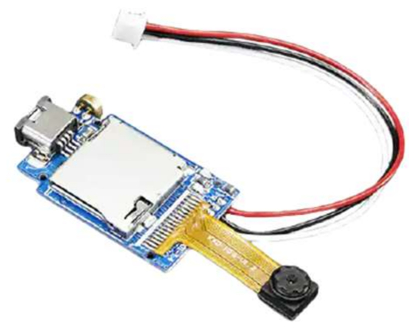
$$Float = x.xx\ (m/s^2)$$



Camera Summary

Sensor Model	CI (s)	Maximum Video Resolution	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
Adafruit 3202 Mini Spy Camera	Camera Serial Interface	640x480 @30fps	6.2 x 6.2 x 4.4 (Camera) 28.5 x 17 x 4.2 (PCB)	2.80 (with PCB)	5.0 V	110	12.50

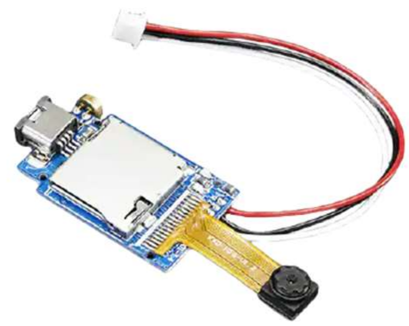
Maximum Video Resolution
640x480 @30fps



Bonus Camera Summary

Sensor Model	CI (s)	Maximum Video Resolution	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
Adafruit 3202 Mini Spy Camera	Camera Serial Interface	640x480 @30fps	6.2 x 6.2 x 4.4 (Camera) 28.5 x 17 x 4.2 (PCB)	2.80 (with PCB)	5.0 V	110	12.50

Maximum Video Resolution
640x480 @30fps



Revolution Counter Sensor

Sensor Model	CI (s)	Operate Point (Gauss)	Release Point (Gauss)	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
HX3144UA	Digital	60 - 100	40 - 80	2 x 3 x 1	<1	5 V	2.5	0.24

Data Processing

```
const int active = digitalRead(HALL_SENSOR_PIN);
if (!was_active && active) {
    distance += 36.128
}
was_active = active;
```

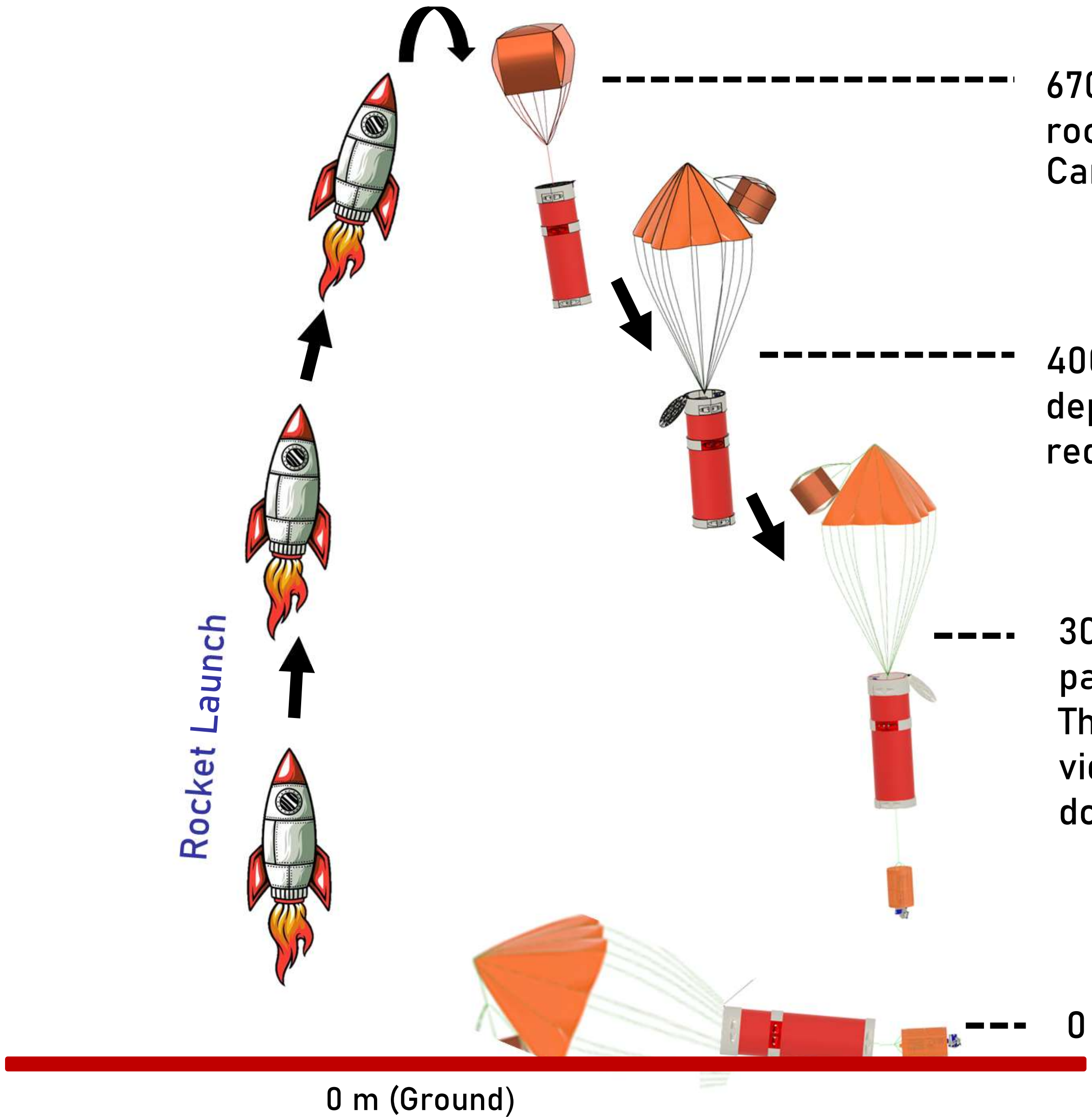
Data Format

$$Float = x.xx\ (mm)$$

Descent Control Design

Nuchit Vichitkijja, Thasvarit Krueklai

Descent Control Overview (1/3)



670-725 m - CanSat is deployed from rocket. With the first parachute, the CanSat descends at a rate of 15 m/s.

400 m – The second parachute will be deployed and the descent rate will be reduced to 5 m/s.

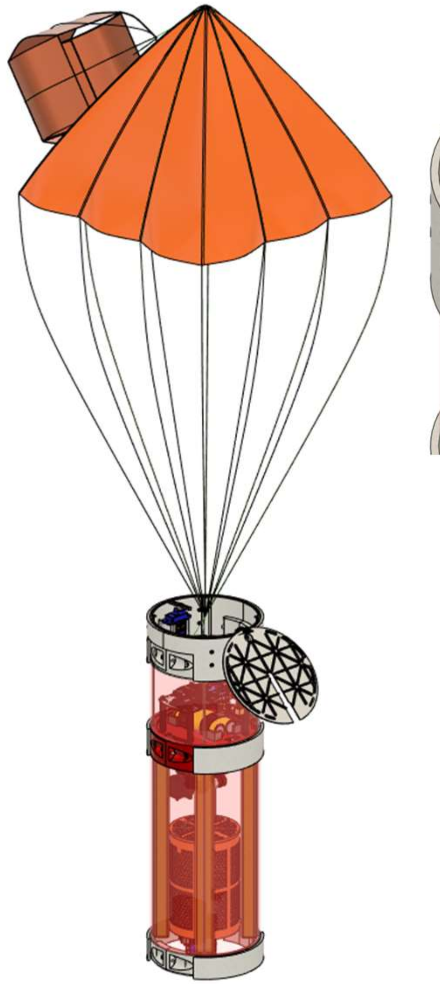
300 m - CanSat releases a tethered payload to a distance of 10 m in 20 s. The payload maintains the orientation of a video camera pointing 45 degrees downward in south direction.

0 m - CanSat landed, ready for recovery.

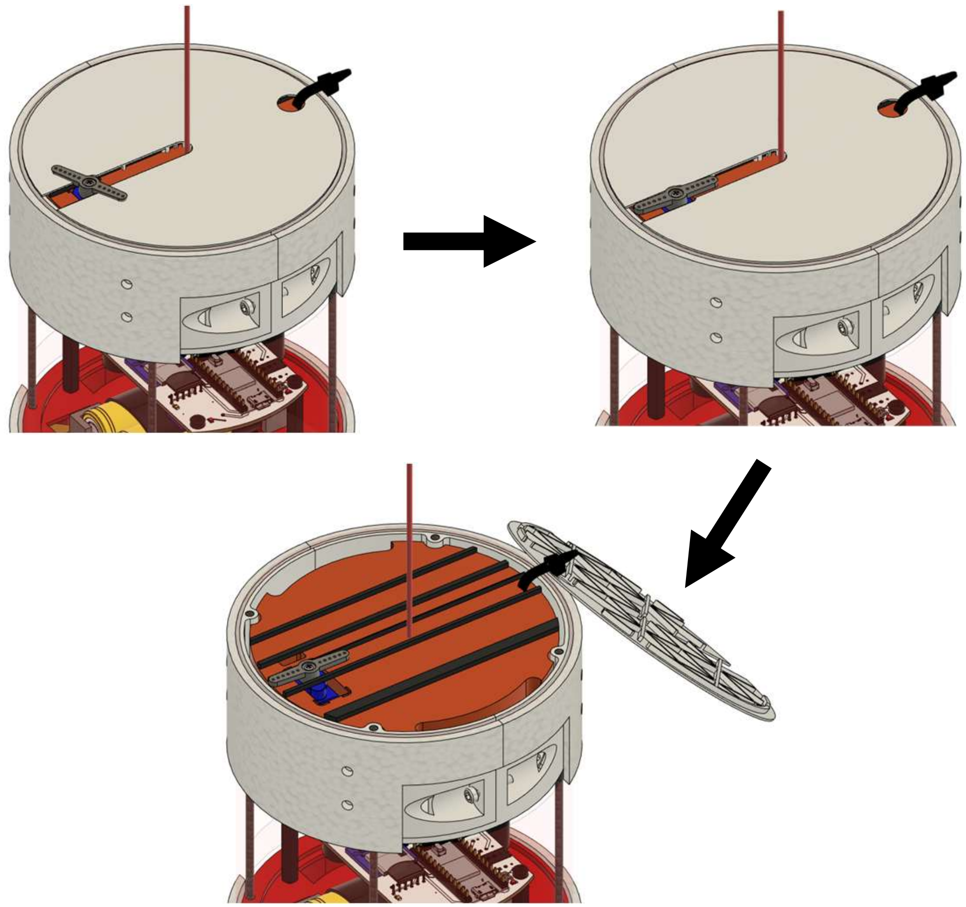
Descent Control Overview
(2 / 3)

Container Descent Control system
[Two-Stage Parachute]

1st Stage



2nd Stage

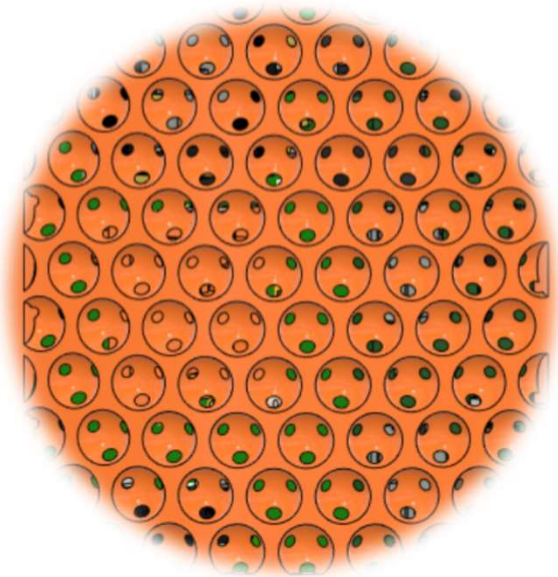


Detailed view on parachute deploy system

Descent Control Overview (3 / 3)

CanSat Stability Control

- Fins have been removed from the design to improve stability to both container and payload
- Hexagonal Close Packed Pattern of the payload will lower the payload's swaying rate



Hexagonal Close Packed Pattern

Container without fins

Descent Control Changes Since PDR (1/4)

Changes Summary

Components	Changes		Rationales
	PDR	CDR	
CanSat stability control	Fins	No Fins	The design without fins is more efficient in roll axis. (according to the test results).
Second parachute slot	Height = 45 mm	Height = 50 mm	Prevent the lid from bending upwards
Second parachute color	Fluorescent Pink	Fluorescent Orange	Fluorescent orange nylon is already available.

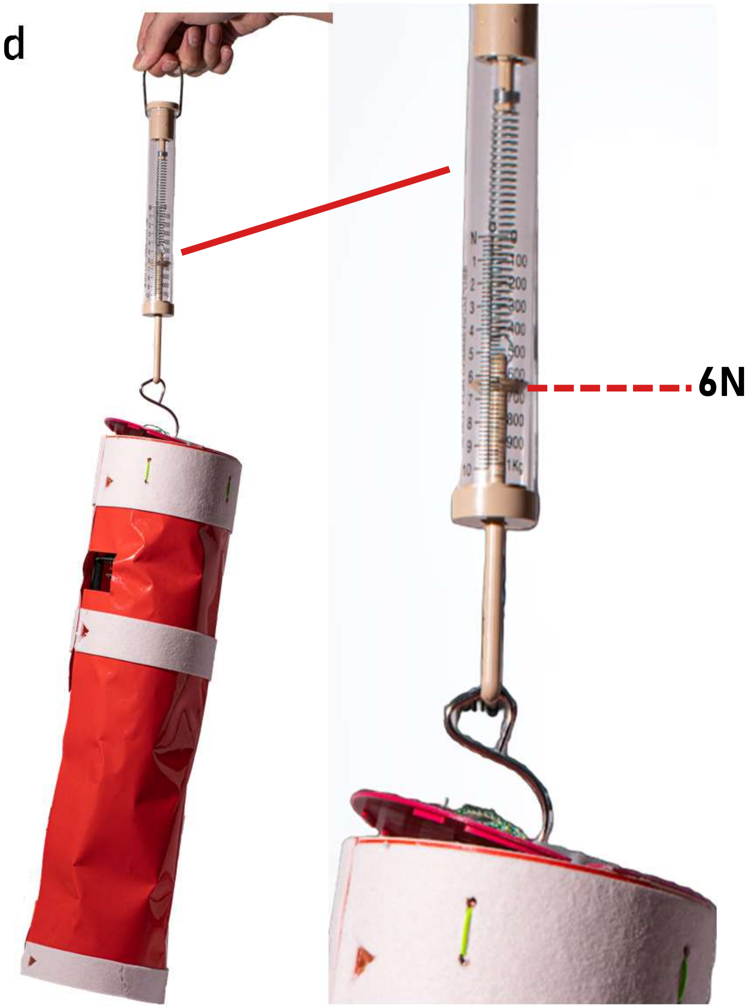
Prototype Testing

Container Descent Control: Second parachute deployment

Objective: To inspect if the SG90 servo arm can hold the lid and withstand the lifting force of the first parachute

Procedures:

- Stow the second parachute in the slot
- Close the lid by servo arm (SG90)
- Lift the lid by the spring balance with 6 N force
- Activate the servo



Results: The parachute was deployed successfully, and the servo arm could withstand the lift force, but the lid was bending upward which is later enlarged.

Descent Control Changes Since PDR

Prototype Testing

Container Descent Control: Two-Stage Parachute

Objective: To examine if the first parachute will affect the CanSat descent rate when the second parachute is deployed

Procedures:

- Sew the first parachute cords to the top of the second parachute
- Place both parachutes on the top of the dummy CanSat (117.5 x 390 mm, 600 g)
- Drop the dummy CanSat from 40 meter high building
- Measure the descent time to determine the descent rate

Results: The first parachute deflated and did not affect the second parachute.

Descent Control Changes Since PDR (4 / 4)

<u>Prototype Testing</u>

CanSat Stability Control: Fins

Objective: To study the efficiency of fins.

Procedures:

- Attach the handmade balsa fins and parachute* to the dummy CanSat (117.5 x 390 mm, 600g, rotation sensor included) *make the CanSat descend with velocity of 5 m/s
- Drop the dummy CanSat from 40 meter high building
- Recover the dummy CanSat, retrieve the SD card
- Run the test again without fins, compare the data

Results: Fins provide instability in roll axis, so they have been removed from the design to improve stability.

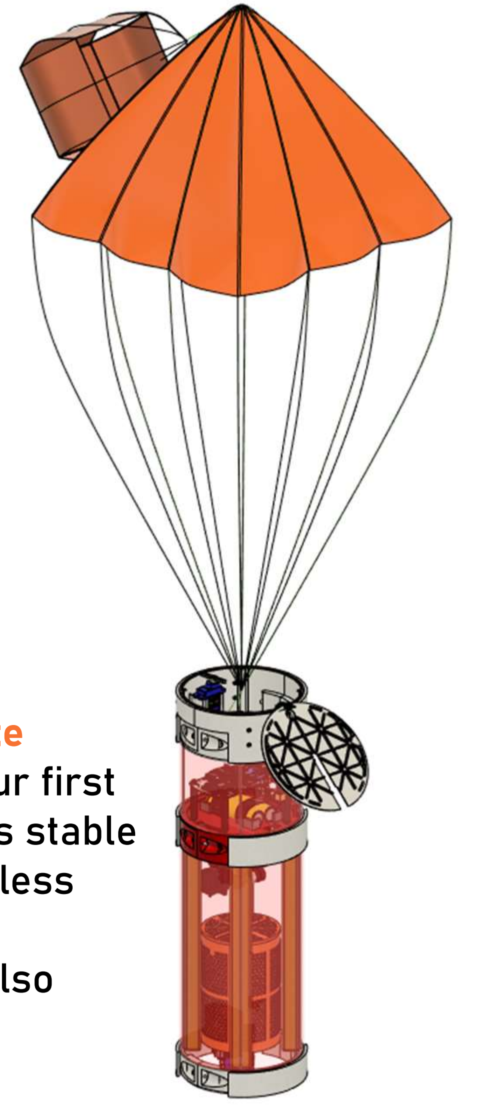
Two-Stage Parachute

- The CanSat has two parachutes for different altitudes.
- Two Parachutes are sewn together. The second parachute is stowed between the lids of the CanSat
- The first parachute will be deployed immediately after ejection from the rocket. It also serves as a drogue chute to pull the second parachute out.
- When the CanSat reaches 400 meters, the upper lid will be opened by a servo and the second parachute will be deployed.
- After second parachute is deployed, the first parachute will remain attached.

Parachutes Material Selection

First Parachute : Cube Parachute

- The cube parachute is chosen as our first parachute because of its stability. It is incredibly stable compared with other types of parachutes.
- We used it in most of our past projects.
- The material is nylon; the color is fluorescent orange.
- The suspension lines are also made up of nylon and sewn to the top of the second parachute.



Second Parachute : da Vinci's parachute

- The cube parachute is chosen as our first parachute because it is slightly less stable than the cube but consumes much less space.
- The material is nylon; the color is also fluorescent orange.
- The suspension lines are nylon.

1st Parachute calculation: Cube parachute

$$A_{eff} = \frac{2mg}{c_{cube}\rho v^2}$$

$$A_{eff} = kl^2$$

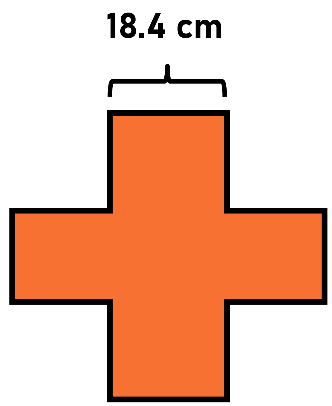
$$kl^2 = \frac{2mg}{c_{cube}\rho v^2}$$

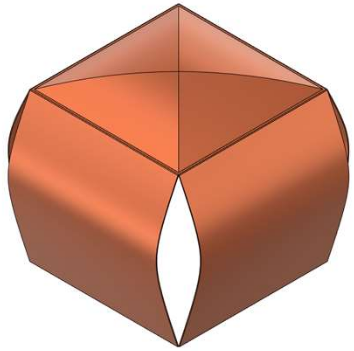
$$l = \sqrt{\frac{2mg}{k c_{cube}\rho v^2}}$$

$$l = \sqrt{\frac{2(0.6)(9.81)}{(\frac{7}{3})(0.54)(1.225)(15)^2}}$$

$$l = 0.184\ m$$

$$A_{total} = 5l^2 = \mathbf{0.17\ m^2}$$





A_{eff}	Effective area of cube parachute
l	Length of cube parachute
$g = 9.81\ \frac{m}{s^2}$	Gravity acceleration
$c_{cube} = 0.54$	Cube parachute drag coefficient
$\rho_{atm} = 1.225\ \frac{kg}{m^3}$	Average air density
$k = \frac{7}{3}$	The effective area of cube parachute coefficient
m	CanSat mass
v	Descent velocity

2nd Parachute calculation: da Vinci's parachute

$$A_{eff} = \frac{2mg}{c_{Da\ vinci}\rho v^2}$$

$$A_{eff} = kl^2$$

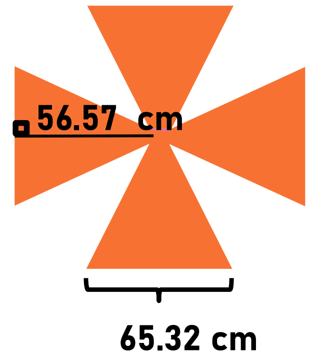
$$kl^2 = \frac{2mg}{c_{Da\ vinci}\rho v^2}$$

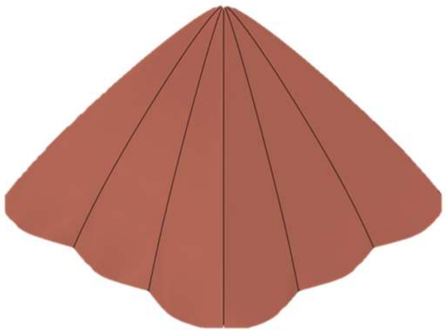
$$l = \sqrt{\frac{2mg}{k c_{Da\ vinci}\rho v^2}}$$

$$l = \sqrt{\frac{2(0.6)(9.81)}{(1)(0.9)(1.225)(5)^2}}$$

$$l = 0.6532\ m$$

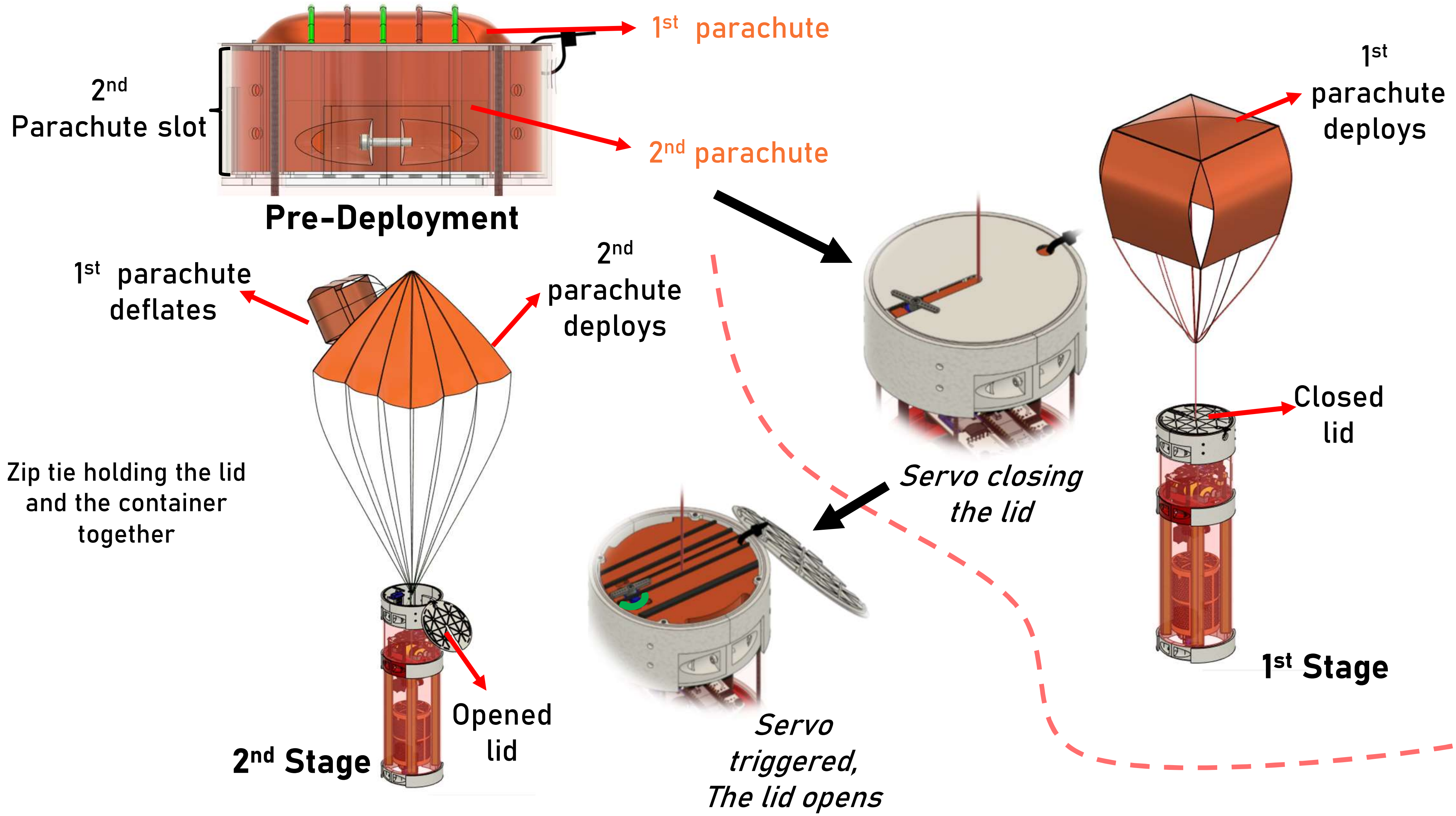
$$A_{total} = \sqrt{3}l^2 = \mathbf{0.74\ m^2}$$





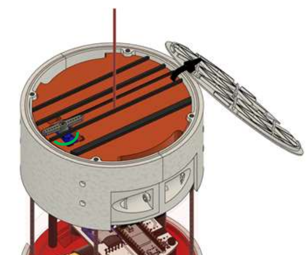
A_{eff}	Effective area of da Vinci's parachute
l	Length of da Vinci's parachute
$g = 9.81\ \frac{m}{s^2}$	Gravity acceleration
$c_{\text{Da vinci}} = 0.9$	da Vinci's parachute drag coefficient
$\rho_{atm} = 1.225\ \frac{kg}{m^3}$	Average air density
$k = 1$	The effective area of da Vinci's parachute coefficient
m	CanSat mass
v	Descent velocity

Two-Stage Parachute – CONOPS



Two-Stage Parachute – Sensor Data Processing

- After reaching APOGEE state, a pressure sensor determines when altitude reaches 400 meters from the ground.
- Flight state will be set to PARADEPLOY and release the second parachute by rotating the servo by 90 degrees.

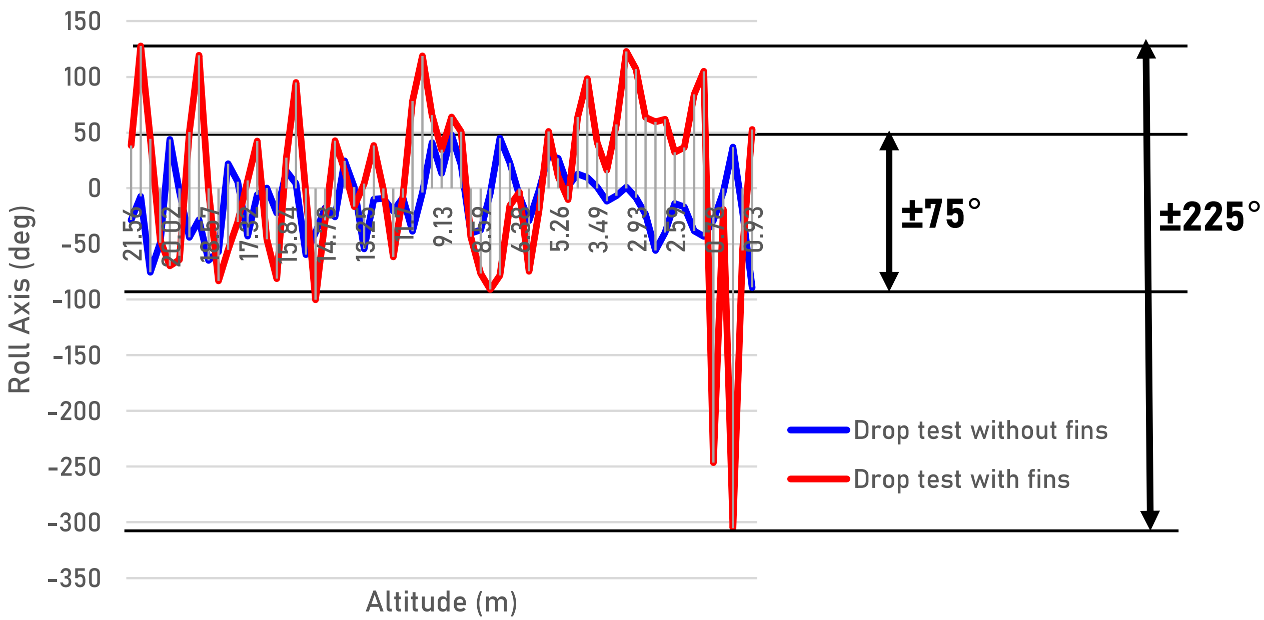


Rocket reaches apogee → Wait until altitude reaches 400 m → Rotate the servo by 90 degrees

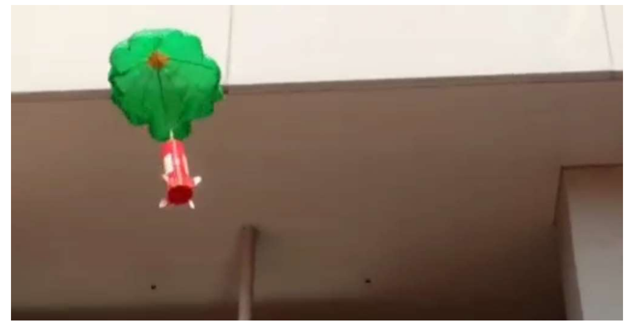
APOGEE | PARADEPLOY

Fin Test Result

- After the PDR, the stability control tests was conducted.
- The tests were done by attaching fins to a dummy container and dropping it from 40 meter high building.
- The data showed that fins were creating more spin on the CanSat, so they have been removed from the design to **improve stability**



Roll Axis Chart from drop test data
(after 20 meter of parachute stabilization)



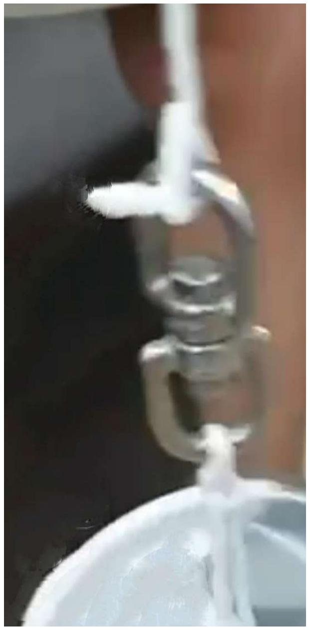
Drop test with fins

Drop test without fins

Joint and Swivel Test Results

- Joints and swivels, the components which passively control stability, have been examined and shown to be ineffective.

	Keychain Swivel	Ball Bearing Swivel	Universal Joint
Purpose	• To improve stability of the container, the component is used as the tether attachment point of the 2nd parachute and the container		• To improve pitch and yaw stability of the payload, the component is used as the tether attachment point of the parachute and the container
Test Result	The components were not moving as planned due to material friction		



Ball Bearing Swivel Test

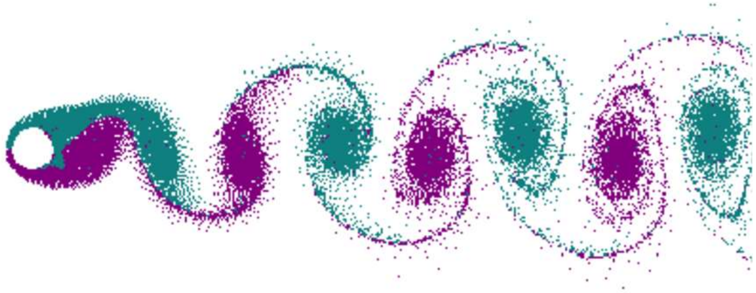
Container and Payload Descent Stability Control Design (3 / 4)

The payload and the effect on stability

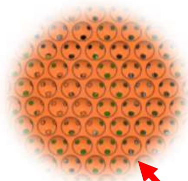
- Because von Karman vortex street in the wake of a cylinder can be observed in the range of Reynolds numbers from about 60 to 5000 (which covers the Reynolds numbers of this mission)
- The hexagonal close-packed pattern on the payload's surface has been designed to reduce von Karman vortex street and **lower the payload's swaying rate, which means keeping the payload's nadir pointed down.**

The effect of parachutes on stability

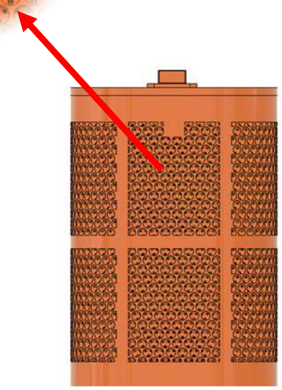
- Parachutes are the components that have the **largest effect on the stability** due to their large surface areas in comparison to other components, or in other words, they dominate the stability of the whole system
- Before the main parachute is inflated, the drogue chute which is a cube parachute will stabilize the system



Laminar flow past the cylinder

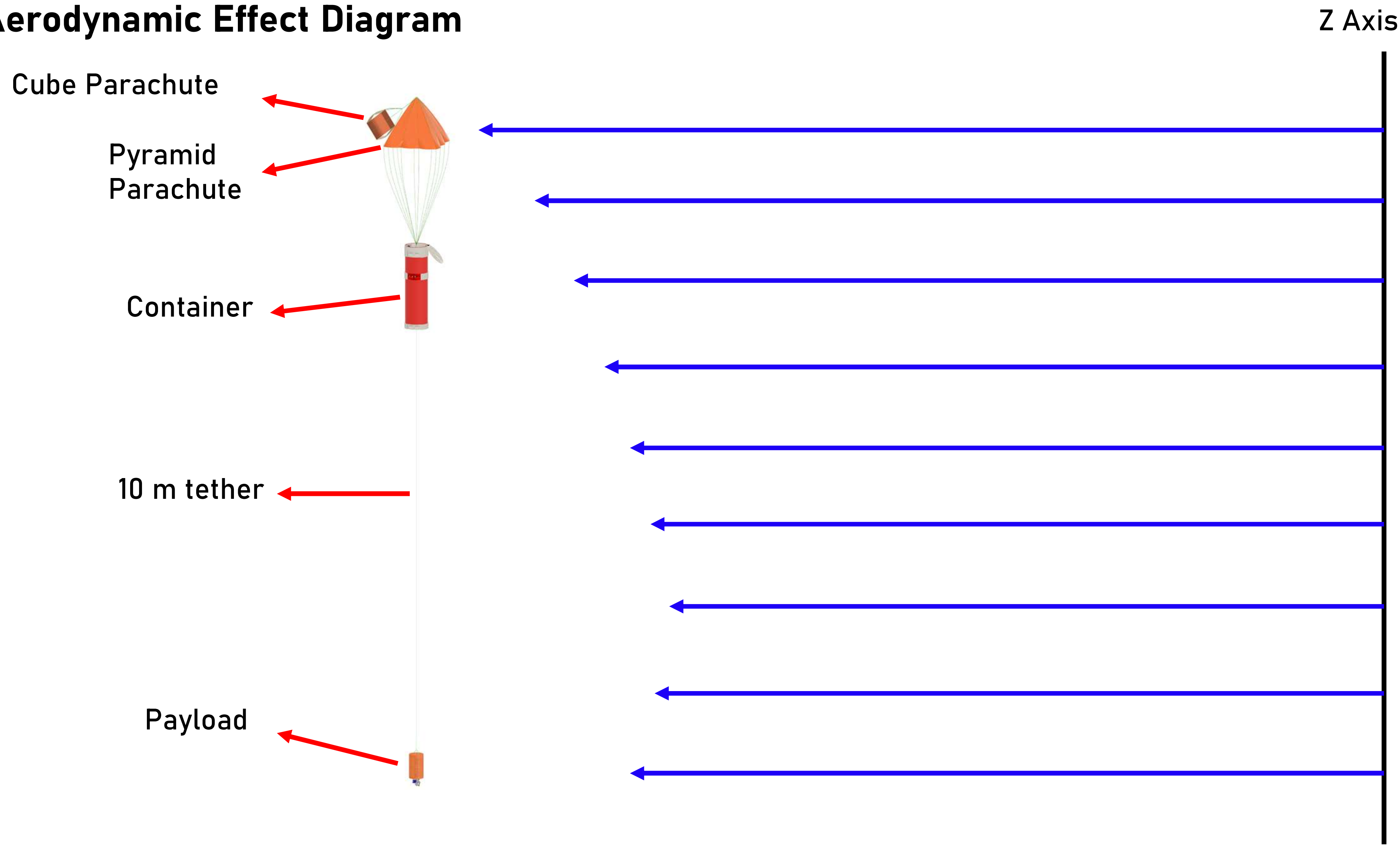


hexagonal close packed pattern



Payload

Aerodynamic Effect Diagram



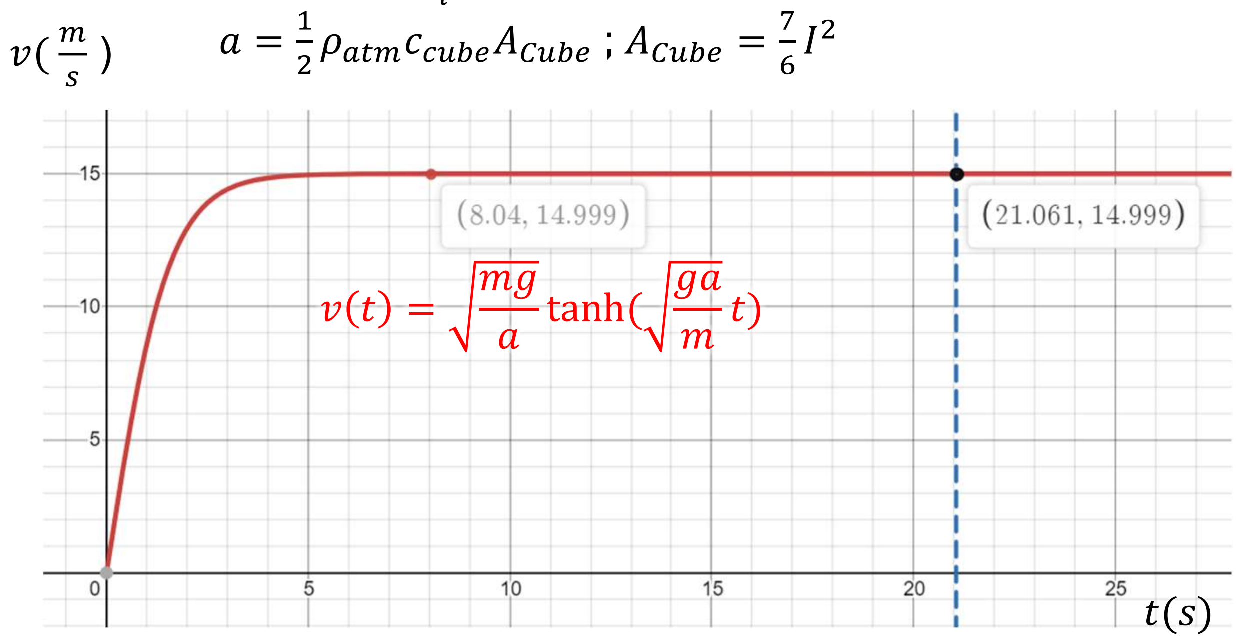
Descent Rate Estimates
(1 / 5)

Descent rate estimates for CanSat with first parachute (Cube) released

Descent Velocity-Time Calculation for CanSat

$$\Delta t = \int_{v_i=0}^{v(t)} \frac{1}{g - \frac{a}{m}v^2}\,dv$$

$$a = \frac{1}{2}\rho_{atm} c_{cube} A_{Cube} \; ; \; A_{Cube} = \frac{7}{6} I^2$$



Δt	Time of descent
v	Descent velocity
m	CanSat mass
I	Length of cube parachute
$g = 9.81 \frac{m}{s^2}$	Gravity acceleration
$\rho_{atm} = 1.225 \frac{kg}{m^3}$	Average of air density
$C_{cube} = 0.54$	Cube parachute drag coefficient

Assuming vertical initial velocity from the 700 m Apogee is 0 m/s, the CanSat descends 300 m from Apogee with velocity of **15.0 m/s** for **21.1** s.

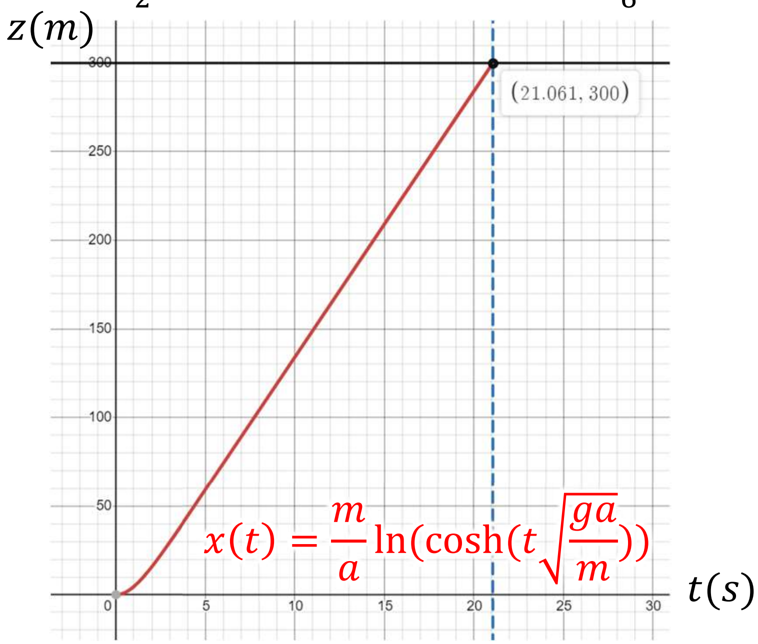
15.0 m/s in 21.1 s with Cube parachute

Descent rate estimates for CanSat with first parachute (Cube) released

Descent Distance-Time Calculation for CanSat

$$\Delta t = \int_{v_i=0}^{v(t)} \frac{1}{g - \frac{a}{m}v^2} dv$$

$$a = \frac{1}{2}\rho_{atm} c_{cube} A_{Cube} \; ; A_{Cube} = \frac{7}{6} I^2$$



Δt	Time of descent
v	Descent velocity
m	CanSat mass
I	Length of cube parachute
$g = 9.81 \frac{m}{s^2}$	Gravity acceleration
$\rho_{atm} = 1.225 \frac{kg}{m^3}$	Average of air density
$C_{cube} = 0.54$	Cube parachute drag coefficient

Assuming vertical initial velocity from the 700 m-Apogee is 0 m/s, the CanSat descends **300 m** from the Apogee for **21.1 s**.

300 m in 21.1 seconds with Cube parachute

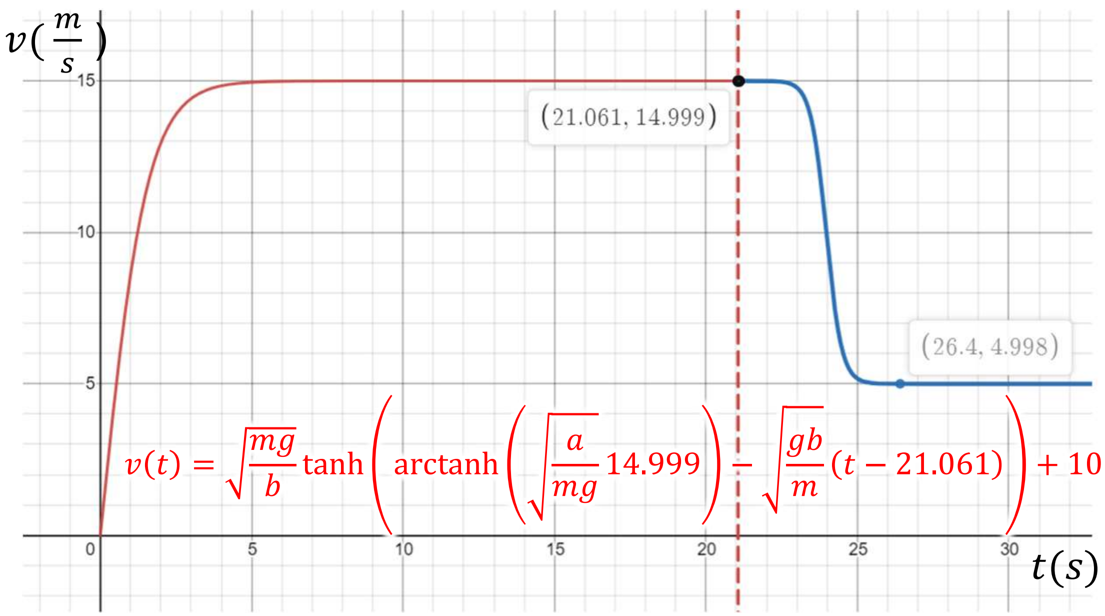
Descent Rate Estimates
(3 / 5)

Descent rate estimates for CanSat with second parachute (da' Vinci's) released

Descent Velocity-Time Calculation for CanSat

$$\Delta t = \int_{v_i=0}^{v(t)} \frac{1}{g - \frac{b}{m}v^2} dv$$

$$b = \frac{1}{2}\rho_{atm} c_{Da\ Cindi} A_{Da\ Vinci}\ ;\ A_{Da\ Vinci} = (l+L)^2$$



Δt	Time of descent
v	Descent velocity
m	CanSat mass
$l + L$	Side length of Da Vinci parachute
$g = 9.81\ \frac{m}{s^2}$	Gravity acceleration
$\rho_{atm} = 1.225\ \frac{kg}{m^3}$	Average of air density
$C_{Da\ Vinci} = 0.9$	Da Vinci parachute type drag coefficient

5.0 m/s in 80.4 s with da Vinci's parachute

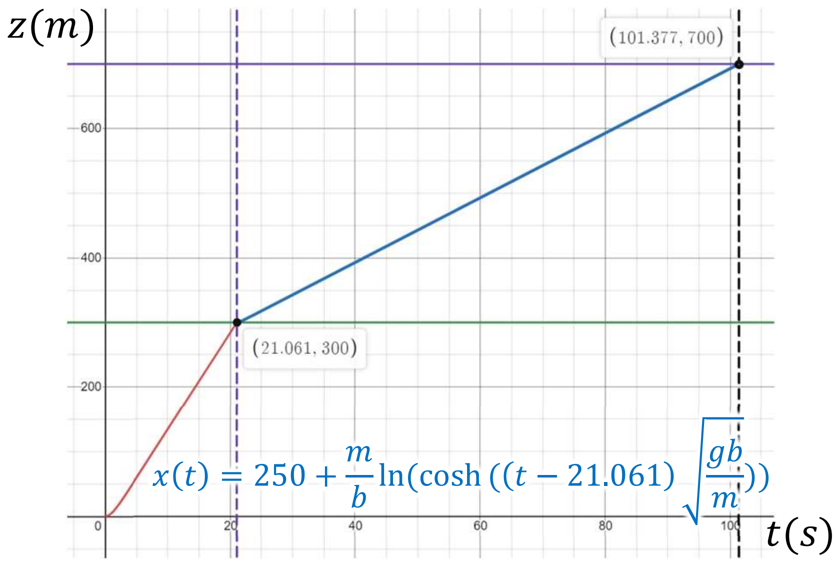
Assuming vertical initial velocity of CanSat after first parachute deployed is 15 m/s, the CanSat descends from 400 m height to the ground the with velocity of **5.0 m/s** for **80.4 s.**

Descent rate estimates for CanSat with second parachute (da' Vinci's) released

Descent Distance-Time Calculation for CanSat

$$\Delta t = \int_{v_i=0}^{v(t)} \frac{1}{g - \frac{b}{m}v^2} dv$$

$$b = \frac{1}{2}\rho_{atm} c_{Da\ Vinvi} A_{Da\ Vinci}\ ;\ A_{Da\ Vinci} = (l+L)^2$$



400 m in 80.4 s with da Vinci's parachute

Δt	Time of descent
v	Descent velocity
m	CanSat mass
$l + L$	Side length of Da Vinci parachute
$g = 9.81\ \frac{m}{s^2}$	Gravity acceleration
$\rho_{atm} = 1.225\ \frac{kg}{m^3}$	Average of air density
$C_{Da\ Vinci} = 0.9$	Da Vinci parachute type drag coefficient

Assuming vertical initial distance from apogee is 300 m, the CanSat descends from **400 m** to the ground for **80.4 s**.

Descent Rate Estimates
(5 / 5)

Final Result

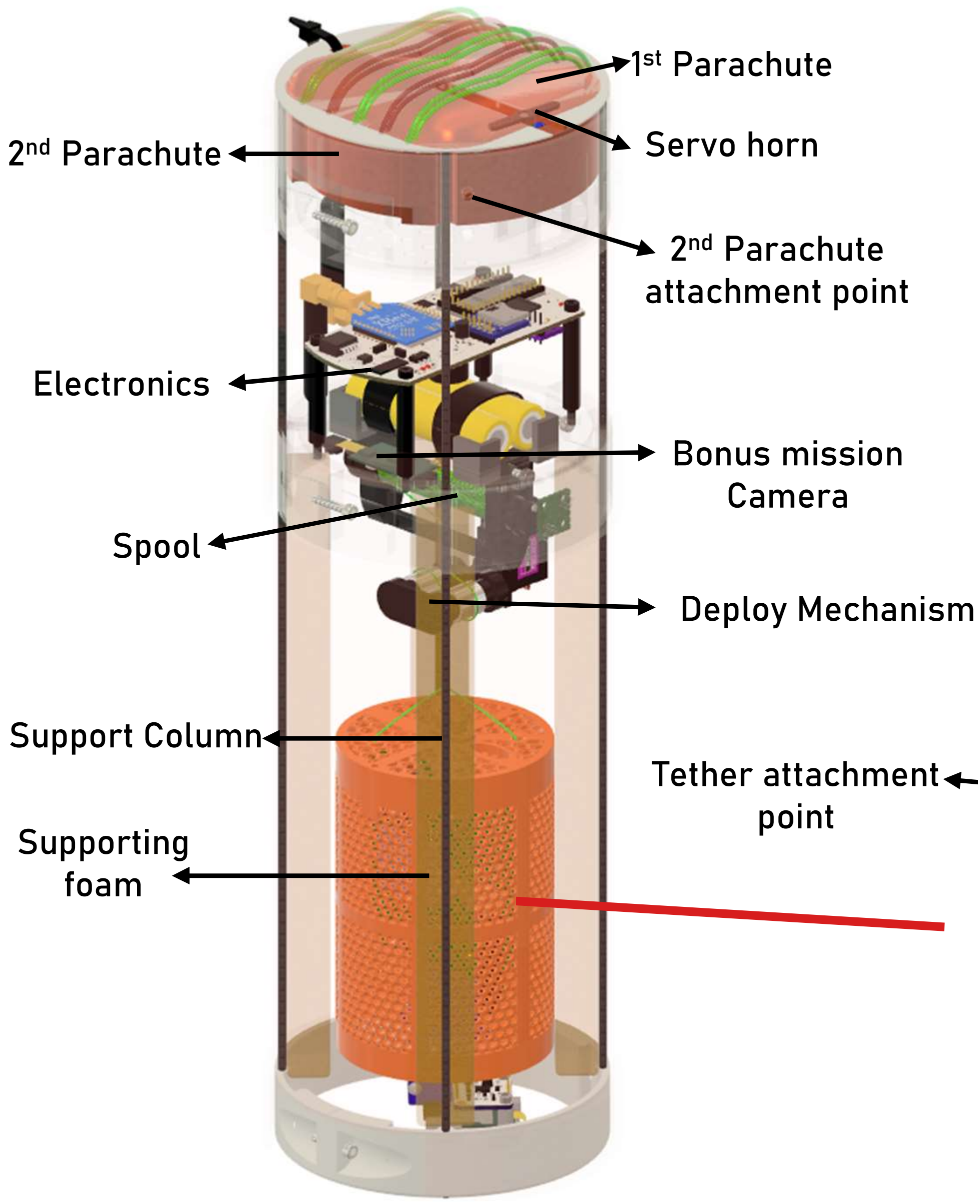
Descent Rate Estimates for CanSat

Phase	Height	Descent rate	Descent time
1st Parachute released	700 - 400 m	**15.0 m/s**	21.1 s
2nd Parachute released	400 - 0 m	**5.0 m/s**	80.4 s
Total Descent time			**101.5 s**

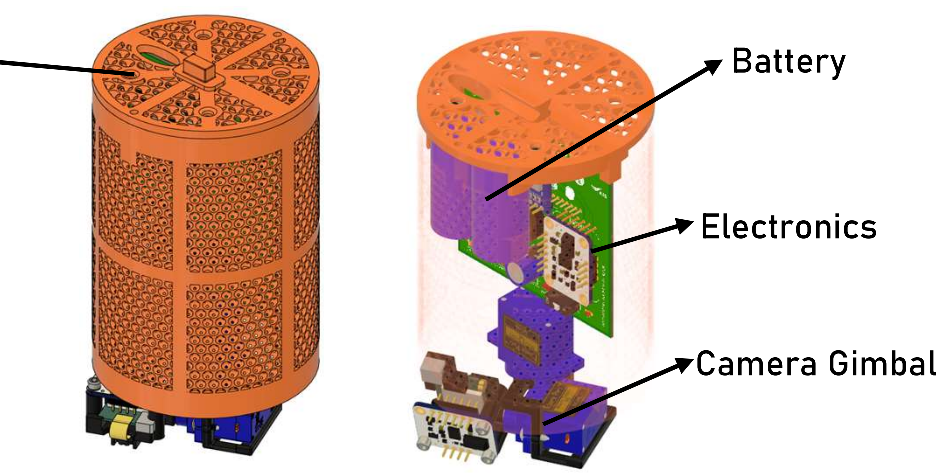
Mechanical Subsystem Design

Kittipon Amornprasertkij, Nuchit Vichitkijja

Mechanical Subsystem Overview (1/2)

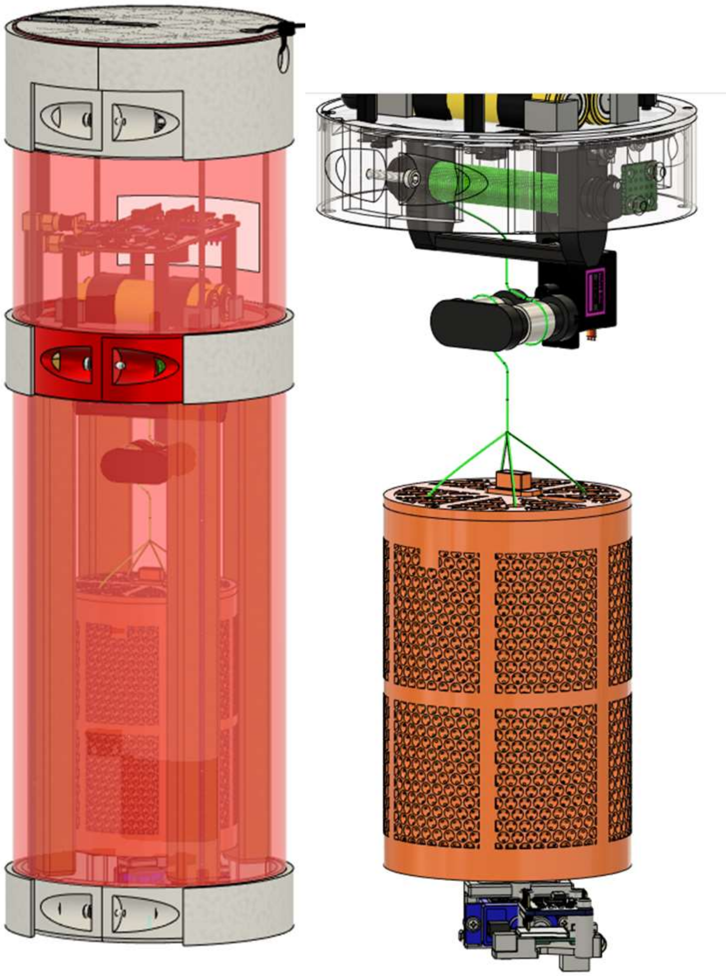


Structure	Material
Container Ribs	PLA-LW
Deployment System	PC
Container support column	Carbon fiber
Container coating	Laminated paper + Ceramic fiber
Payload	PETG
Parachutes & Cords	Nylon
Tether	
Bolts & Standoffs	

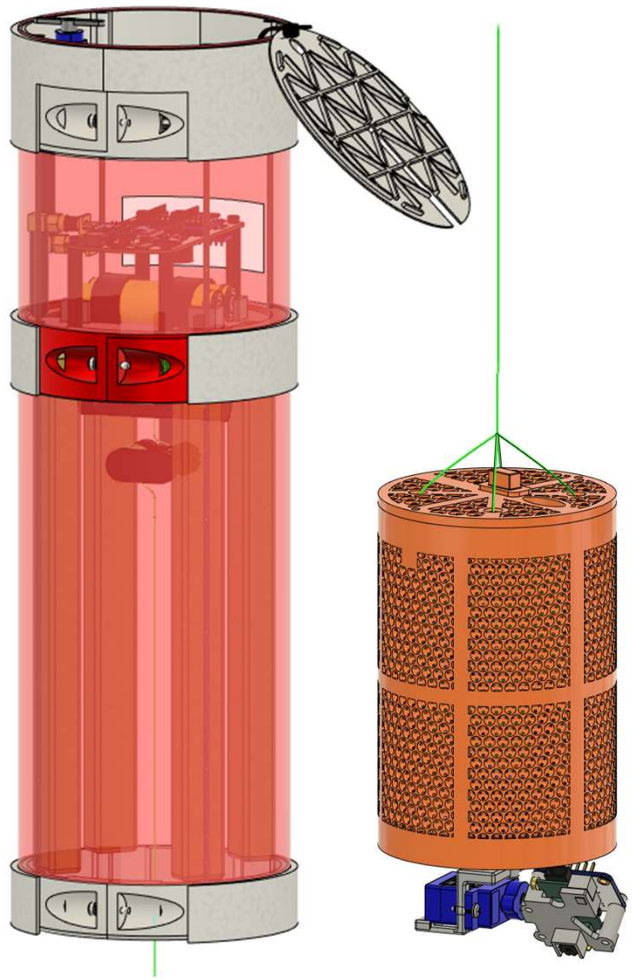


Mechanical Subsystem Overview (2/2)

Mechanical Configurations



Launch Configuration

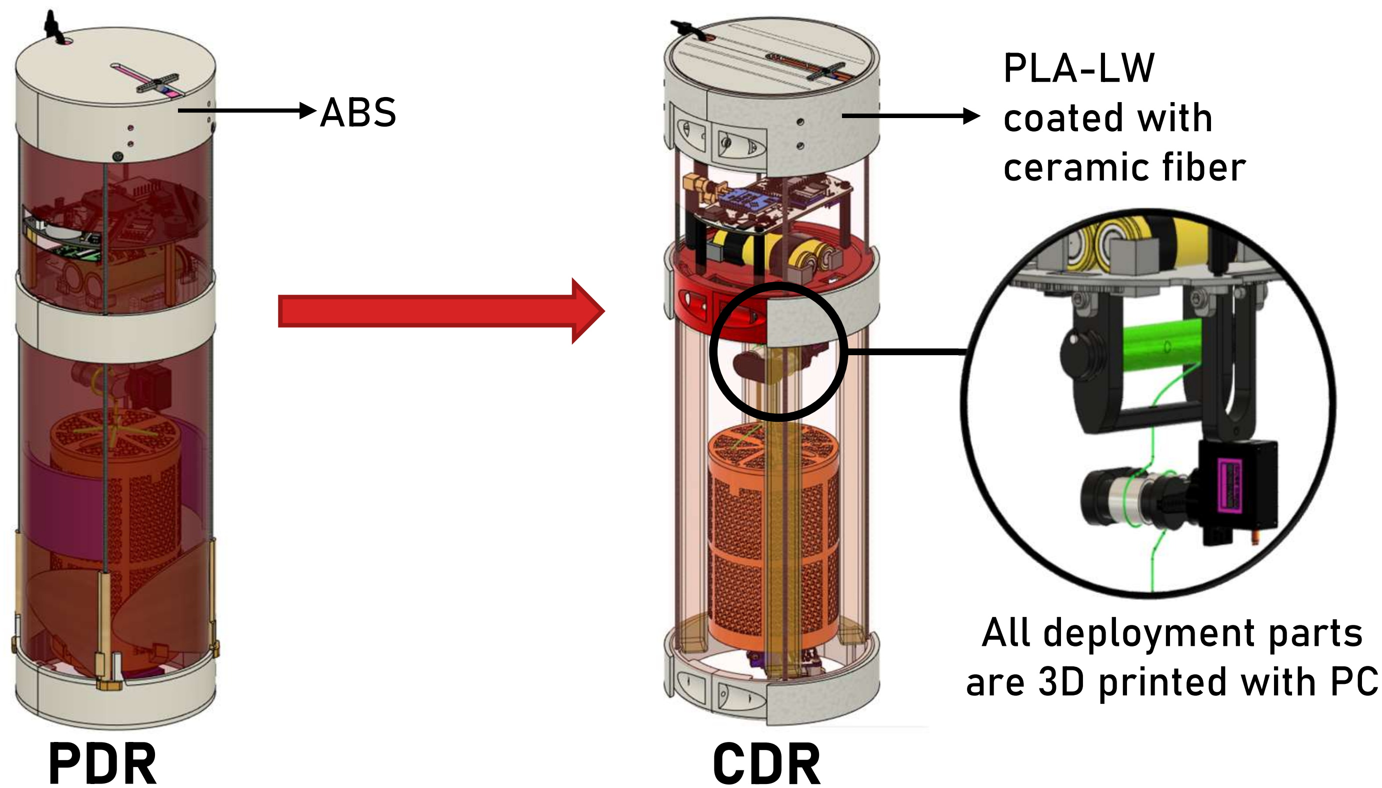


Deployed Configuration

Mechanical Subsystem Changes Since PDR (1/8)

Container Structural Material

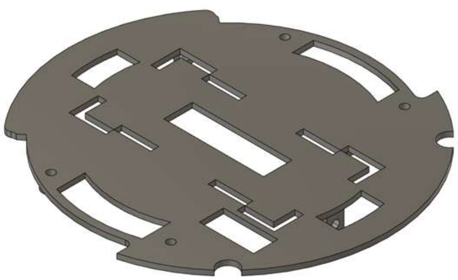
- The main structural material is switched from ABS to PLA-LW because the mass exceeded.
- Some of the components which carry large amount of loads are printed with PC and PETG to prevent deformation.
- The outerside of the ribs are coated with sheets of ceramic fiber for thermal insulation.



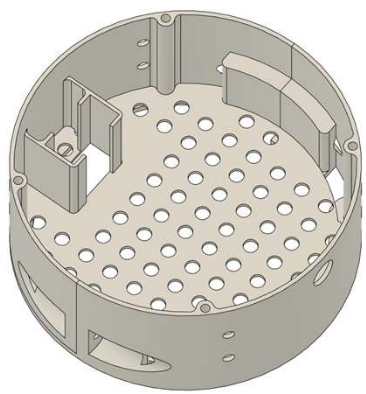
Mechanical Subsystem Changes Since PDR
(2 / 8)

Container Design

- The second parachute slot is enlarged.
- Most of the mechanical parts have been optimized to make them more lightweight and structurally efficient.
- Container PCB's shape is changed from Semi-circular to Capsule.

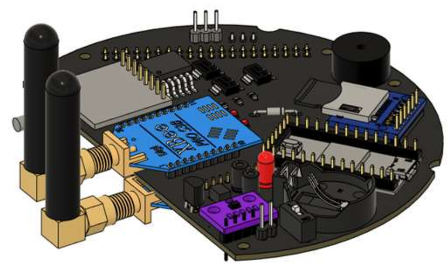


PCB mount

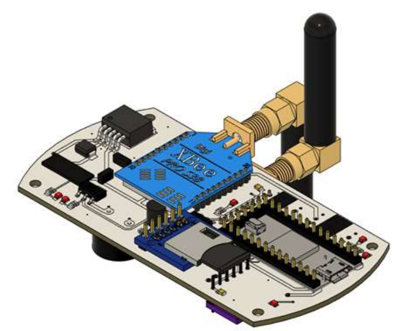


2nd Parachute Slot

Shape-Optimized Part



PDR

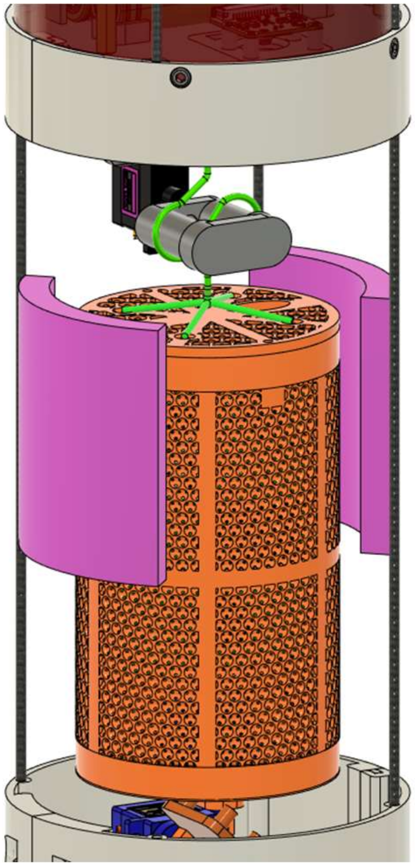


CDR

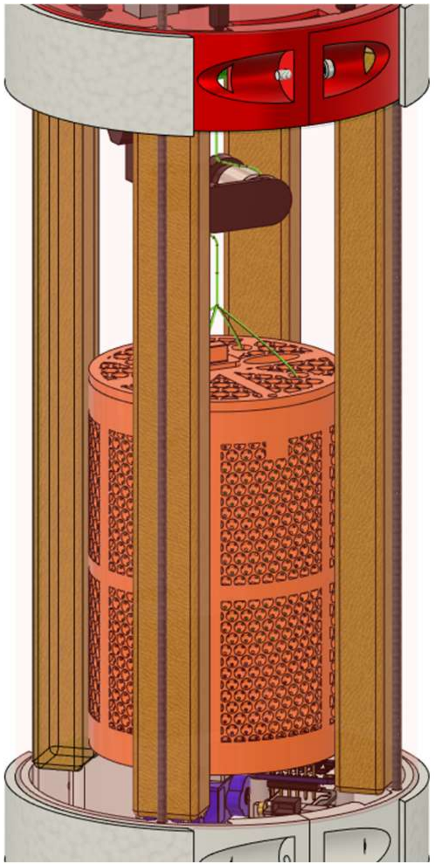
PCB

Container Payload Mount

- The supporting foam is attached to all of carbon fiber rods to keep the payload secured during launch.



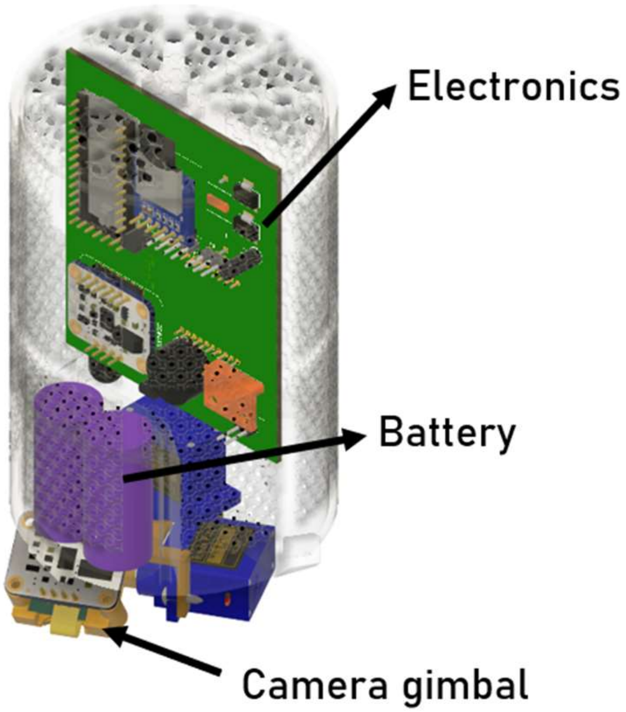
PDR



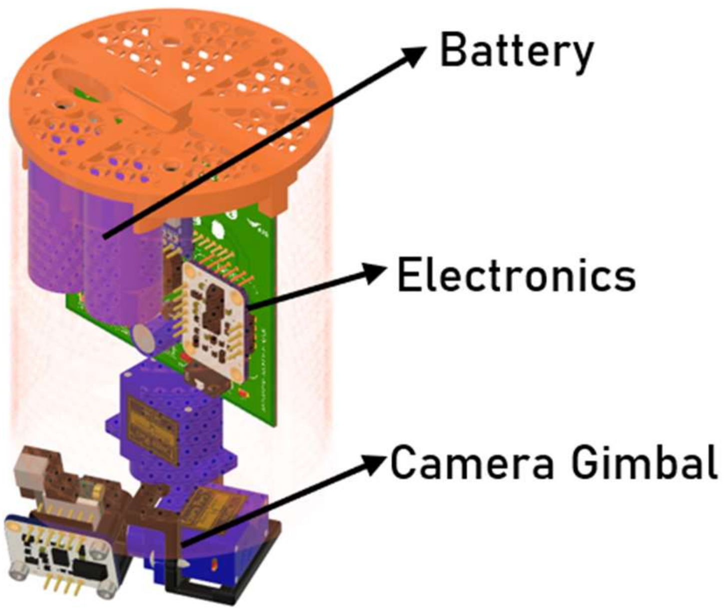
CDR

Payload Design

- The battery tray is moved to the top of the payload to allow easy removal.



PDR



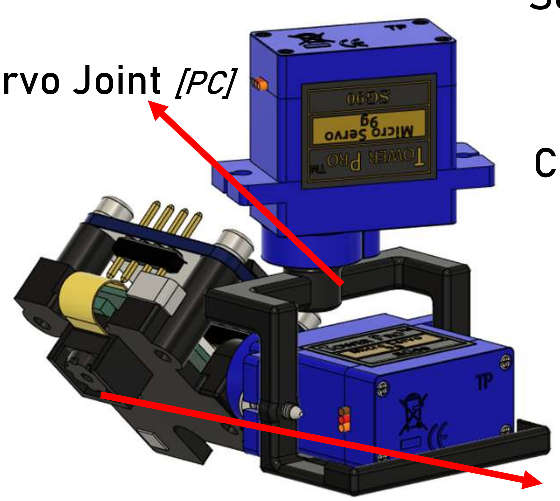
CDR

Mechanical Subsystem Changes Since PDR

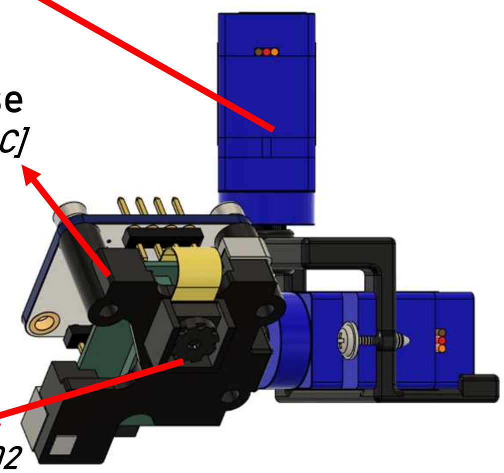
Camera Gimbal

- The drop test was conducted to verify the strength of the payload structure. The result was the camera gimbal printed with PETG was broken and fell out of the payload when it reached the ground.
- Therefore, the structural material is changed to PC for better impact resistance.

Broken Gimbal fell out of the payload



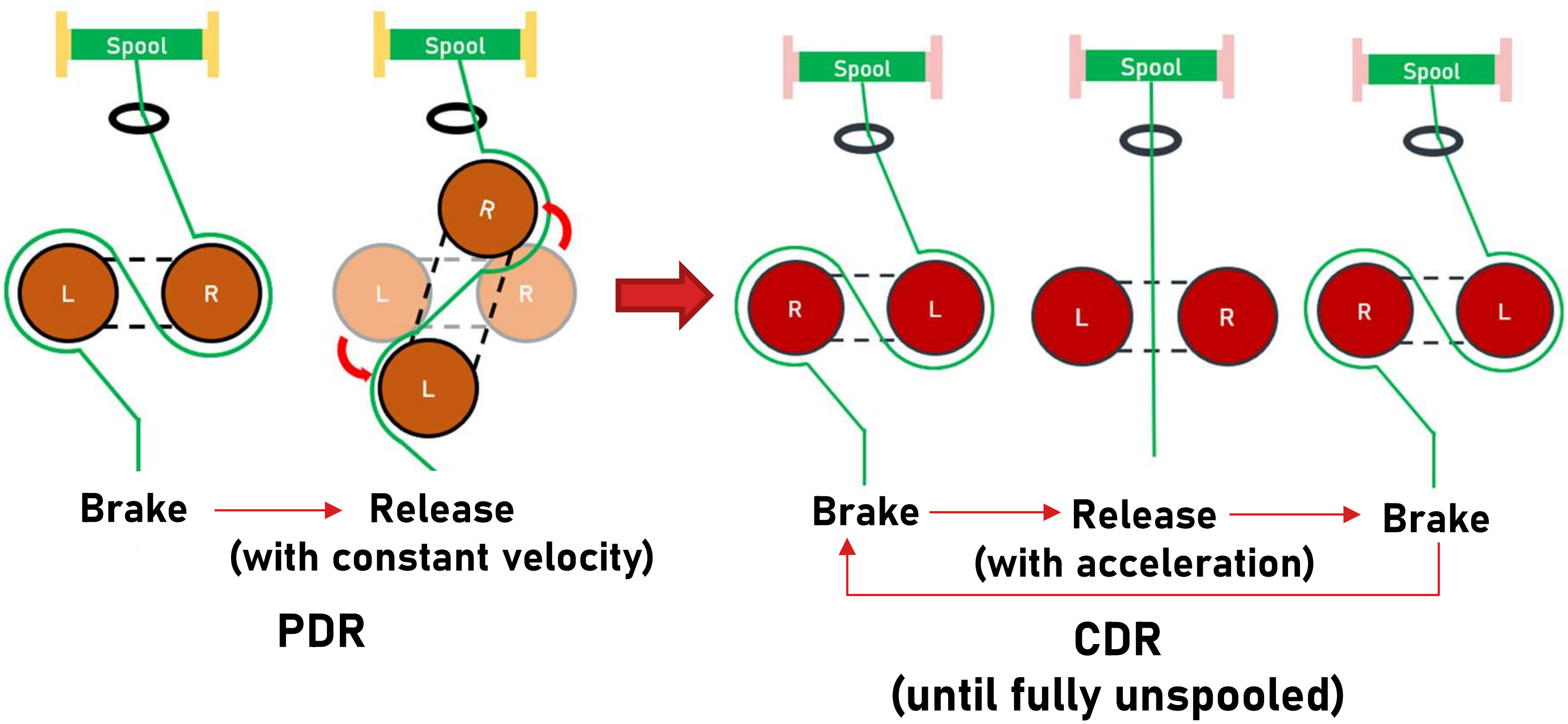
Front view



Side view

Tether Design (1/2)

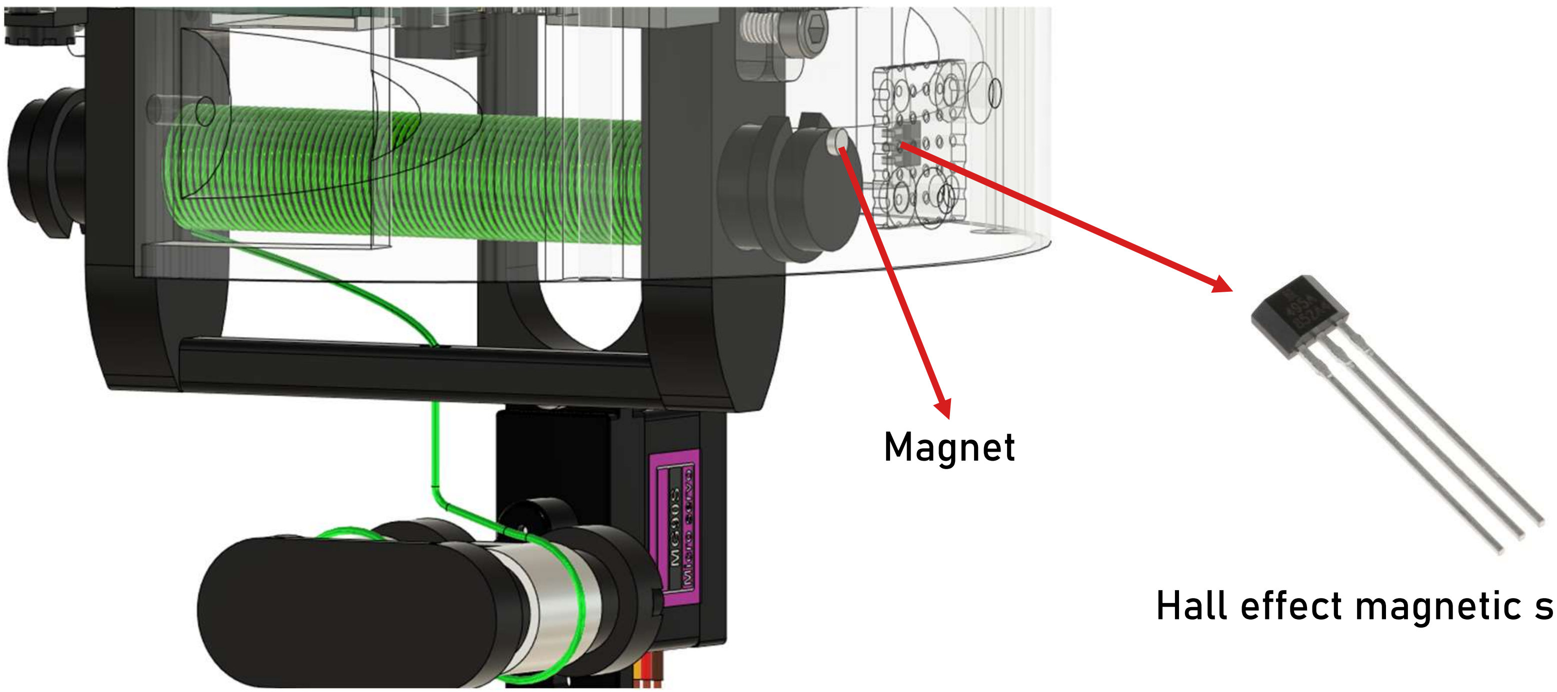
- To deploy the payload with constant velocity, the brake has to be very precise which cannot be done in real life. Hence, the brake is still split into two phases; *Release* and *Brake.* But these two phases will be repeated until the tether is fully unspooled.
- Acrylic foam tape is added to the brake to cause more friction.



Brake
[with acrylic tape]

Tether Design (2/2)

- Small magnet and Hall effect magnetic sensor are added to measure the deployed distance of payload (calculated from the number of revolutions of the spool)

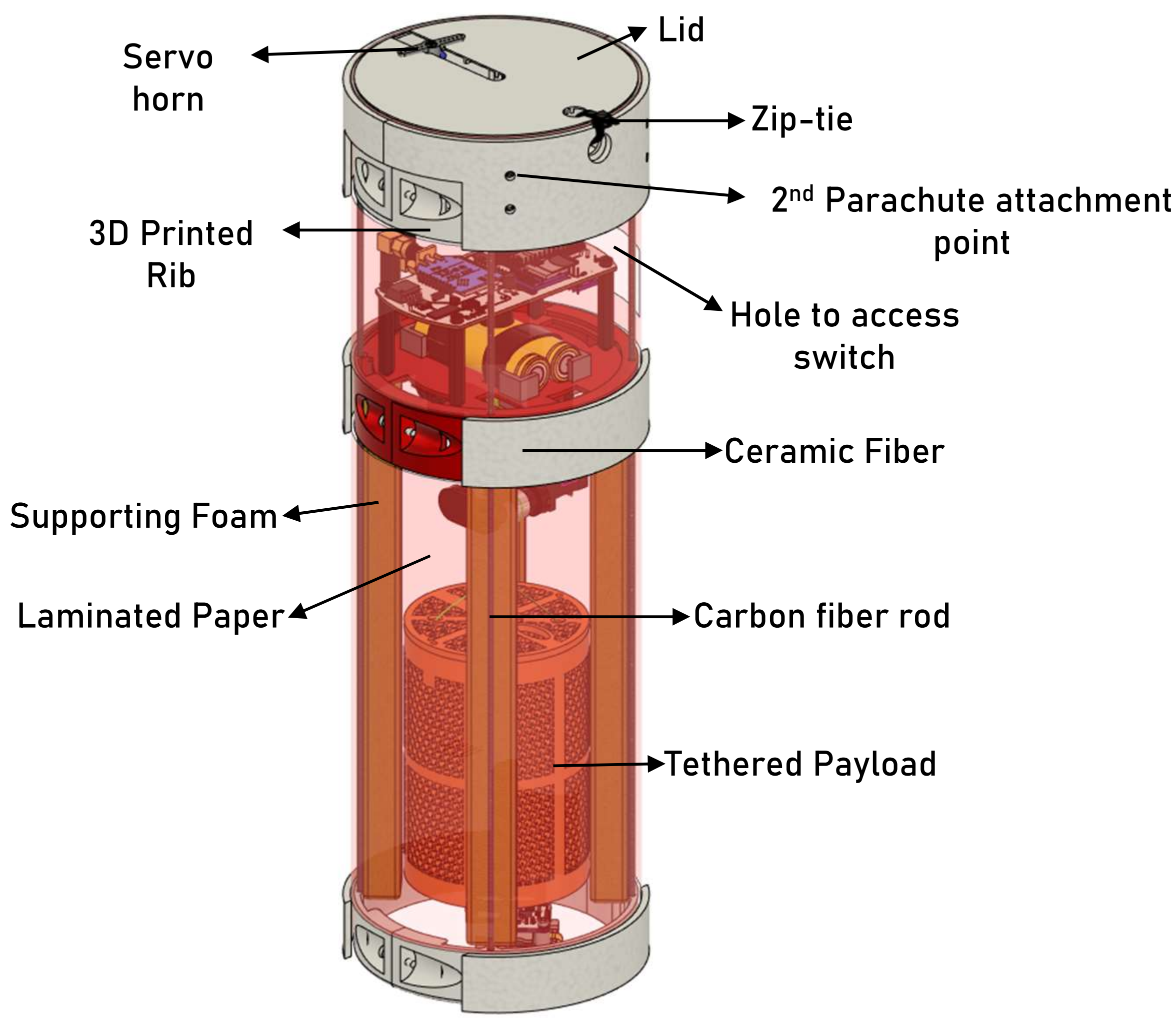


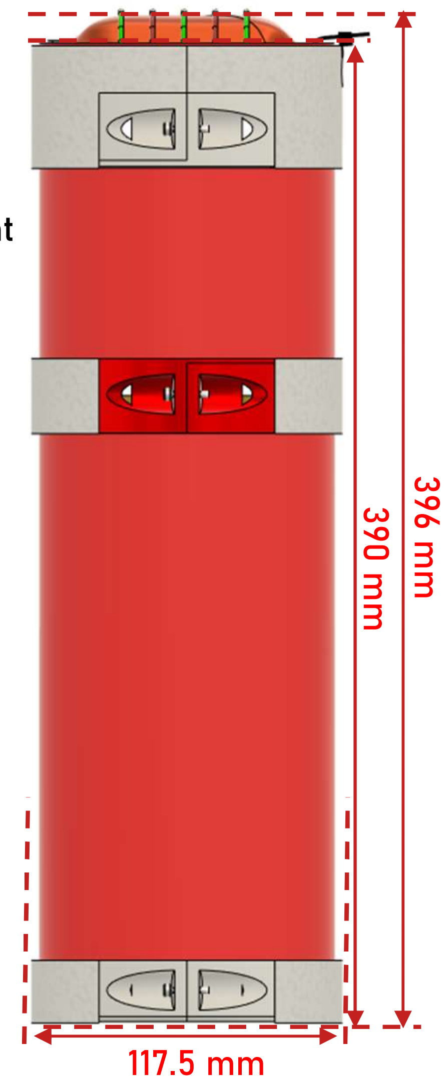
Mechanical Subsystem Changes Since PDR (8 / 8)

Changes Summary

Components	Changes	
	PDR	CDR
Container Structural Material	ABS	PLA-LW/PC
Container Coating	Laminated paper	Laminated paper + Ceramic Fiber
Container PCB	Semi-circular shape	Capsule shape
Container Payload mount	Two sides of the container	All of carbon fiber rods
Payload Battery Position	Placed at the bottom	Moved to the top
Camera Gimbal Structural Material	PETG	PC
Tether Design	Unspool with constant velocity	- Split the deployment into two repeated phases (variable velocity) - Revolutions counter is added. - Acrylic foam tape is added to the brake.

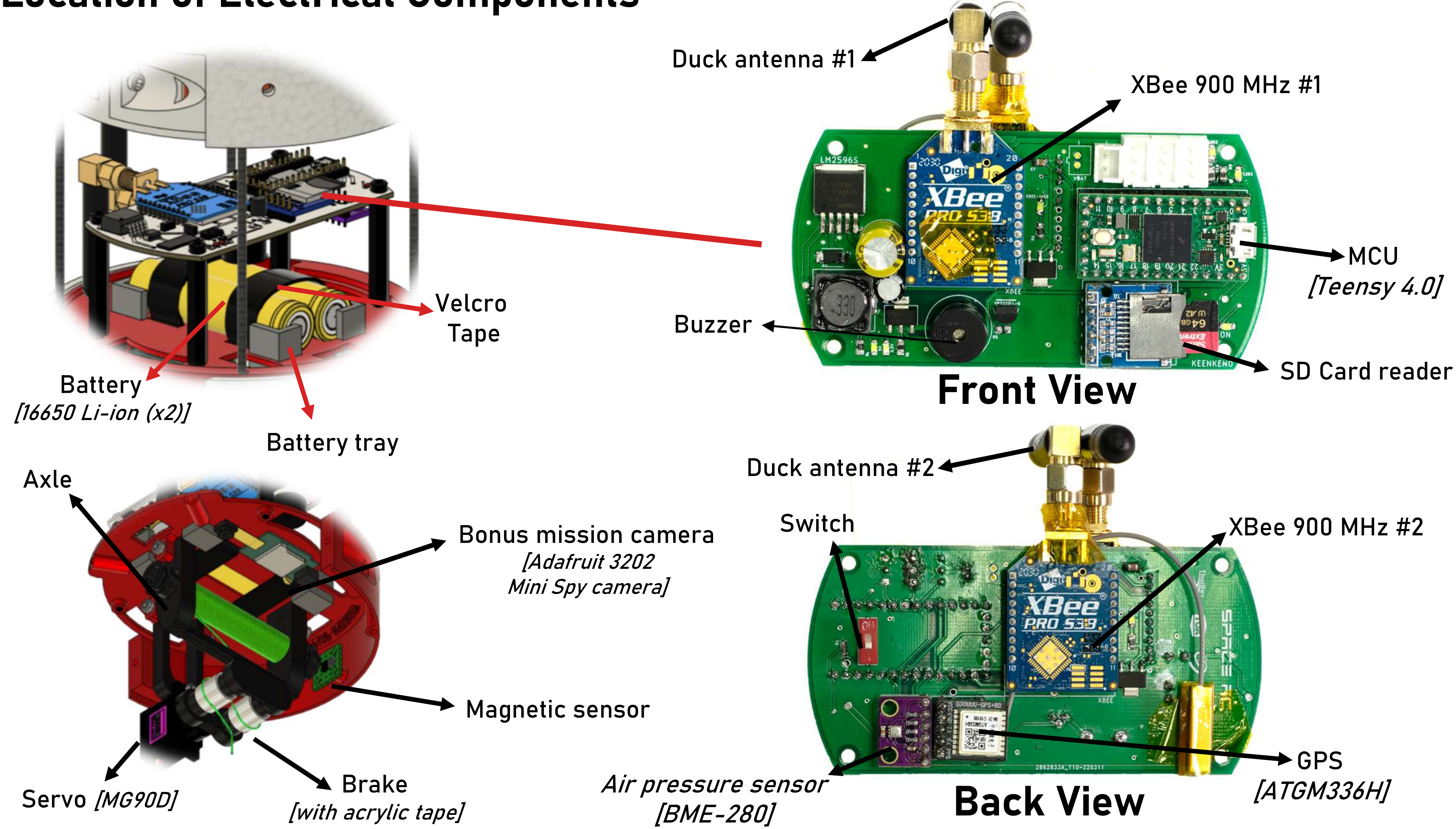
Container CAD model & Dimension





Container Mechanical Layout of Components (2 / 3)

Location of Electrical Components



Container Mechanical Layout of Components (3 / 3)

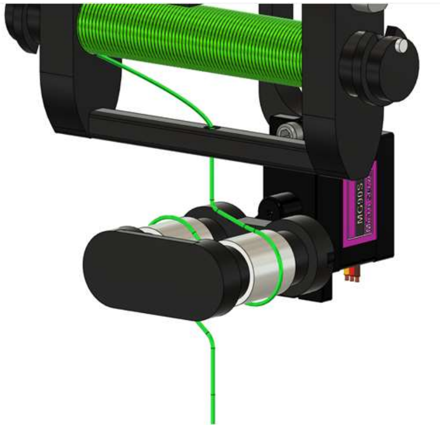
Structural Material Selection

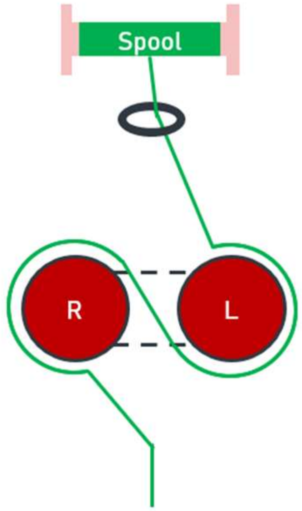
Components	Material		Rationale
	PDR	CDR	
Ribs	ABS	PLA-LW	Lighter
Lid	ABS	PETG	Provide better flexural strength which can prevent bending
Support column	Carbon Fiber		Lightweight and strong
Coating	Laminated paper	Laminated paper + Ceramic fiber	Ceramic fiber is added for better thermal insulation.
Bolts and Standoffs	Aluminum	Nylon	Lighter and electrical insulation.

Container Payload Mount

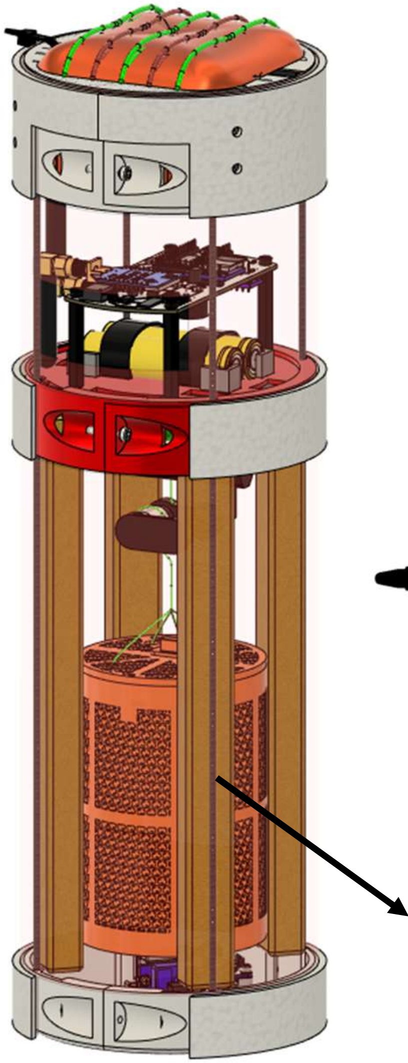
Brake Mechanism with Depron foam

- The tether is wrapped around the brake.
- Depron foam is provided to secure the payload.
- Payload is placed in position loosely.
- Depron foam keeps the payload from swaying during launch.

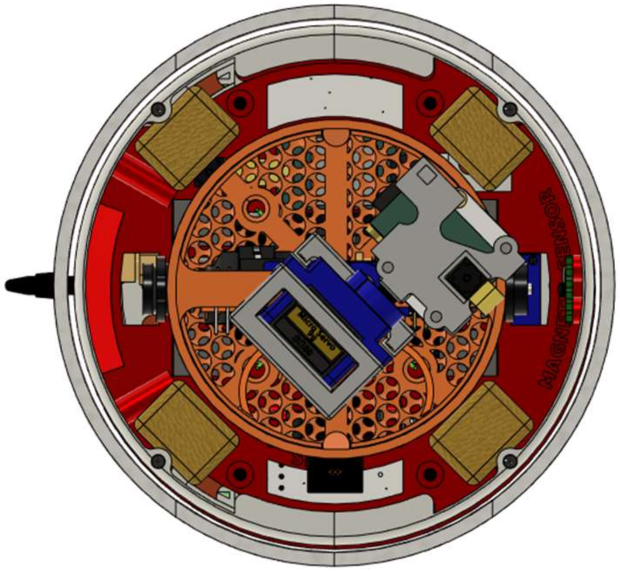




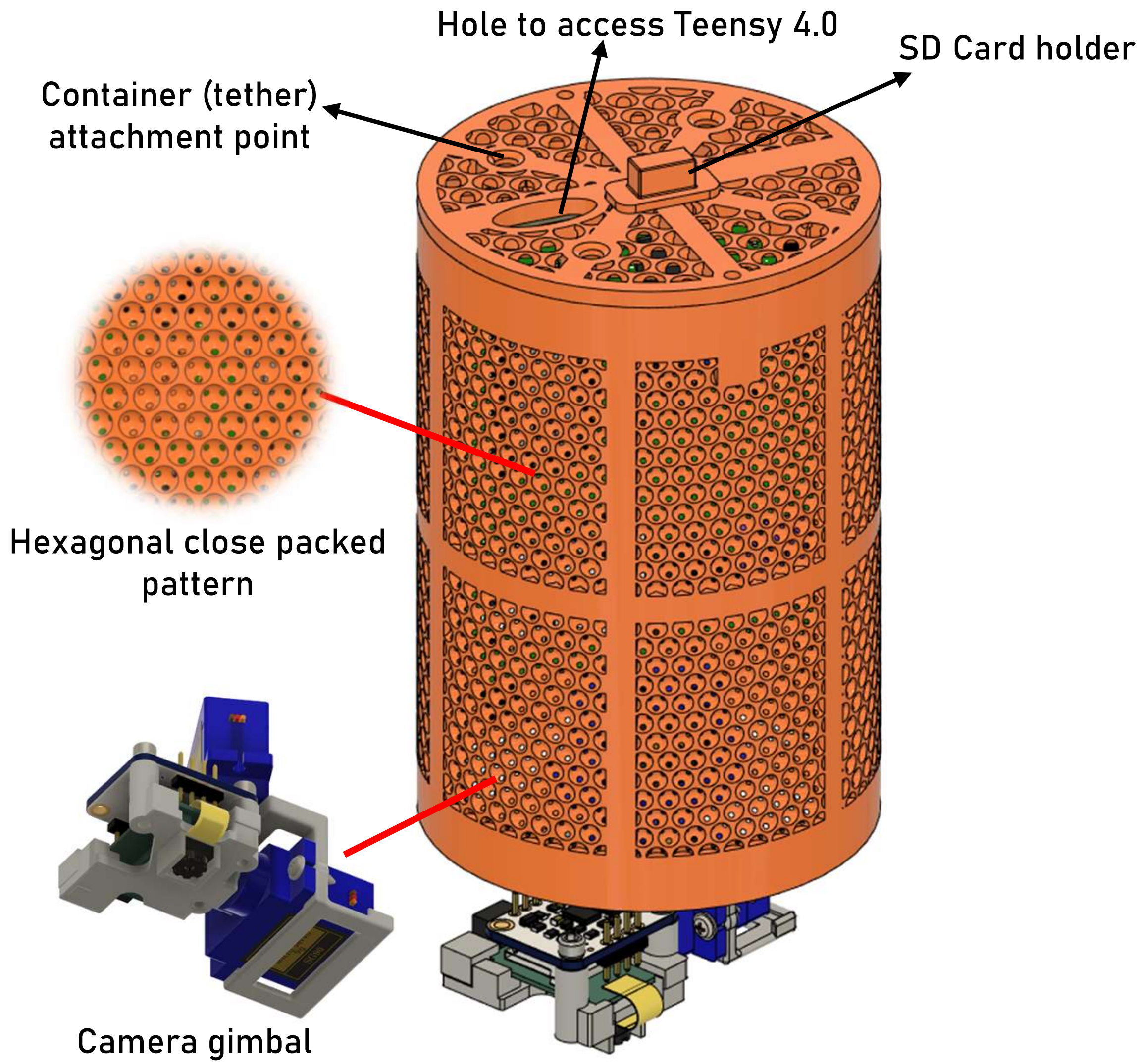
Brake prevents tether from unspooling

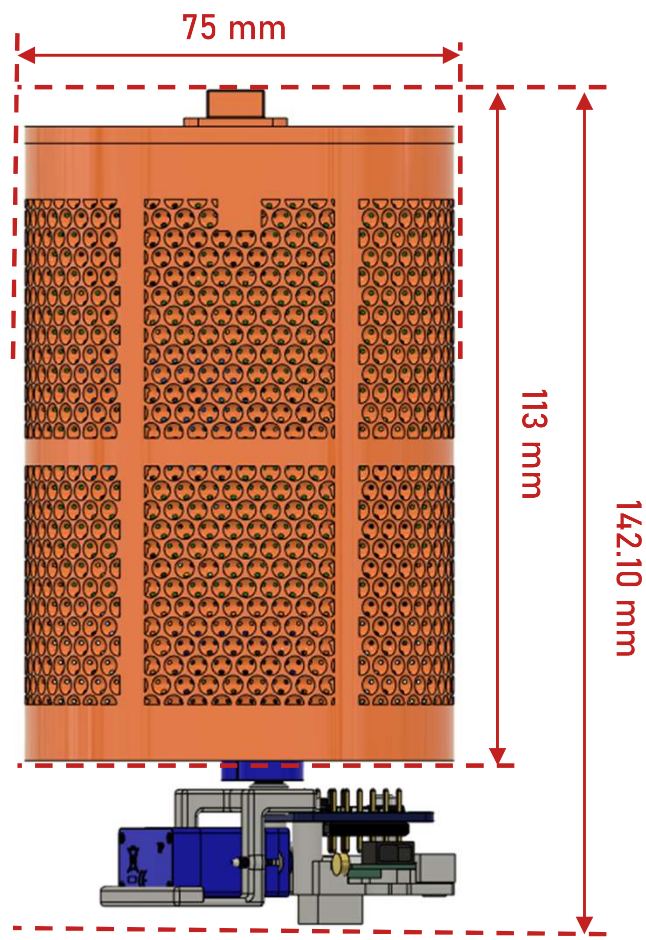


Bottom View



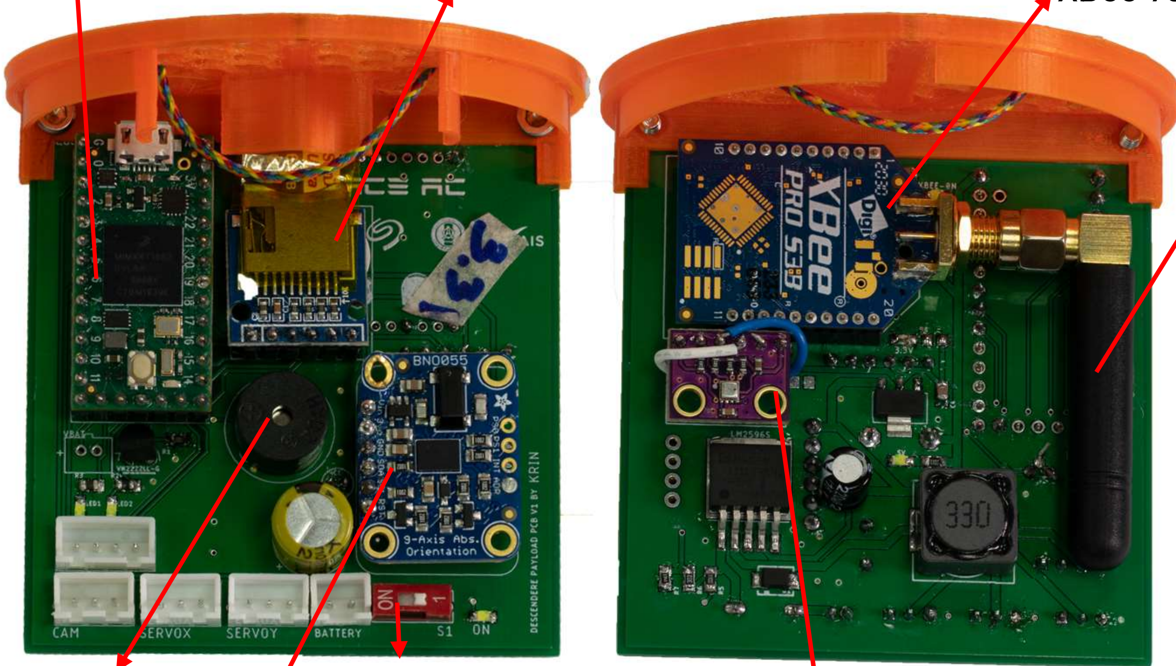
Payload CAD model & Dimension



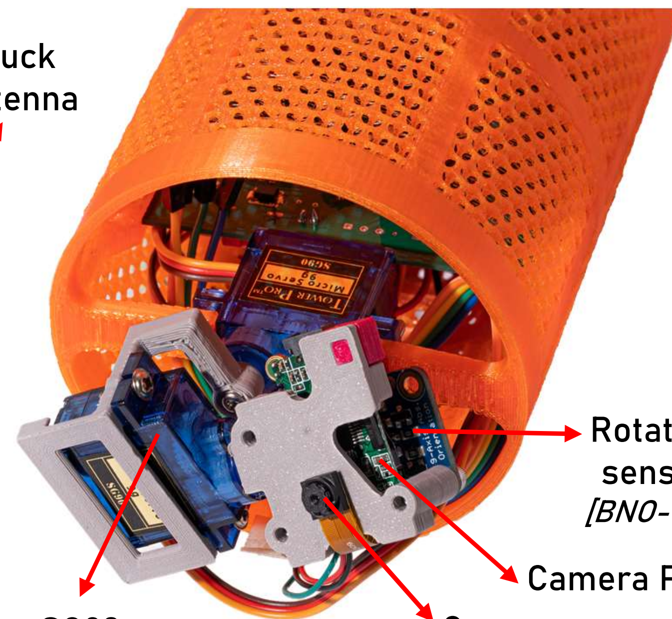


Payload Mechanical Layout of Components (2 / 4)

Location of electrical components



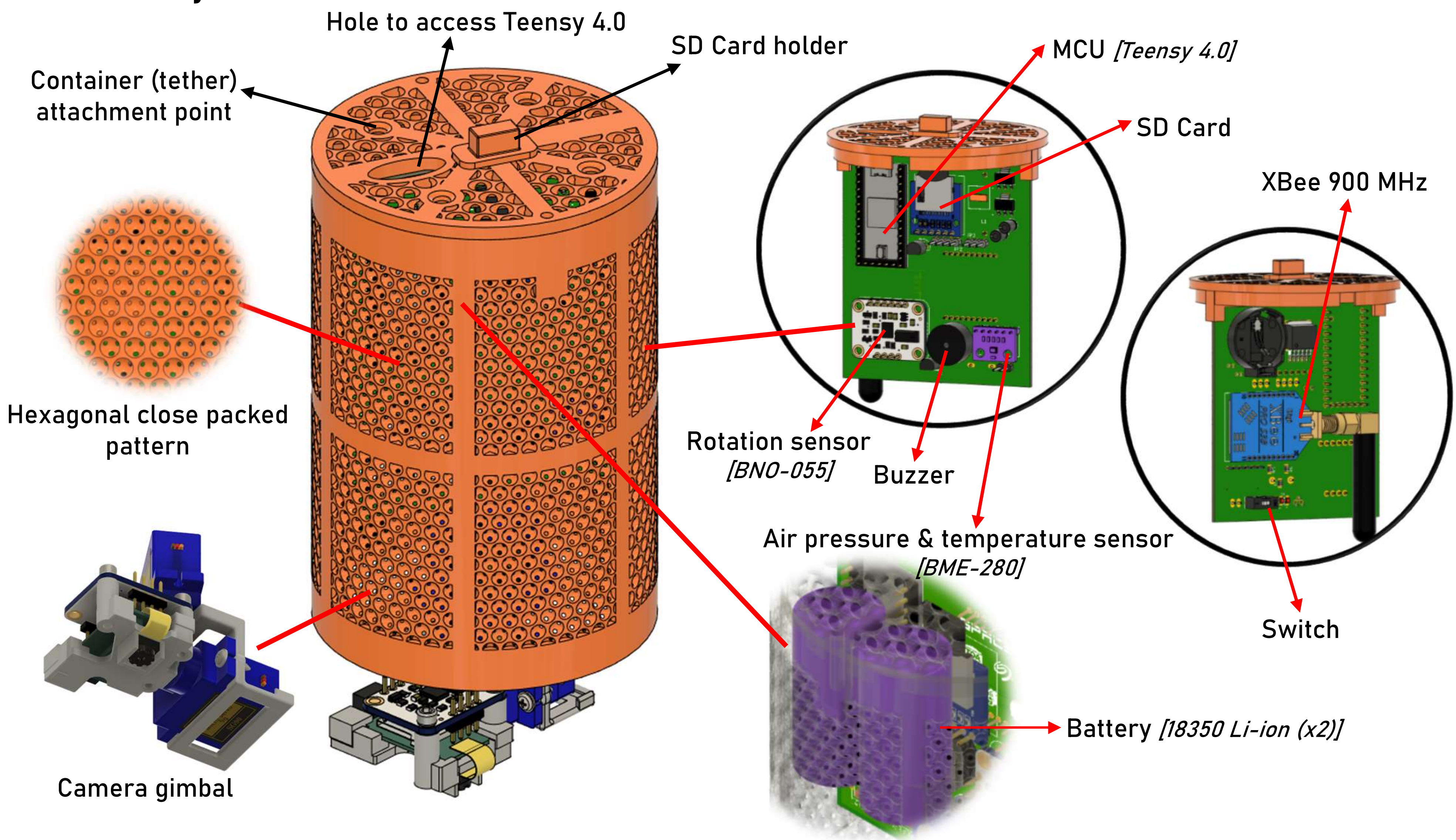
PCB bolted to the lid



Camera gimbal

Payload Mechanical Layout of Components (3 / 4)

Tethered Payload



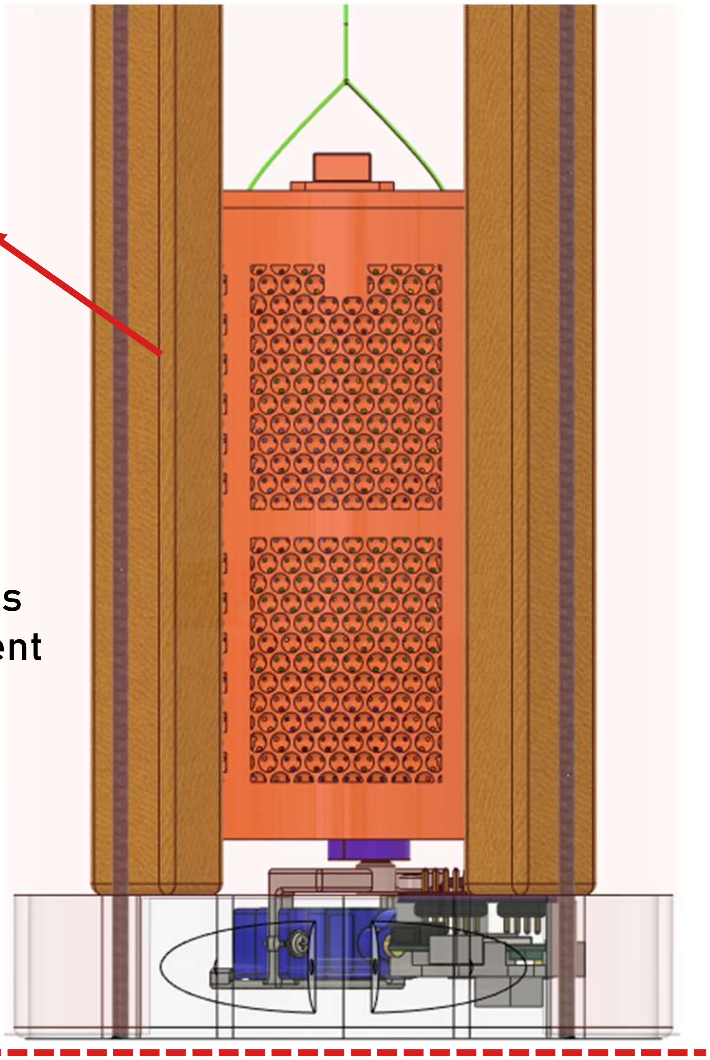
Payload Mechanical Layout of Components (4 / 4)

Material Selection

<table>
<tr><th rowspan="2">Components</th><th colspan="2">Material</th><th rowspan="2">Rationale</th></tr>
<tr><th>PDR</th><th>CDR</th></tr>
<tr><td>Payload Body</td><td colspan="2">PETG</td><td rowspan="2">Easy to print and provide enough strength</td></tr>
<tr><td>Payload Lid</td><td colspan="2">PETG</td></tr>
<tr><td>Gimbal structure</td><td>PETG</td><td>PC</td><td>Provide better impact resistance than PETG since it is the first part reaching the ground</td></tr>
</table>

Payload Pre Deployment Configuration

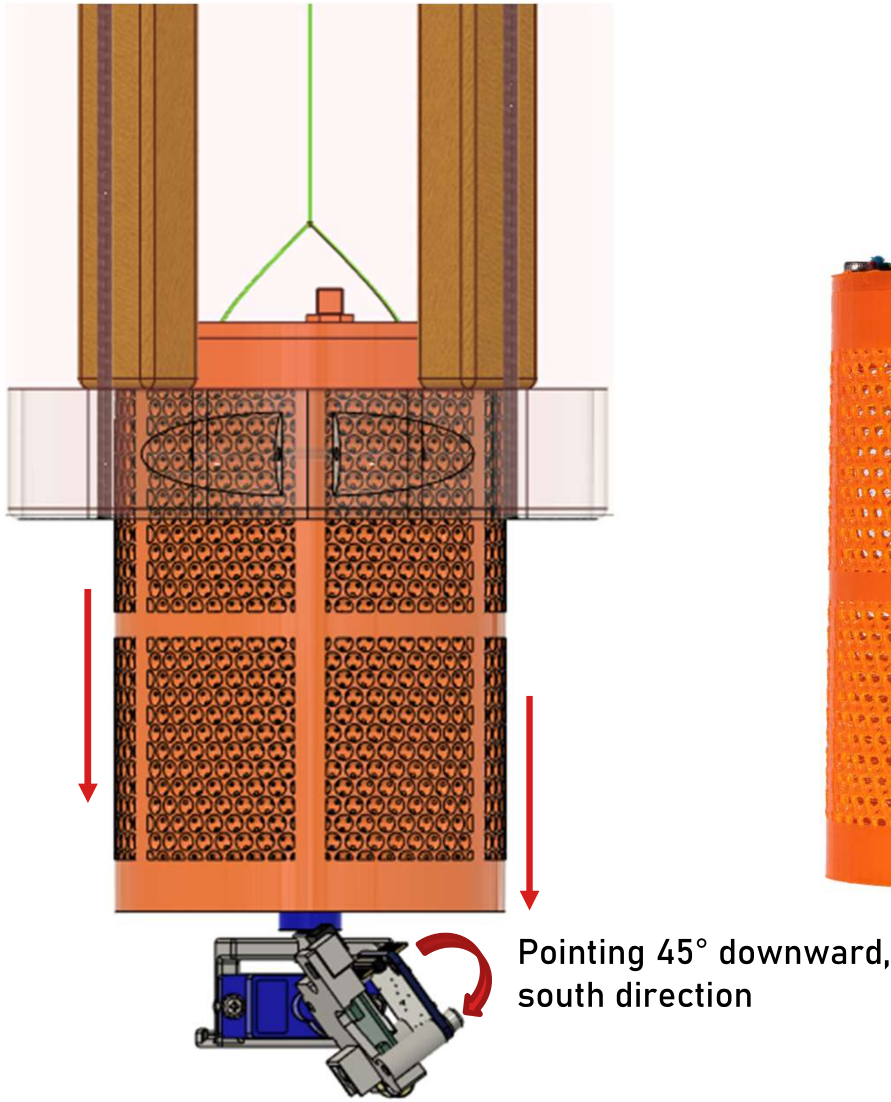
Supporting foam protects the payload during launch

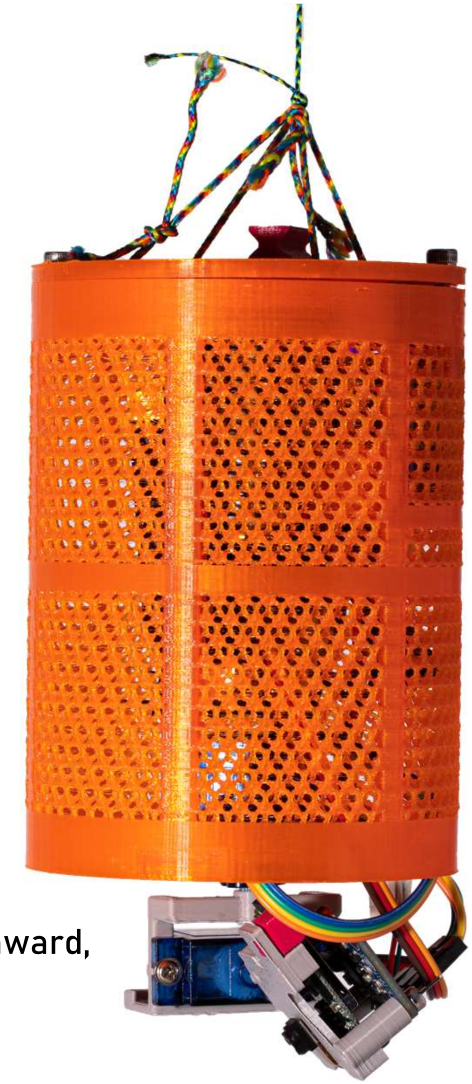


Camera gimbal is **inactive** to prevent protrusion from the container

The camera gimbal is parallel to the ground for the ease of CanSat loading

Payload Deployment Configuration





The camera gimbal is activated.

Tether Design Description
(1 / 4)

Tether	Material	Diameter	Tensile Strength	Mass per 10 m	Cost ($)
Nano cord	**Nylon/Polyester**	**0.75 mm**	**17 kg**	**4.1 g**	**$9.52**

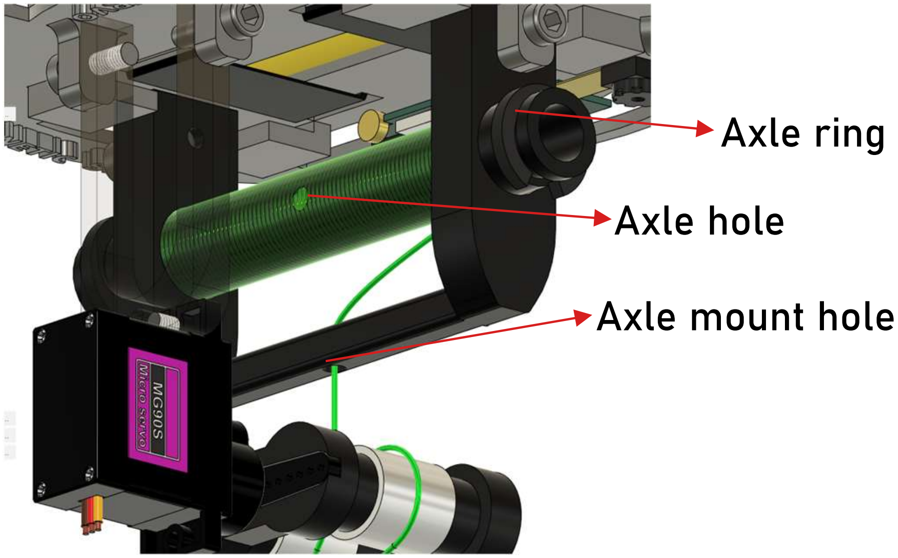
Rationales

- Space-saving when spooled
- Lightweight
- Provide enough strength to resist shock of the payload

Tether Design Description
(2 / 4)

Tether management

- The tether is carefully spooled into the 3D printed axle by a drill to prevent the tangling of the tether.
- The beginning part of the tether will be knotted and put in the axle hole. The axle rings are made to prevent the tether from slipping out when unspooled.
- After the tether is fully spooled, the axle will be insert into the axle mount.
- The axle mount hole is made to control the direction of the tether. It also has a small magnet attached at the end of it to measure the distance of the payload.



Tether Design Description

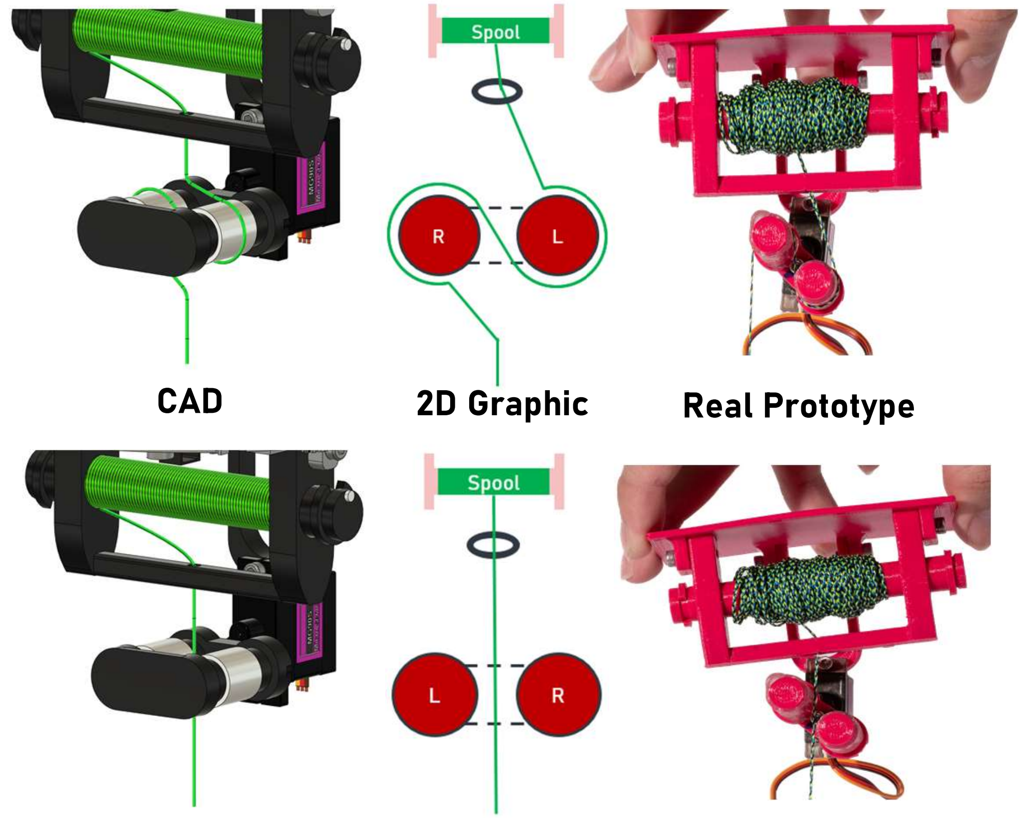
Spooling rate control – Brake Mechanism

- The brake is now split into two phases *Release* and *Brake*

Release – Once the payload transitions from a stowed configuration to deployed configuration, the brake will tilt and fully let go of the tether, causing the payload to free fall for 2 meters.

.

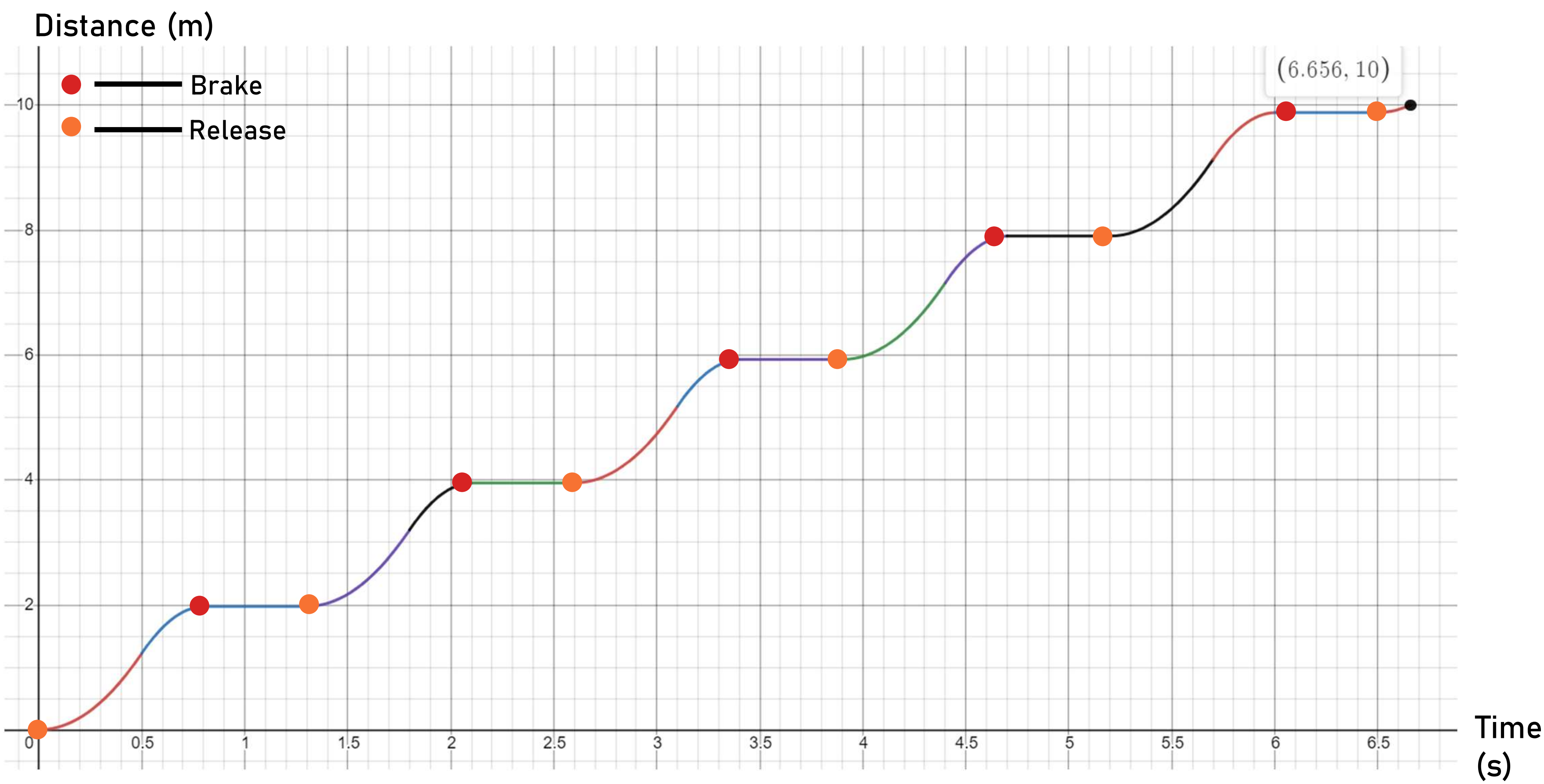
Brake – The brake will tilt back to restrict the tether and gently stall the payload into the stationary position.



These two steps will be repeated until the payload is fully deployed.

Tether Design Description
(4 / 4)

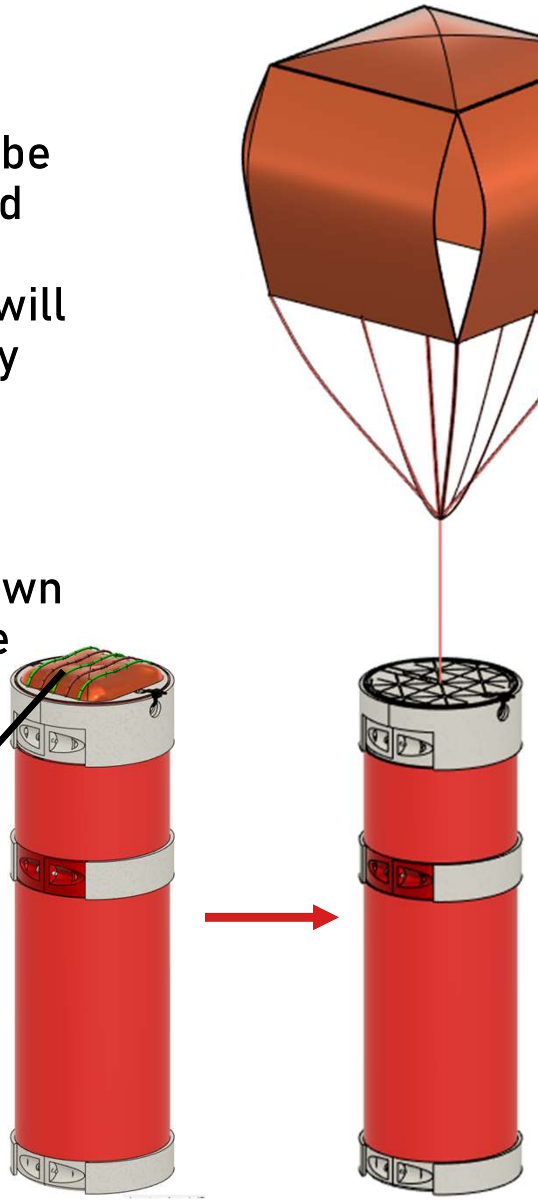
Distance-time graph of payload



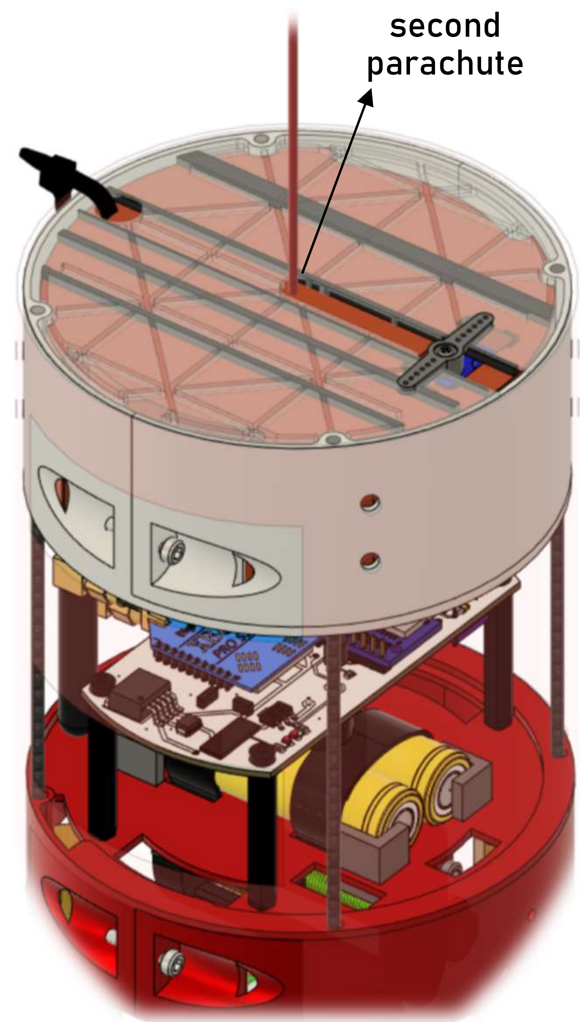
Container Parachute Attachment Mechanism (1/3)

First Parachute

- The first parachute will be folded and simply placed on top of the container without any cover so it will be released immediately after the CanSat is deployed.
- The first parachute suspension lines are sewn to the second parachute through the hole on the upper lid.

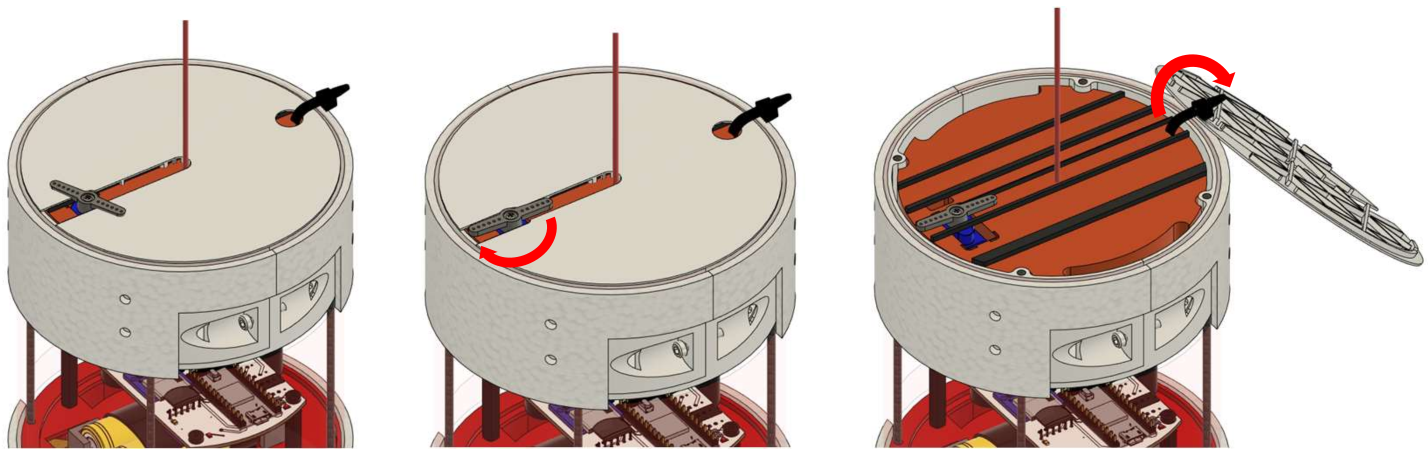


Stowed 1st parachute

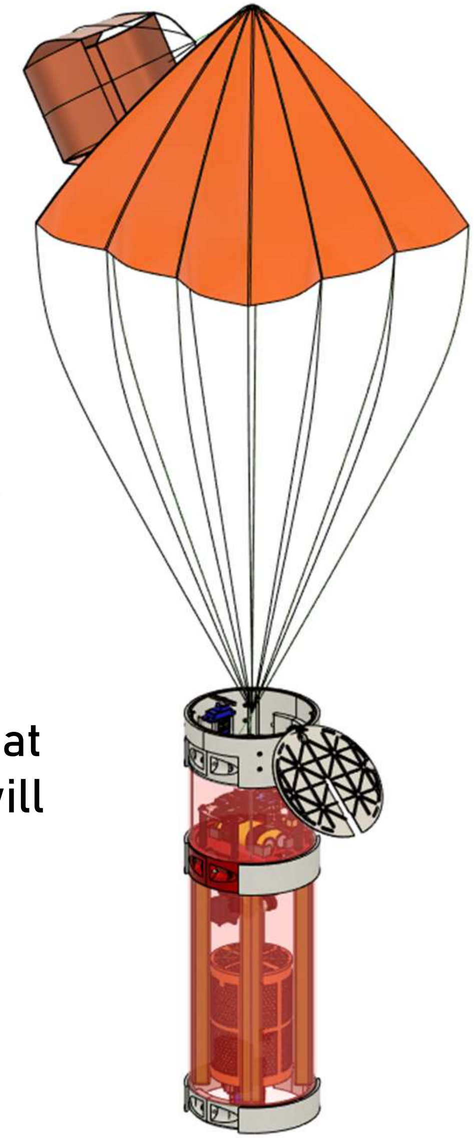


Container Parachute Attachment Mechanism (2 / 3)

Second Parachute

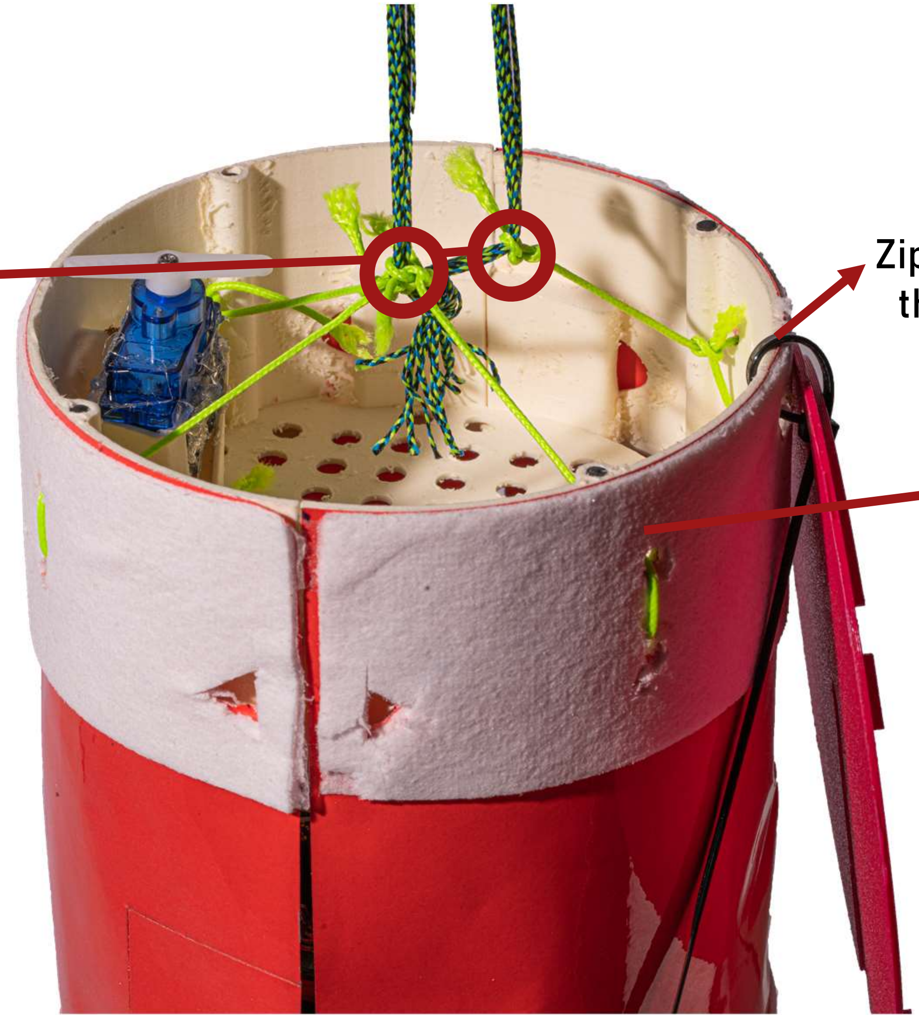


- The first parachute is sewn to the second parachute
- The second parachute is placed between the lids of the container and is attached to the container by nylon ropes.
- The upper lid is jointed with the container via zip-tie.
- The servo will be triggered at 400 meters, the upper lid will be lifted by the folded parachute itself.
- The second parachute is deployed.



Deployed Configuration

Second Parachute attachment point



2nd Parachute cords

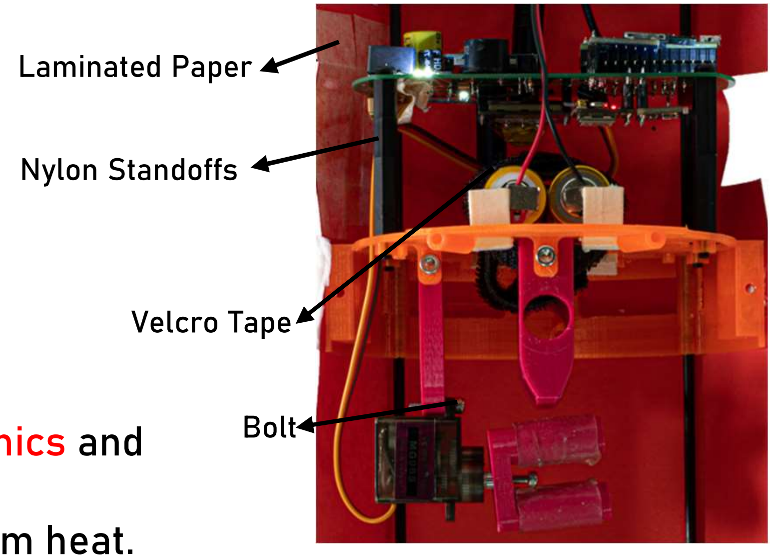
Zip-tie holds the lid and the container together

Container attachment point

Structure Survivability (1/2)

Electronics Mounting

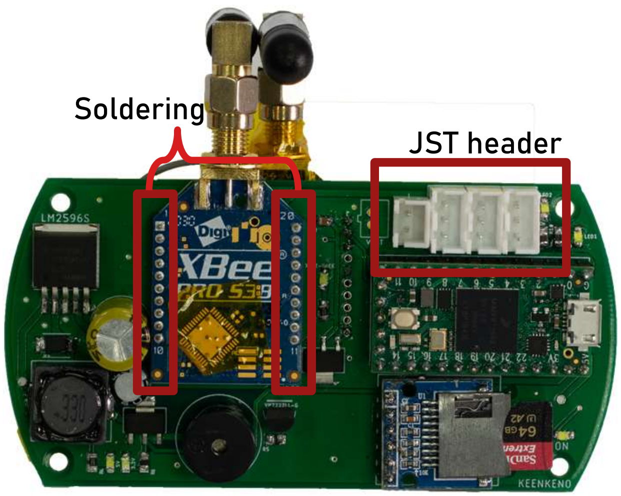
- The PCBs are mounted to the 3D printed structure by nylon standoffs and bolts.
- The container's batteries are placed in the tray and strapped with Velcro tapes.
- The payload's batteries are also placed in the tray but enclosed with bolted lids.
- The camera modules are bolted to the 3D printed structures.



Middle part of container

Electronics Enclosures

- Laminated paper provides full enclosure to container electronics and payload.
- Sheets of ceramic fiber will protect the inner components from heat.



Container PCB

Securing electrical connections

- All connectors of electronic components will be soldered to the PCB.
- The batteries are connected to the PCB through the JST header allow easy swap.

Descent Control Attachments

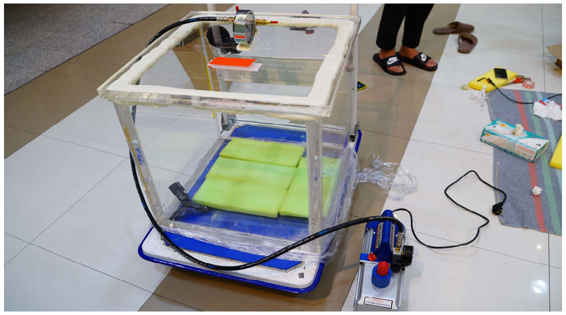
- The parachute cords will be firmly tied at the container.
- The second parachute will be deployed by servo which is glued and bolted to the housing in the slot.
- All the payload deployment system are bolted to the 3D printed structure.

Acceleration, shock force requirements and testing

- All structures shall be built to survive 15 Gs of launch acceleration and 30 Gs of shock.
- The mounting of the electronics and sensors will be reviewed and scored in FRR.
- The CanSat will be subjected to the environmental test which includes drop test, vibration test, thermal test, and vacuum test.

Drop test

- To verify that the container parachute and attachment point will survive the deployment (about 30 Gs of shock)



Vacuum test

- To verify deployment operation of payload

Thermal test

- To verify the CanSat can operate in hot temperature (up to 35°C)

Vibration test

- To verify the mounting integrity of all components

The test will be conducted as the same procedures as the last year competition.

Mass Budget
(1 / 5)

Container Mass Budget (Electronic Subsystem)

Components		Mass (g)	Error (g)	Reference
Electronics Components	Vapcell 16650 M20 (x2)	74.00	±0.00	Measurement
	SG90 Servo	13.00	±0.00	Measurement
	MG90D Servo	15.00	±0.00	Measurement
	Teensy 4.0	7.00	±0.00	Measurement
	BME-280	1.00	±0.00	Measurement
	ATGM-336H	4.40	±0.00	Measurement
	Adafruit 3202	2.80	±1.00	Measurement
	Cr2032 + Cell holder	4.50	±0.00	Measurement
	LM2596S	1.60	±0.00	Measurement
	ams1117-3.3 (x3)	0.6	±0.00	Measurement
	Buzzer	1.60	±2.00	Measurement
	Inductor	4.30	±0.00	Measurement
	DIP Switch	0.20	±0.00	Measurement
	Capacitor (680uF + 220uF)	1.40	±0.00	Measurement
	XBee + Antenna 900 MHz (x2)	26.00	±0.00	Measurement
	Micro SD card reader + SD card	2.50	±0.00	Measurement
	PCB	5.00	±5.00	Approximation
	Solder	10.00	±3.00	Approximation

TOTAL
174.90±11.00
grams

Mass Budget
(2 / 5)

Container Mass Budget (Mechanical Subsystem)

Components			Mass (g)	Error (g)	Reference
Structure	3D Printed	3D printed rib (x3)	56.30	±5.00	Software Estimation
		Deployment System	13.12		
	Tether (10 m)		8.88	±2.00	Datasheet
	Supporting foam		8.00	±1.00	Measurement
	Ceramic Fiber		8.10	±1.00	Measurement
	M3 Nylon bolt (x2)		8.00	±1.00	Measurement
	Adhesives		5.00	±1.00	Approximation
	Standoffs (x6)		3.00	±1.00	Measurement
	Laminated Paper		23.40	±1.00	Measurement
	Carbon fiber rod (x6)		17.50	±1.00	Measurement
	Parachute		73.00	±1.00	Measurement

TOTAL
224.30±15.00
grams

TOTAL
CONTAINER
MASS
399.20±15.00
grams

Payload Mass Budget (Electronic Subsystem)

Components		Mass (g)	Error (g)	Reference
Electronics Components	Vapcell 18350 F14 (x2)	52.00	±1.00	Datasheet
	SG90 Servo (x2)	26.00	±0.00	Measurement
	Teensy 4.0	7.00	±0.00	Measurement
	Adafruit 3202	2.80	±1.00	Measurement
	BNO-055 (x2)	5.00	±0.00	Measurement
	Micro SD card reader + SD card	2.50	±0.00	Measurement
	BME-280	1.00	±0.00	Measurement
	XBee + Antenna 900 MHz	13.00	±0.00	Measurement
	Buzzer	1.60	±2.00	Measurement
	Inductor	4.30	±0.00	Measurement
	DIP Switch	0.20	±0.00	Measurement
	LM2596S	1.60	±0.00	Measurement
	ams1117-3.3 (x2)	0.4	±0.00	Measurement
	Capacitor (680uF + 220uF)	1.40	±0.00	Measurement
	Cr2032 + Cell holder	4.50	±0.00	Measurement
	PCB		±0.00	Approximation
	Solder	10.00	±3.00	Approximation

TOTAL
133.30±7.00
grams

Mass Budget
(4 / 5)

Payload Mass Budget

Components			Mass (g)	Error (g)	Reference
Structure	3D Printed	Body	49.75	±5.00	Software Estimation
		Lid	12.07		
		Battery tray	1.6		
		Servo joint	1.06		
		Gimbal Structure	2.67		
	M3 nuts (x6)		3	±1.00	Measurement

TOTAL
70.15±6.00
grams

TOTAL
PAYLOAD
MASS
200.95±13.00
grams

Total mass of the CanSat

Component	Mass
Total Container mass	399.20±15.00 grams
Total Payload mass	200.95 ±13.00 grams
Total CanSat mass	600.15 ± 28.00 grams

Total Mass Margin = |600.00 – 600.15 |= 0.15 g

Methods of correction to meet mass requirement (in case the mass exceeds)

- The wall thickness and infill will be reduced.
- Consider using alternative materials and manufacturing methods.
- All parts will be shape optimized.

Communication and Data Handling (CDH) Subsystem Design

Krin Kaweewongsonthorn,
Krissada Singhakachain

CDH Overview
(1 / 3)

Container

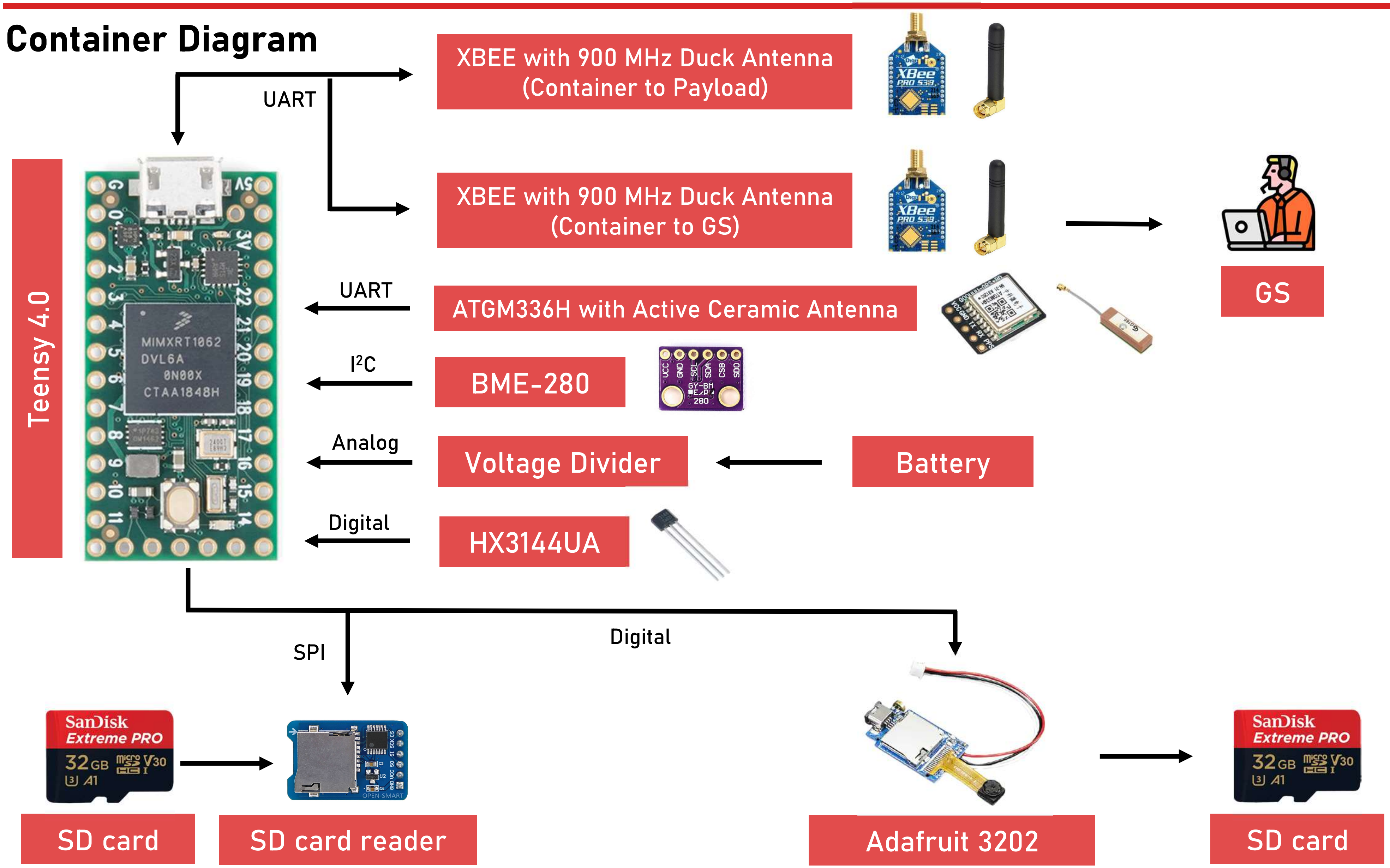
MCU - Teensy 4.0	• Control all other components
XBee radio – XBee Pro 900MHz	• For communication between the container, the ground station and the payload
Antenna – 900MHz Duck Antenna	• An external antenna is applied to increase the gain of the XBee radio
Data storage – Sandisk Extreme PRO	• Store telemetry data
Sensors	• GPS, Air pressure sensor, voltage divider and Revolution Counter Sensor
Others	• Camera has an internal SD card module. • Buzzer 92 dB loud audio beacon • Teensy's real-time clock power is supplied by a CR2032 cell (to maintain track of time even when the switch is off).

Payload

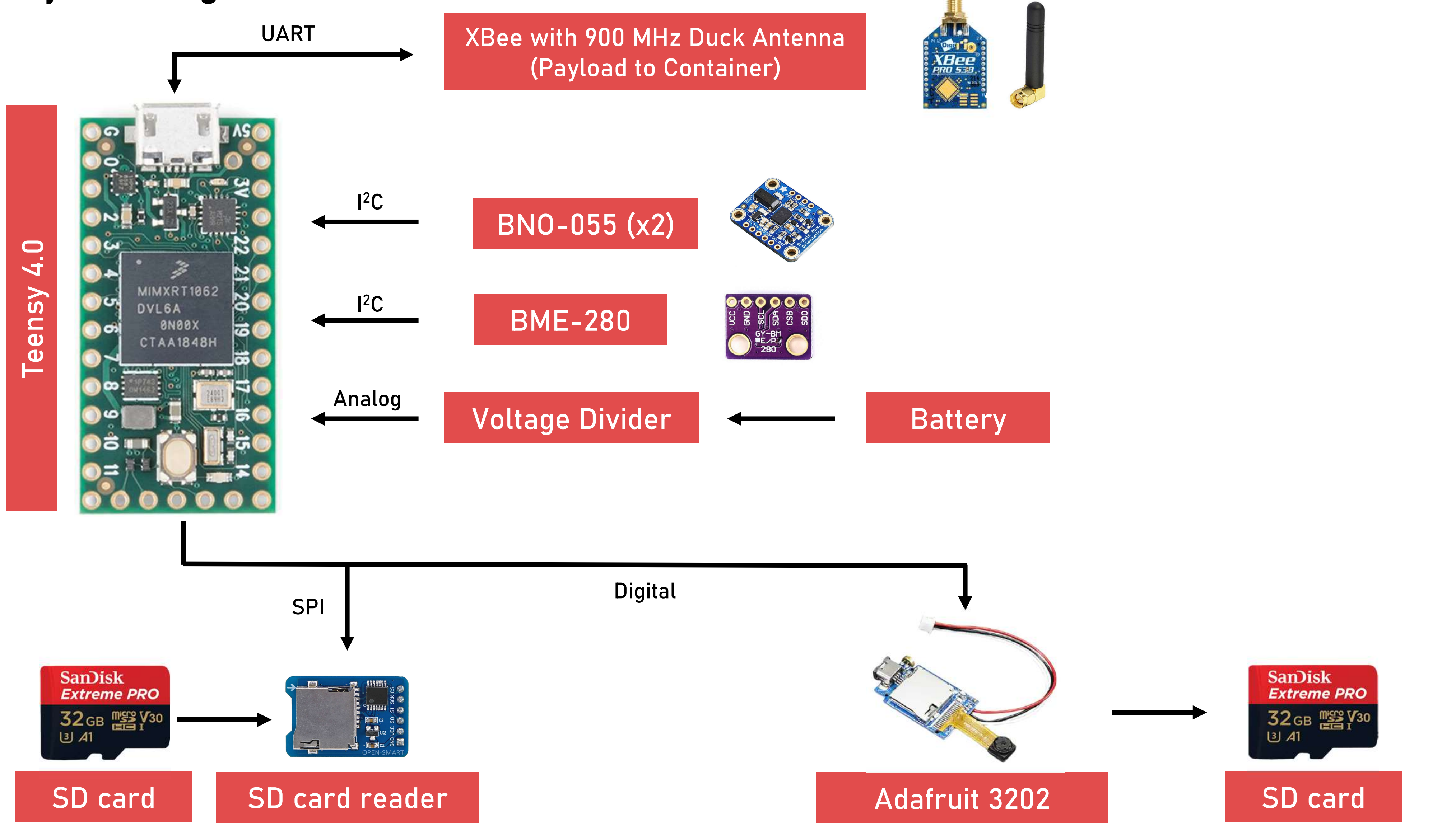
MCU - Teensy 4.0	• Control all other components
XBee radio – XBee Pro 900MHz	• For communication between the payload and the container.
Antenna – 900MHz Duck Antenna	• An external antenna is applied to increase the gain of the XBee radio
Data storage – Sandisk Extreme PRO	• Store telemetry data
Sensors	• Air pressure sensor, air temperature sensor, rotation sensors and voltage divider
Others	• Camera has an internal SD card module. • Buzzer 92 dB loud audio beacon • Teensy's real-time clock power is supplied by a CR2032 cell (to maintain track of time even when the switch is off).

CDH Overview
(2 / 3)

Container Diagram



Payload Diagram

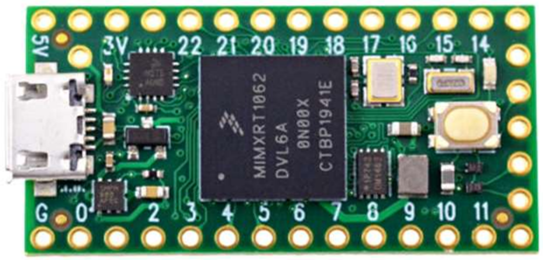


CDH Changes Since PDR

Components	PDR	CDR	Rationale
Container Memory	SanDisk Ultra 16 GB	SanDisk Extreme PRO 32 GB	• More memory space is needed in case the received data from any sensors exceeds 16 GB.
Payload Memory	SanDisk Ultra 16 GB	SanDisk Extreme PRO 32 GB	• More memory space is needed in case the received data from any sensors exceeds 16 GB.
Bonus Camera Memory	SanDisk Extreme PRO 64 GB	SanDisk Extreme PRO 32 GB	• Since Bonus Camera video resolution has been decreased due to the changed camera, there is no need to use a 64 GB microSD Card.

SanDisk Extreme PRO 32 GB

Container Processor & Memory Selection (1/3)



Main Processor - TEENSY 4.0

Clock Speed (MHz)	600
Supply Voltage (V)	3.3, 5.0
GPIO Pins	40
Interfaces	UART 7 SPI 3 I^2C 2 USB 2
Memory (kB)	2048
RAM (kB)	2048
EEPROM (kB)	64
Boot time (s)	1.4
Cost ($)	19.95
Data bus width (bit)	64

Note:

- Since the container camera is changed to the Adafruit 3202, which has its own processor, the second processor won't be needed anymore.

Container Processor & Memory Selection
(2 / 3)

Main Memory - Mini microSD Card reader + SanDisk Extreme PRO

Mini microSD Card	
Supply Voltage (V)	4.5 ~ 5.5
Interface	SPI
Size (mm)	18 x 25 x 3
Cost ($)	13.00

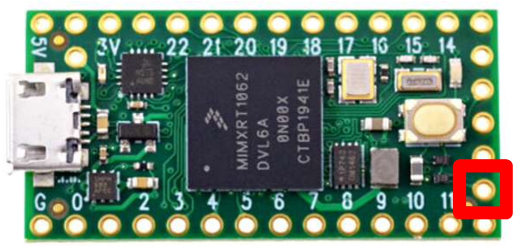
SanDisk Extreme PRO	
Memory Storage (GB)	32
Interface	SPI and SD
Read Speed (MB/s)	100
Write Speed (MB/s)	90
Cost ($)	13.00

Container Processor & Memory Selection (3 / 3)

Bonus Camera Memory - SanDisk Extreme PRO

SanDisk Extreme PRO	
Memory Storage (GB)	32
Interface	SPI and SD
Read Speed (MB/s)	100
Write Speed (MB/s)	90
Cost ($)	13.00

Container Real-Time Clock



TEENSY build-in RTC

Size (mm)	Included in the microcontroller
Weight (g)	Included in the microcontroller
Supply Voltage (V)	3.3
Status	Hardware
Reset tolerance	External supply battery
Cost ($)	0

Container Antenna Selection

Container to Payload Antenna –
900 MHz Quad-Band Cellular Duck Antenna

Connection Type	RP-SMA Male
Frequency (MHz)	900~1800
Type	Omnidirectional
Gain (dBi)	3
Weight (g)	6
Cost ($)	3.00

Container to GS –
900 MHz Quad-Band Cellular Duck Antenna

Connection Type	RP-SMA Male
Frequency (MHz)	900~1800
Type	Omnidirectional
Gain (dBi)	3
Weight (g)	6
Cost ($)	3.00

Container Radio Configuration

	Container to GCS	Container to Payload
Frequency	900 MHz	900 MHz
Power consumption	0.974 W·h	0.974 W·h
TX Power	4 dBm	4 dBm
NETID	1022	6022
Node Identifier	CG	CT
Baudrate	115200	115200
Serial High	13A200	13A200
Serial Low	41D9F72B	41D9F63A
Destination High	0	0
Destination Low	FFFF	FFFF
Cost ($)	57	57

Container Telemetry Format
(1 / 3)

FIELD	EXPLANATION	Size (byte)
TEAM_ID	The assigned team identification.	4
MISSION_TIME	UTC time in format hh:mm:ss, where hh is hours, mm is minutes, and ss.ss is seconds (including hundredths of a second)	8
PACKET_COUNT	The total count of transmitted packets, which is to be maintained through processor reset. One cumulative count is used for transmission of both 'C' and T packets. A separate count, shall be used for optional X' custom packets, if Used	1~4
PACKET_TYPE	The ASCII character 'C' for Container telemetry, character T for Tethered Payload relay telemetry, and character 'X' for optional custom packets	1
MODE	'F' for flight (the default mode upon system start) and 'S' for simulation	1
TP_RELEASED	'N' for not released and 'R' for released	1
ALTITUDE	Altitude in units of meters and must be relative to ground level. The resolution must be 0.1 meters	1~4
TEMP	Temperature in degrees Celsius with a resolution of 0.1 degrees C	1~4
VOLTAGE	Voltage of the CanSat power bus. The resolution must be 0.01 volts	4
GPS_TIME	Time generated by the GPS receiver. The time must be reported in UTC and have a resolution of a second	8
GPS_LATITUDE	The latitude generated by the GPS receiver in decimal degrees with a resolution of 0.0001 degrees North	7
GPS_LONGITUDE	The longitude generated by the GPS receiver in decimal degrees with a resolution of 0.0001 degrees West	7

Container Telemetry Format
(2 / 3)

FIELD	EXPLANATION	Size (byte)
GPS_ALTITUDE	The altitude generated by the GPS receiver in meters above mean sea level with a resolution of 0.1 meters	1~4
GPS_SATS	The number of GPS satellites being tracked by the GPS receiver. This must be an integer	1
SOFTWARE_STATE	Operating state of the software. (e.g., LAUNCH_WAIT, ASCENT, ROCKET_SEPARATION, DESCENT, TP_RELEASE, LANDED, etc.). Teams may define their own states	1~4
CMD_ECHO	Fixed text command id and argument of the last received command with no commas. For example, CXON or SIMENABLE.	4~10
	Total size	**57~90**

Container Telemetry Format
(3 / 3)

Packet Data Example:

1022,00:00:38.21,287,C,F,N,2.85,37.57,8.14,07:50:27,13.709933,100.778297,-22.90,4,TPDEPLOY,CXON

Packet Data Format:
(comma separated, terminated with a carriage return)

TEAM_ID,MISSION_TIME,PACKET_COUNT,PACKET_TYPE,MODE,
TP_RELEASED,ALTITUDE,TEMP,VOLTAGE,GPS_TIME,GPS_LATITUDE,
GPS_LONGITUDE,GPS_ALTITUDE,GPS_SATS,SOFTWARE_STATE,CMD_ECHO

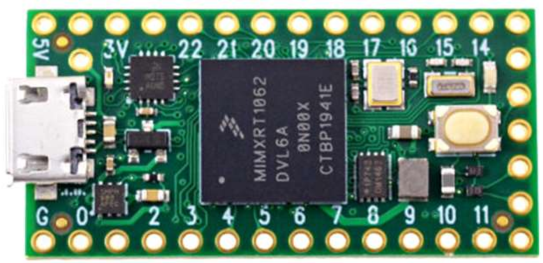
- Upon receipt of the telemetry activation command (CX ON), the CanSat **Container** shall collect the required Container telemetry at a **1 Hz** sample rate and transmit the telemetry data in Container (PACKET_TYPE='C') type telemetry packets to the ground station.
- Container shall poll the **Tethered Payload** and relay the collected telemetry data to the ground station in Tethered Payload packets (PACKET_TYPE='T')
- at a rate of **4 Hz**.
- The container buzzer will start beeping upon landing.
- CSV file will be generated with the name **Flight_1022_C.csv.**
- If the file already exists, a number will be appended to the name to avoid accidental overwrites.

Container Command Formats

COMMAND	FORMAT	EXAMPLE
CX - Container Telemetry On/Off	CMD,<TEAM_ID>,CX,<ON_OFF>	CMD,1022,CX,ON
ST - Set Time	CMD,<TEAM_ID>,ST,<UTC_TIME>	CMD,1022,ST,13:35:59
SIM - Simulation Mode Control	CMD,<TEAM_ID>,SIM,<MODE>	CMD,1022,SIM,DISABLE
SIMP - Simulated Pressure Data	CMD,<TEAM_ID>,SIMP,<PRESSURE>	CMD,1022,SIMP,101325

FIELD	MEANING
<ON_OFF>	On or Off : CX->Container telemetry transmissions
<UTC_TIME>	Time in the format hh:mm:ss, hh is hours, mm is the minutes and ss is the seconds
<MODE>	ENABLE to enable the simulation mode ACTIVATE to Activate the simulation mode DISABLE both disables and deactivates the simulation mode
<PRESSURE>	Simulated atmospheric pressure data in units of pascals with a resolution of one Pascal

Payload Processor & Memory Selection (1/3)



Main Processor - TEENSY 4.0

Clock Speed (MHz)	600
Supply Voltage (V)	3.3, 5.0
GPIO Pins	40
Interfaces	UART 7 SPI 3 I^{2}C 2 USB 2
Memory (kB)	2048
RAM (kB)	2048
EEPROM (kB)	64
Boot time (s)	1.4
Cost ($)	19.95
Data bus width (bit)	64

Payload Processor & Memory Selection (2 / 3)

Main Memory - Mini microSD Card reader + SanDisk Extreme PRO

Mini microSD Card	
Supply Voltage (V)	4.5 ~ 5.5
Interface	SPI
Size (mm)	18 x 25 x 3
Cost ($)	13.00

SanDisk Extreme PRO	
Memory Storage (GB)	32
Interface	SPI and SD
Read Speed (MB/s)	100
Write Speed (MB/s)	90
Cost ($)	13.00

Payload Processor & Memory Selection
(3 / 3)

Payload Camera Memory - SanDisk Extreme PRO

SanDisk Extreme PRO	
Memory Storage (GB)	32
Interface	SPI and SD
Read Speed (MB/s)	100
Write Speed (MB/s)	90
Cost ($)	13.00

Payload Antenna Selection

Payload to Container Antenna -
900 MHz Quad-Band Cellular Duck Antenna

Connection Type	RP-SMA Male
Frequency (MHz)	900~1800
Type	Omnidirectional
Gain (dBi)	3
Weight (g)	6
Cost ($)	3.00

Payload Radio Configuration

As defined in
Base Requirements #41

Payload to Container	
Frequency	900 MHz
Power consumption	0.974 W·h
TX Power	4 dBm
NETID	6022
Node Identifier	TC
Baudrate	9600
Serial High	13A200
Serial Low	41D9F79D
Destination High	0
Destination Low	FFFF
Cost ($)	57

Payload Telemetry Format
(1 / 3)

Field	Explanation	Size (bytes)
TEAM_ID	The assigned team identification.	4
MISSION_TIME	UTC time in format hh:mm:ss, where hh is hours, mm is minutes, and ss.ss is seconds (including hundredths of a second)	11
PACKET_COUNT	The total count of transmitted packets, which is to be maintained through processor reset. One cumulative count is used for transmission of both 'C' and 'T' packets. A separate count, shall be used for optional 'X' custom packets, if Used	1 - 4
PACKET_TYPE	The ASCII character 'C' for Container telemetry, character 'T' for Tethered Payload relay telemetry, and character 'X' for optional custom packets	1
TP_ALTITUDE	Altitude in units of meters and must be relative to ground level. The resolution must be 0.1 meters.	1 – 4
TP_TEMP	The measured temperature in degrees Celsius with a resolution of 0.1 degrees C	1 – 4
TP_VOLTAGE	The voltage of the Tethered Payload power bus with a resolution of 0.01 volts	1 – 4
GYRO_R, GYRO_P, GYRO_Y	Gyro readings in degrees per second for the roll, pitch, and yaw axes.	3 – 12
ACCEL_R, ACCEL_P, ACCEL_Y	Accelerometer readings for the roll, pitch and yaw axes	3 – 12
MAG_R, MAG_P, MAG_Y	Magnetometer readings in the roll, pitch and yaw axes in gauss	3 – 12
POINTING_ERROR	The yaw pointing error in degrees. Zero degrees is due South	1 – 4

Payload Telemetry Format
(2 / 3)

Field	Explanation	Size (bytes)
TP_SOFTWARE_STATE	The operating state of the Tethered Probe software. (e.g., STANDBY, RELEASED, ACQUIRING_TARGET, TARGET_POINTING, etc.).	7 - 16
TOTAL		37 – 88

Payload Telemetry Format
(3 / 3)

Packet Data Example:

1022,00:38:15.49,236,T,-0.30,37.13,7.76,0.69,-2.12,-0.69,9.41,-1.83,-1.41,-17.00,-17.25,-34.38,15,STANDBY

Packet Data Format:
(comma separated, terminated with a carriage return)

TEAM_ID,MISSION_TIME,PACKET_COUNT,PACKET_TYPE,TP_ALTITUDE,TP_TEMP,TP_VOLTAGE,GYRO_R,
GYRO_P,GYRO_Y,ACCEL_R,ACCEL_P,ACCEL_Y,MAG_R,MAG_P,MAG_Y,POINTING_ERROR,
TP_SOFTWARE_STATE

- Data is transmitted from the payload to container and to ground station when polled.
- Tethered payload will be polled at the rate of 4 Hz.
- Ground station will generate a file for payload data with filename Flight_1022_T.csv
- Ground station will append number to the filename if already exists, eg. Flight_1022_T_1.csv, Flight_1022_T_2.csv
- The payload will stop responding to commands upon landing.

Electrical Power Subsystem Design

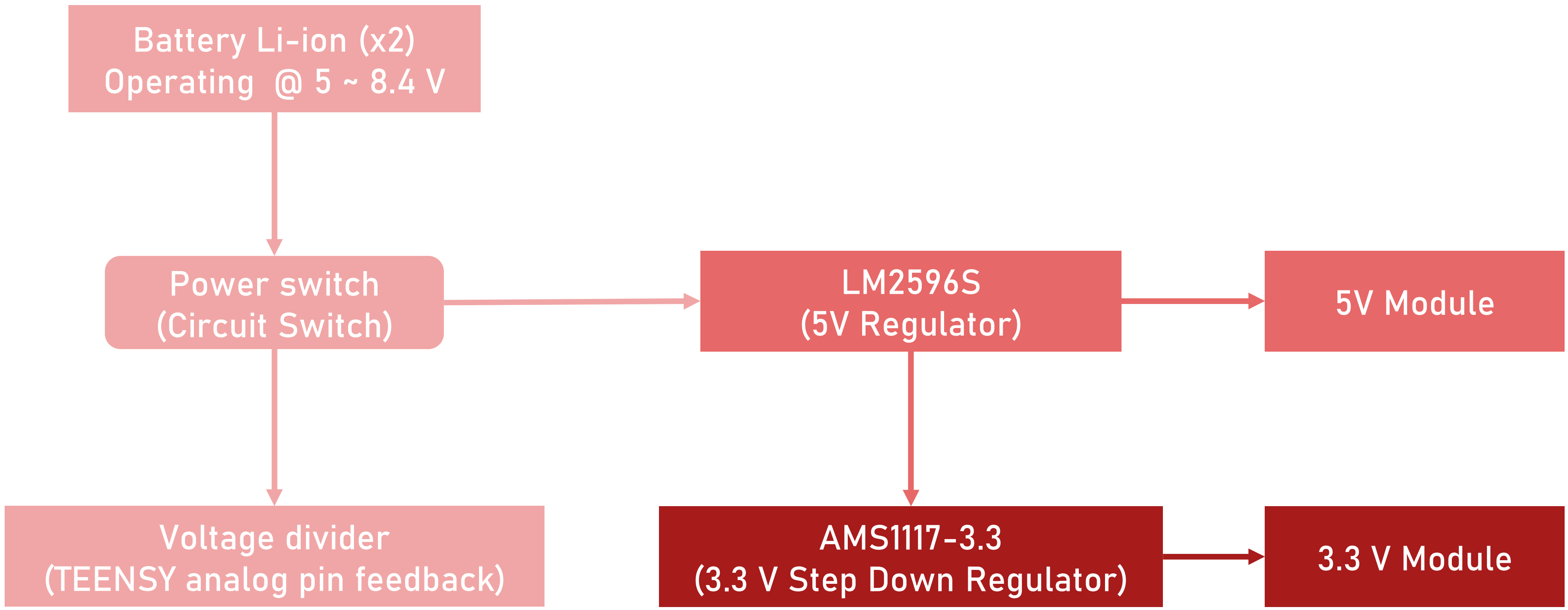
Pitiphoom Achapramote

EPS Overview (1/2)

Components	Purpose(s)
Battery	Supplies voltage to the circuit
Power Switch	Allows power on/off state of the board
Voltage Step-down Regulator	Lowers the voltage from above 3.3 V to 3.3 V
Voltage Regulator	Steps down voltage from above 5 V to 5 V
Voltage Divider	Provides voltage feedback and measurement with the analog pin of Teensy
LED	Indicates whether the components are working

EPS Overview (2/2)

Container & Payload



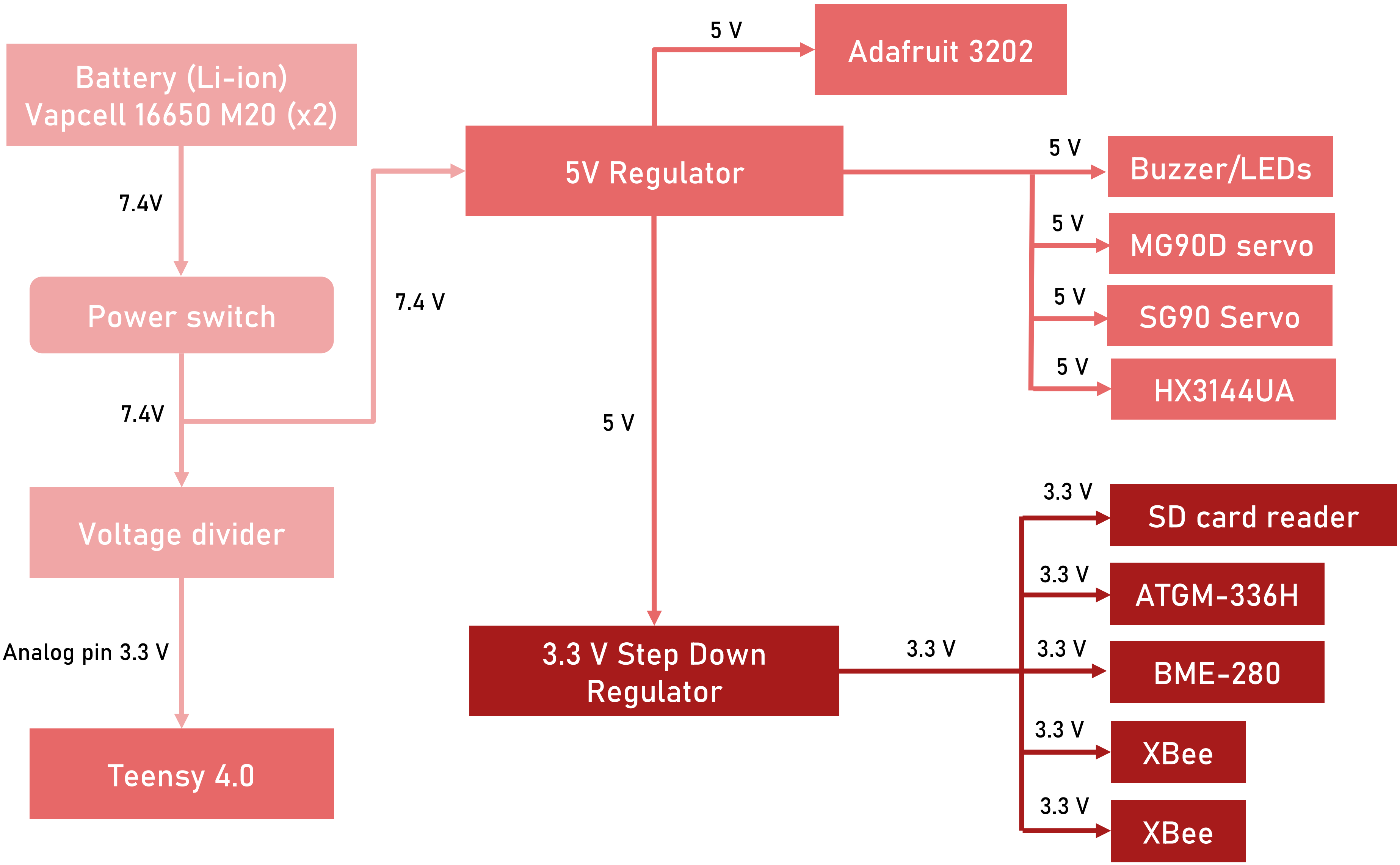
EPS Changes Since PDR

Components	PDR	CDR	Rationale
Bonus Camera	Raspberry pi camera v2.1	Adafruit 3202	• Since the bonus camera doesn't have any rotation, there is no need to use a high fps camera. • Take up less space • Significantly reduced weight
Container Battery	2x SONY VTC5D (Series connected)	2x Vapcell 16650 M20 (Series connected)	• Reduced the weight from 92 g to 74 g
Payload Battery	2x UltraFire TR16340 (Series connected)	2x Vapcell 18350 F14 (Series connected)	• The test result showed us that UltraFire TR16340 can't supply power for up to 2 hours, which doesn't meet the requirement.
Container Revolution Counter Sensor	-	HX3144UA	• To measure the deployed distance of payload when unspool

Vapcell 16650 M20 (Container Battery)

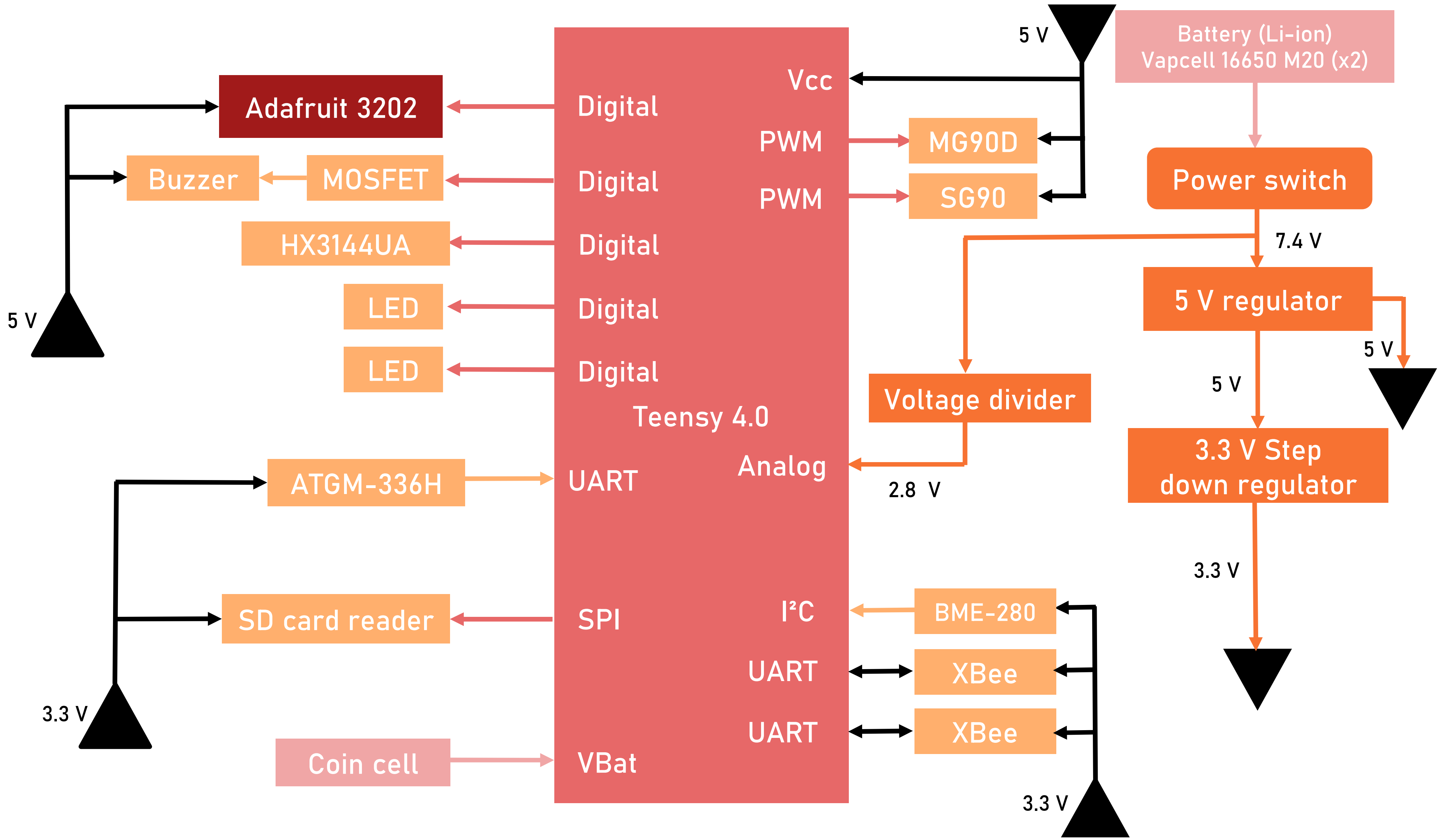
Vapcell 18350 F14 (Payload Battery)

Container Electrical Block Diagram (1/2)



*Every module are connected to ground(GND)

Container Electrical Block Diagram
(2 / 2)



Container Power Source

Vapcell 16650 M20 (x2)

Battery type	Li-ion
Quantity	2
Configuration	Series
Size (mm)	65 x 16 x 32
Mass (g)	74
Supply voltage	7.4
Charge (mA·h)	2000
Maximum Continuous Discharge Current (A)	8
Cost ($)	9

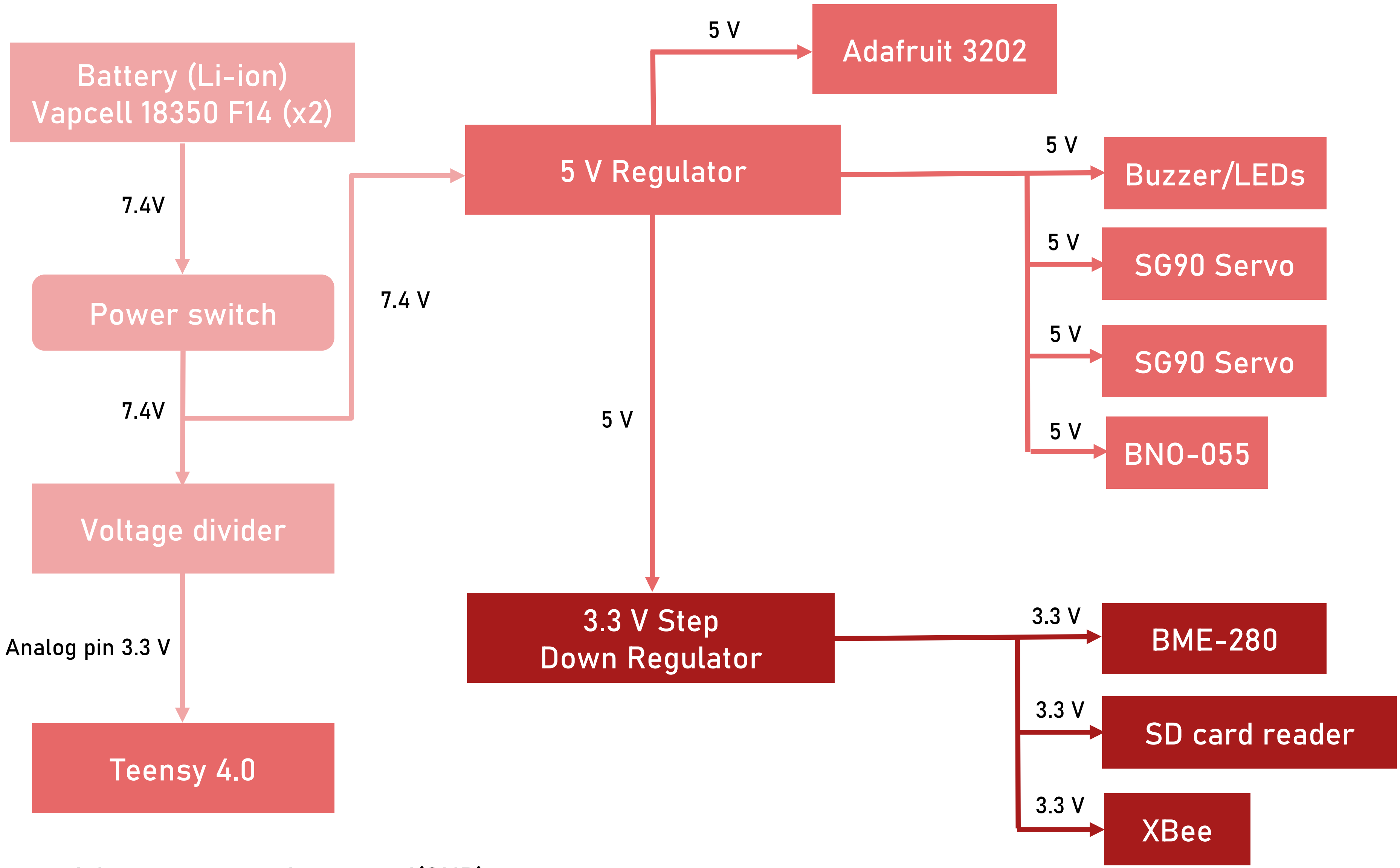
Note :

- According to the test results, these batteries can supply power to a Container's breadboard circuit for 3 hours and the voltage dropped to just 7.4 V from 8.2 V (Camera and servo weren't activated).

Container Power Budget

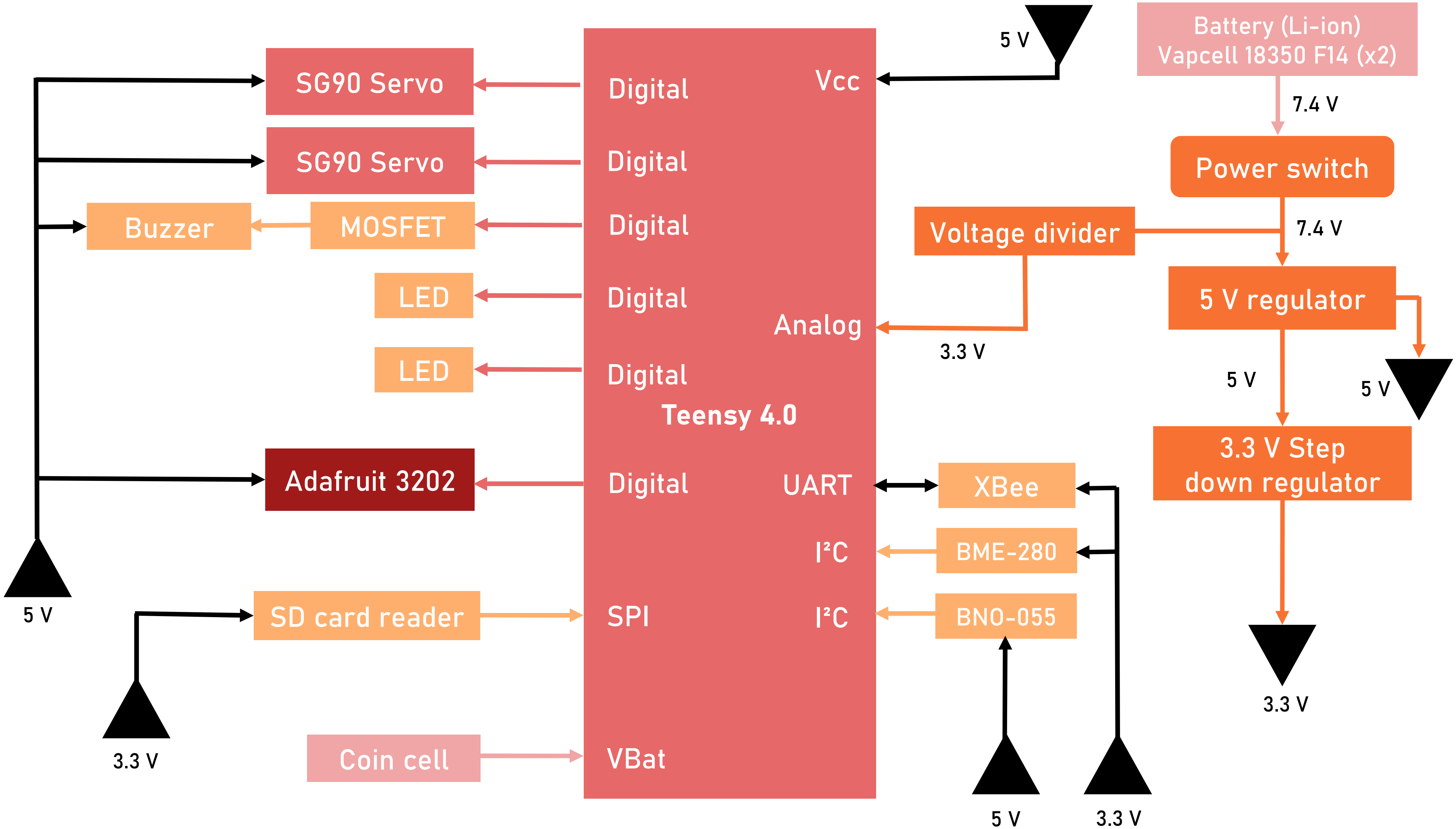
Component	Supply voltage(V)	Current (Peak)	Power	Power Consumption (W·h)	Duty cycle	Data reference
Teensy 4.0	3.3	100.0 mA	0.330 W	0.330	100%	Datasheet
Adafruit 3202	5.0	110.0 mA	0.550 W	0.165	30%	Datasheet
ATGM336H	3.3	25.0 mA	0.0825 W	8.258×10^{-2}	100%	Datasheet
SD card reader	3.3	200.0 mA	0.660 W	0.660	100%	Datasheet
BME-280	3.3	3.6 µA	11.880 µW	1.188×10^{-7}	100%	Datasheet
XBEE	3.3	590.0 mA	1.948 W	1.948	100%	Datasheet
Buzzer	5.0	45.0 mA	0.225 W	0.0225	10%	Measurement*
LED	3.3	5.0 mA	0.016 W	0.016	100%	Measurement*
LED	3.3	5.0 mA	0.016 W	0.0016	10%	Measurement*
LED	3.3	5.0 mA	0.016 W	0.0016	10%	Measurement*
MG90D Servo	5.0	400.0 mA	2.000 W	0.100	5%	Measurement*
SG90 Servo	5.0	360.0 mA	1.800 W	0.090	5%	Measurement*
HX3144UA	5.0	5.0 mA	0.025 W	0.00125	5%	Datasheet
TOTAL			**7.66 W**	**3.08 W·h**		
Battery	7.4	2000mAh	-	**14.8 W·h**	Margin	**11.72 W·h**
*The measurement of current is approximated, but no uncertainly is given.					Time	**4 hours 48 minutes**

Payload Electrical Block Diagram (1/2)



*Every module are connected to ground(GND)

Payload Electrical Block Diagram
(2 / 2)



Payload Power Source

Vapcell 18350 F14

Battery type	Li-ion
Quantity	2
Configuration	Series
Size (mm)	18.3 x 35 x 70
Mass (g)	52
Supply voltage	7.4
Charge (mA·h)	1400
Maximum Continuous Discharge Current (A)	3
Cost ($)	13.36

Payload Power Budget

Component	Supply voltage(V)	Current	Power	Power Consumption (W·h)	Duty cycle	Data reference
Teensy 4.0	3.3	100.0 mA	0.330 W	0.330	100%	Datasheet
Adafruit 3202	5.0	110.0 mA	0.550 W	0.165	30%	Datasheet
BNO-055	5.0	12.28 mA	0.061 W	0.0614	100%	Datasheet
SD card reader	3.3	200.0 mA	0.660 W	0.66	100%	Datasheet
BME-280	3.3	3.6 µA	11.880 µW	1.188×10^{-7}	100%	Datasheet
XBEE	3.3	295.0 mA	0.974 W	0.974	100%	Datasheet
Buzzer	5.0	45.0 mA	0.225 W	0.0225	10%	Measurement*
LED	3.3	5.0 mA	0.016 W	0.016	100%	Measurement*
LED	3.3	5.0 mA	0.016 W	0.0016	10%	Measurement*
LED	3.3	5.0 mA	0.016 W	0.0016	10%	Measurement*
SG90 Servo	5.0	360.0 mA	1.800 W	0.09	5%	Measurement*
SG90 Servo	5.0	360.0 mA	1.800 W	0.09	5%	Measurement*
TOTAL			**6.45 W**	**2.41 W·h**		
Battery	7.4	1400 mAh	-	**10.36 W·h**	**Margin**	**7.95 W·h**
*The measurement of current is approximated, but no uncertainty is given.					**Time**	**4 hours 18 minutes**

Flight Software (FSW) Design

Krissada Singhakachain
Arkhanirut Pandej

FSW Overview
(1/2)

Overview of the CanSat FSW Design

- The CanSat container will collect sensor data, save them to SD card, and send them to the ground station via XBee.
- The CanSat payload sensor data will be requested by the container and sent to ground station via XBee of the container.
- A self-rotating camera is included on the payload which will correct itself to point to the South.
- A bonus camera is included in the container to record the deployment of the payload.

Programming Language

- **C/C++** for CanSat container and payload
- **Python** for ground station

Development Environment

- Arduino IDE
- Visual Studio Code
- Qt Designer

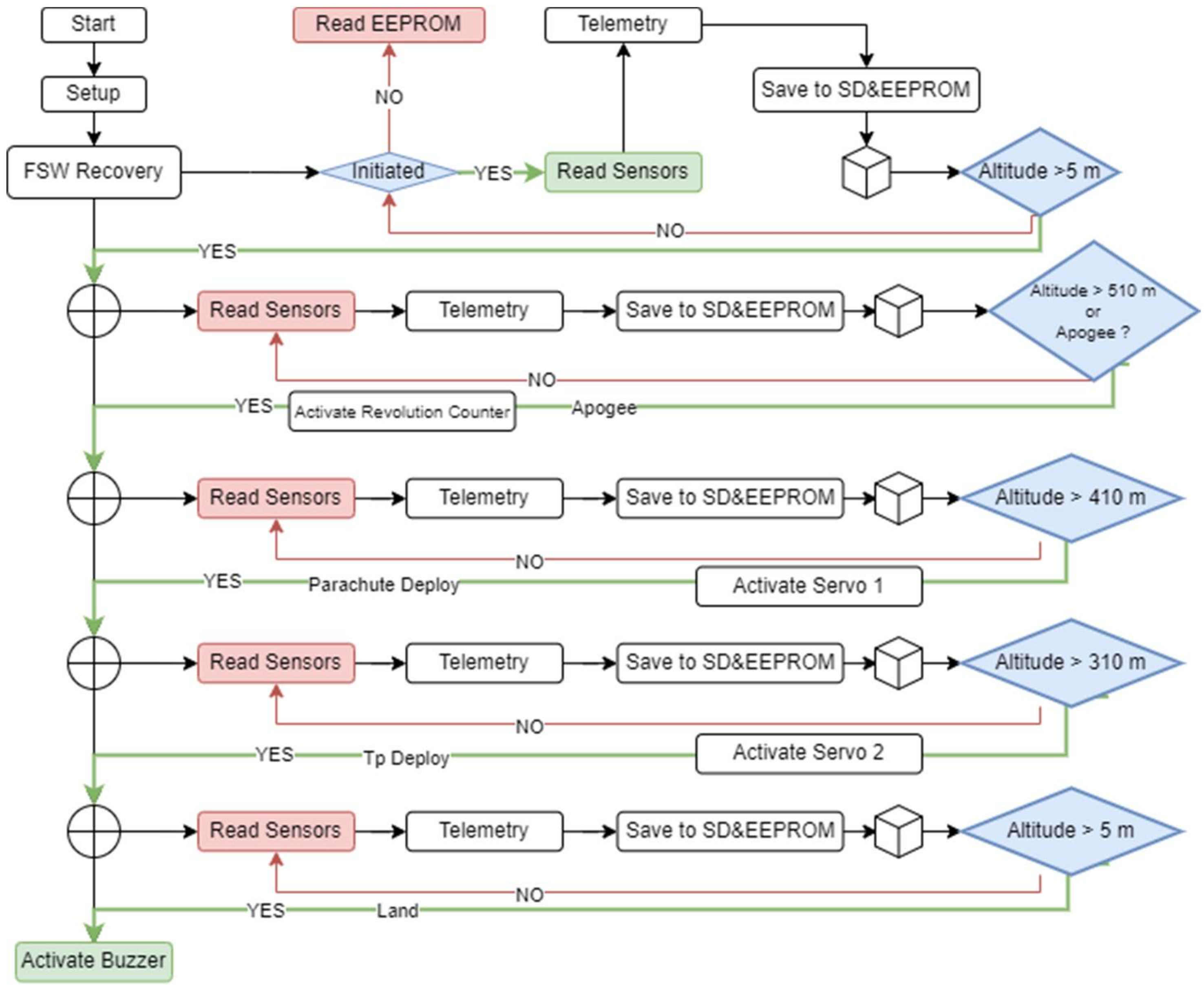
FSW Overview
(2 / 2)

1. Electronic system will be activated via a switch.
2. Container activation command will be received from GCS.
3. Container set time command will be received from GCS.
4. Payload activation command will be received from container.
5. Container saves sensor data to SD card and send to GCS via XBee.
6. Payload activation command will be received from container.
7. Container saves sensor data to SD card and send to GCS via XBee.
8. Container polls tethered payload for telemetry data.
9. Second parachute will be deployed at 400 m height.
10. Tethered payload will be deployed at 300 m height. Camera will start recording pointing to South.
11. The buzzer will keep beeping after landing and until turned off with power switch.

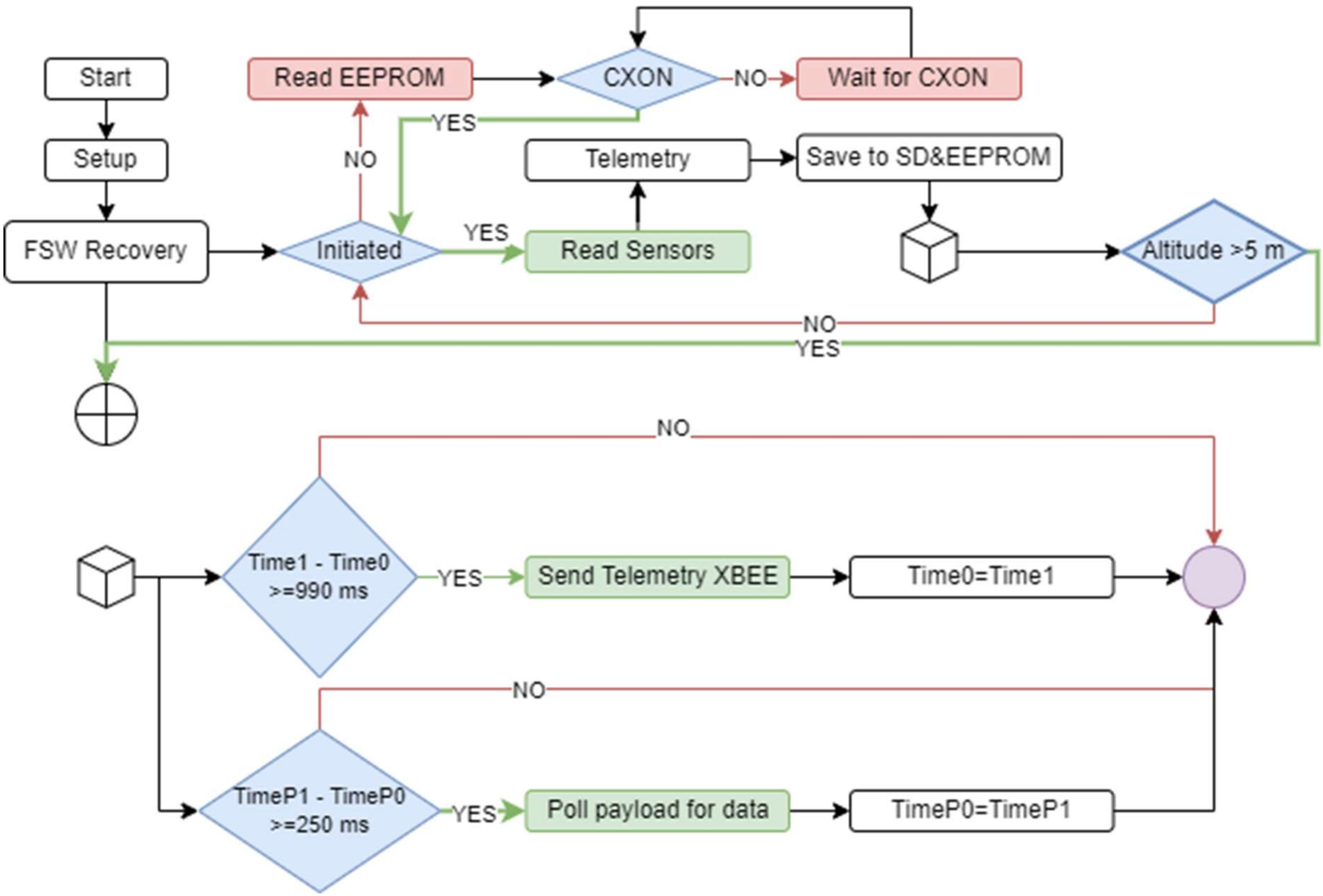
FSW Changes Since PDR

PDR	CDR	Rationale
• Apogee is detected when altitude reaches a certain height	• Apogee detection is triggered when altitude reaches 510 m and/or altitude start to decrease	• Concern that either a drift in altitude or rocket not reaching expected apogee could lead to overall mission failure.

Container CanSat FSW State Diagram
(1/3)



Container CanSat FSW State Diagram (2 / 3)



Container CanSat FSW State Diagram
(3 / 3)

Data Recovery

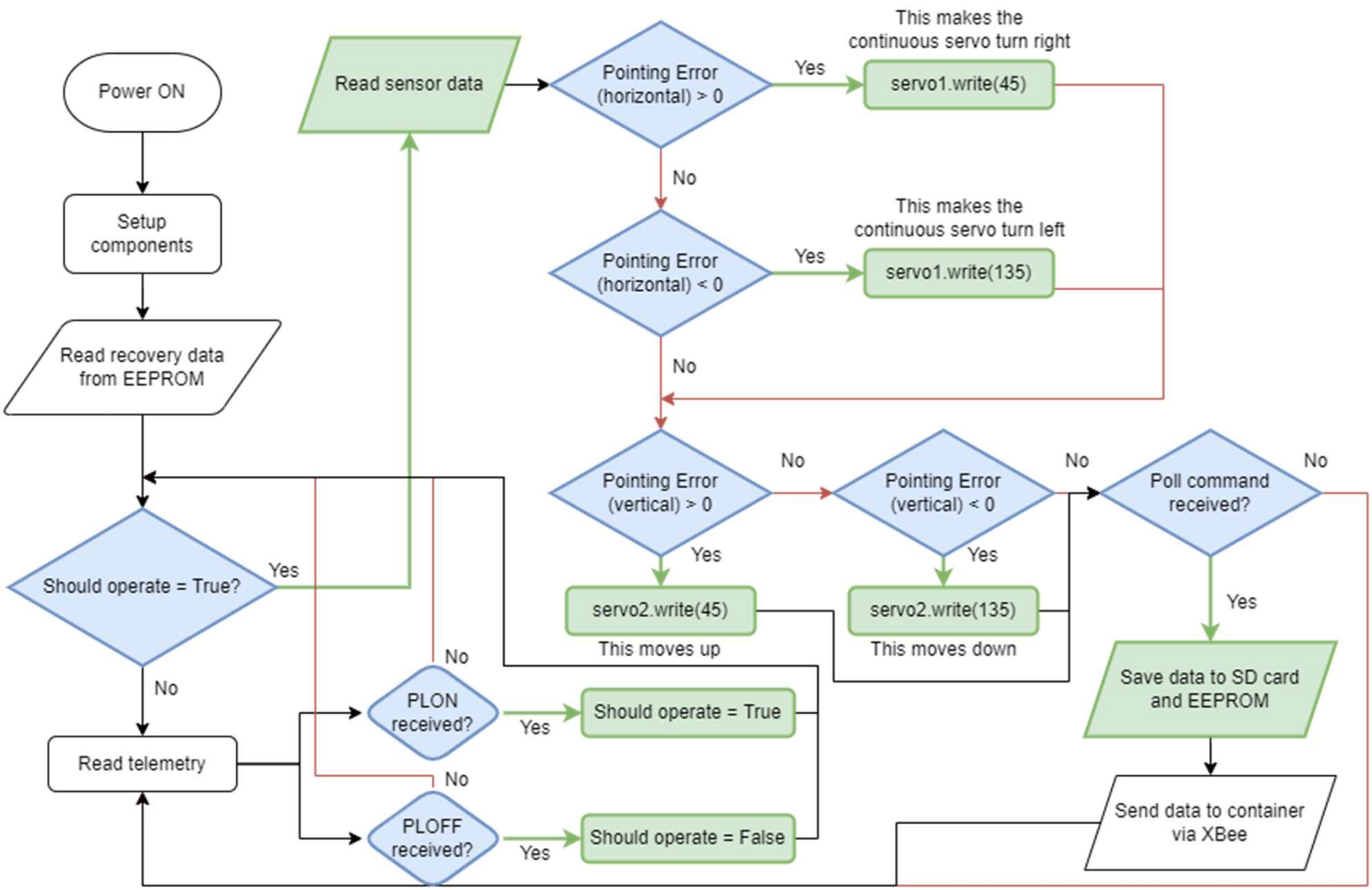
Reasons for reset

Most probable reasons for processor reset include high G-force impact, exposure of the PCB to high temperature and flash memory limit. However, actual causes may differ from our analyzed predictions.

Data to recover

- State, packet count, and reference altitudes save written onto into the processor EEPROM and to be read on recovery.
- Recovered state is used to determine whether to operate.
- Time is to be read from RTC's internal EEPROM.

Payload CanSat FSW State Diagram (1/2)



Payload CanSat FSW State Diagram (2/2)

Data Recovery

Reasons for reset

Most probable reasons for processor reset include high G-force impact, exposure of the PCB to high temperature and flash memory limit. However, actual causes may differ from our analyzed predictions.

Data to recover

- State, packet count, and reference altitudes save written onto into the processor EEPROM and to be read on recovery.
- Recovered state is used to determine whether to operate.
- Time is to be read from RTC's internal EEPROM.

Simulation Mode Software

Ground Station

`CMD,1022,SIM,ENABLE`

`CMD,1022,SIM,ACTIVATE`

SIM file

`CMD,1022,SIMP,<PRESSURE>`

Data with substituted altitude calculated from given pressure

Keep looping until commanded to stop

`CMD,1022,SIM,DISABLE`

CanSat (container)

Wait for ACTIVATE command

Stop using sensor pressure data and wait for pressure from GCS

Use the received pressure in place of pressure sensor data

Stop reading to pressure data and use the pressure sensor data as before

Software Development Plan (1/2)

Prototyping and prototyping environment

- Sensors are tested separately.
- Prototype box with all the components has been tested.
- Software has been uploaded and tested.
- Data output is inspected for potential errors.

Software subsystem development sequence

Hardware: Sensors selection → Libraries selection → Test sensors functionality

Software: Write flowchart diagram → Algorithm for different parts are written separately. → Every part is merged and debugged to form a full system.

- Tests are conducted as soon as respective components arrive to avoid late development.
- Software logic is written roughly beforehand and needs minor adjustments when connected with sensors.
- Codebase is maintained on GitHub for accessibility and collaboration.

Software Development Plan (2/2)

Test methodology

- A box comprised of all CanSat electrical components is used as a prototype to inspect any potential sources of failure. This allows the PCB to be integrated into the actual model successfully.
- All sensors and electrical components are tested separately before integrated into the CanSat prototype to prove the functionality of the software.
- FSW is evaluated to comply with the mission requirements.

Progress since PDR

- Communication has been successfully tested with the whole system on an actual PCB.
- Flight software and ground station software has been finished and fully tested.

Development Team

Krissada Singhakachain → Responsible for combining all system and developing GCS software

Arkkhanirut Pandej → Responsible for testing subsystem and developing CanSat software

Ground Control System (GCS) Design

Krissada Singhakachain

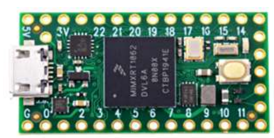
GCS Overview

Wireless

Digi XBee – PRO 900 MHz
(from Container)

Yagi Antenna 900MHz

Adapter



Ground Station laptop
(≥2 hours battery life)

Teensy 4.0 on GS board

Digi XBee on GS board –
PRO 900 MHz

GCS Changes Since PDR

Section	PDR	CDR	Rationale
GCS	There was no ground station board in place to receive data from the CanSat.	Ground station PCB is added to forward received data from the antenna to laptop.	• GNSS and altitude data from the CanSat and GS board can be merged together to create useful information such as where we find the CanSat.
User Interface	Use internal map to display GPS data.	Data are exported to external files to be read and displayed by Google Earth.	• We observed significant performance drops during re-render of the internal map.

GCS Design

Yagi Antenna 900MHz

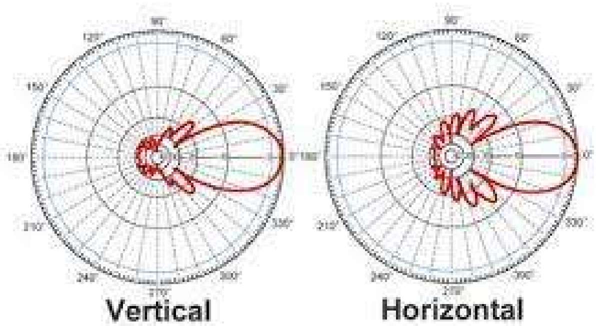
Digi XBee PRO 900 MHz
(ground station's)

Laptop

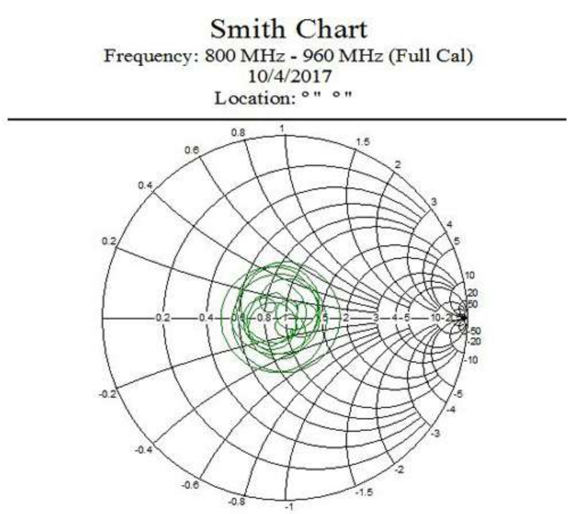
- The laptop can operate for more than 2 hours on battery.
- Windows auto-update feature will be disabled.
- An umbrella is equipped to prevent laptop from overheating.
- A cooling pad will be brought to the field and used when needed.

GCS Antenna
(1/3)

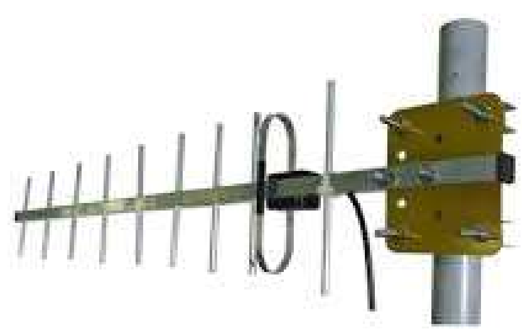
Antenna Model	Connection Type	Frequency (GHz)	Type	Gain (dBi)	Cost
YAGI UDA ANTENNA 10E	SMA-Male	800 - 960	Directional	13.9	$32.00



Radiation Pattern



Impedance

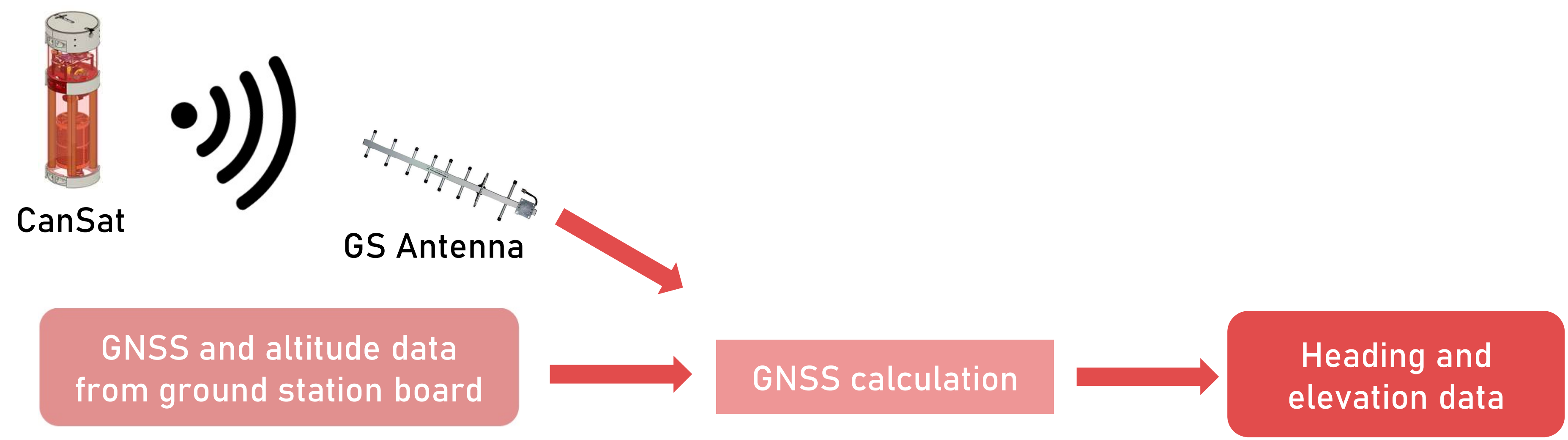


YAGI UDA ANTENNA 10E

GCS Antenna
(2 / 3)

Operation:

- One of our team members will be responsible for pointing the antenna.
- The antenna will be pointed with an error of less than 10 degrees.
- Position of the CanSat can be determined by calculating heading and elevation using combined data from the container and the ground station board.
- GNSS and altitude data will be used to calculate heading and elevation.



GCS Antenna
(3 / 3)

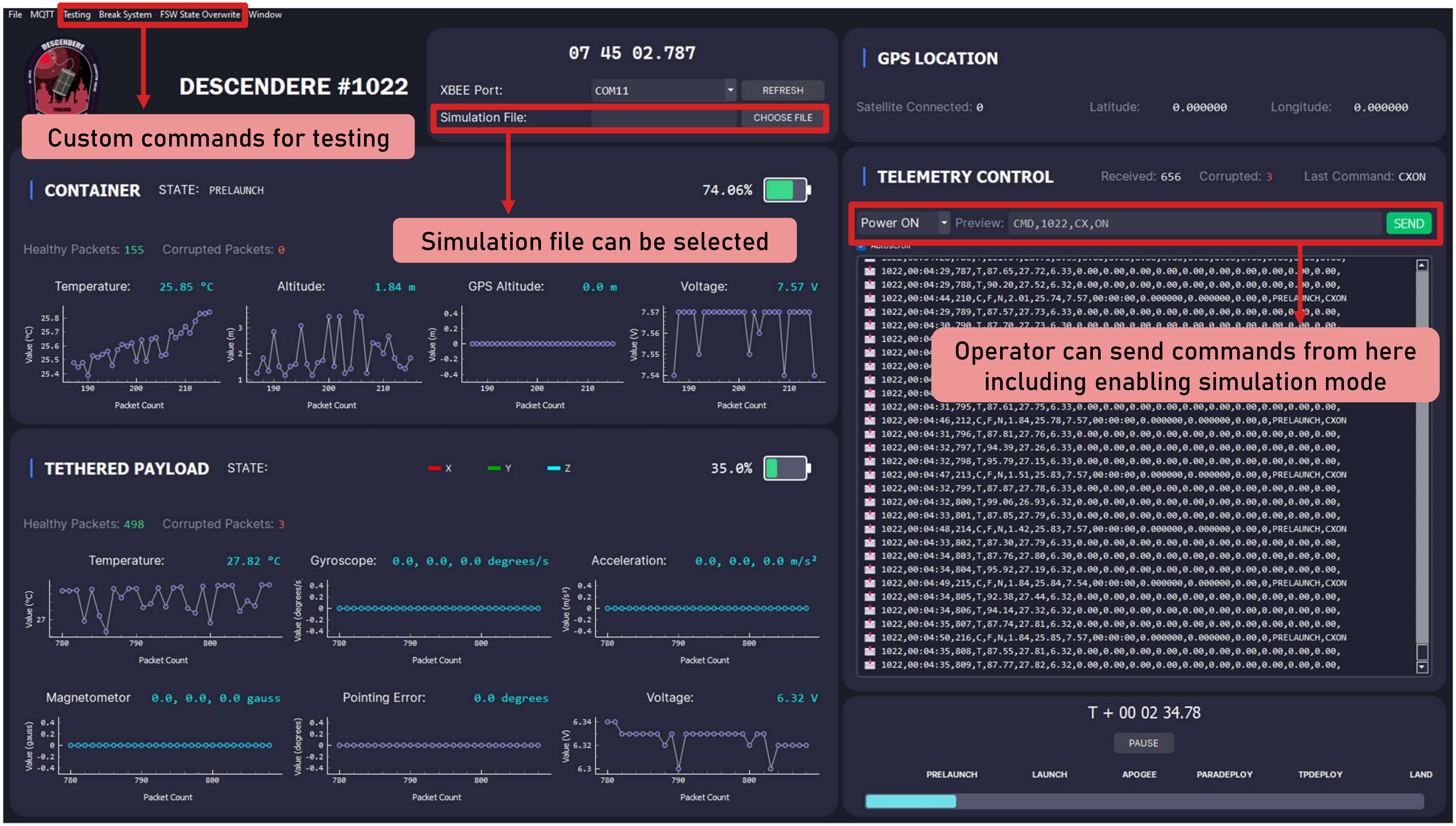
Coverage:

- Our team has done a preliminary test on communication range.
- Some team members will stand by at the ground station while some will be walking away from the ground station in straight line.
- Received data from wireless communication is indicated as the green line on the map shown on the right.
- A full line-of-sight range test at **3 km** will be conducted with similar method.

GCS Software
(1/4)

Telemetry display protypes	• Telemetry data is displayed and plotted in real-time using graphs and a map for location. • Data is displayed in SI unit as defined in the mission guide. • Raw telemetry data is visible in a text field in the ground station software GUI.
COTS software packages used	• **Visual Studio Code** and **Arduino IDE** for writing programs • **Qt Designer** for UI design • **XCTU** for radio configuration
Real-time plotting software design	• **pyqtgraph** library in PyQt5 framework is used for real-time plotting.
Command software and interface	• Commands can be sent to the container using a dropdown menu in the ground station software GUI. • All telemetry data received from the CanSat will be saved to .csv file.
Telemetry data recording and media presentation to judges for inspection	• Recorded telemetry data in .csv file will be transferred the judge's USB drive after the mission.
.csv telemetry file creation for judges	• Telemetry data transmitted to the Ground Station will be saved in .csv file format with each field separated with a comma and ending every line with a carriage return character.

GCS Software
(2 / 4)



GCS Software
(3 / 4)

Map data is exported to a kml file to be read by Google Earth in real time.

GCS Software
(4 / 4)

Received telemetry data will be saved into csv files with a carriage return character separating each line. The files can then be easily transferred to judges' portable drive.

Flight_1022_C.csv	24/3/2022 10:16	Microsoft Excel C...	1,636 KB
Flight_1022_C_with_corrupted.csv	24/3/2022 10:16	Microsoft Excel C...	1,637 KB
Flight_1022_T.csv	24/3/2022 10:03	Microsoft Excel C...	989 KB
Flight_1022_T_with_corrupted.csv	24/3/2022 10:03	Microsoft Excel C...	1,471 KB

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	TEAM_ID	MISSION_	PACKET_COUNT	PACKET_TYPE	MODE	TP_RELEASE	ALTITUDE	TEMP	VOLTAGE	GPS_TIME	GPS_LATI	GPS_LON	GPS_ALTI	GPS_SATS	SOFTWARE_STATE	CMD_ECI
2	1022	2:36:56	8343	C	F	N	-12.29	26.69	4.27	6:07:00	0	0	0	0	TPDEPLOY	CXON
3	1022	2:36:57	8344	C	F	N	-12.97	26.76	4.37	6:07:01	0	0	0	0	TPDEPLOY	CXON
4	1022	2:36:58	8345	C	F	N	-12.97	26.76	4.38	6:07:02	0	0	0	0	TPDEPLOY	CXON
5	1022	2:36:59	8346	C	F	N	-14.31	26.85	4.38	6:07:03	0	0	0	0	TPDEPLOY	CXON
6	1022	2:37:00	8347	C	F	N	-14.06	26.84	4.33	6:07:04	0	0	0	0	TPDEPLOY	CXON
7	1022	2:37:01	8348	C	F	N	-12.8	26.75	4.37	6:07:05	0	0	0	0	TPDEPLOY	CXON
8	1022	2:37:02	8349	C	F	N	-13.55	26.78	4.36	6:07:06	0	0	0	0	TPDEPLOY	CXON
9	1022	2:37:03	8350	C	F	N	-14.39	26.85	4.33	6:07:07	0	0	0	0	TPDEPLOY	CXON
10	1022	2:37:04	8351	C	F	N	5.58	25.37	4.38	6:07:08	0	0	0	0	TPDEPLOY	CXON
11	1022	2:37:05	8352	C	F	N	-14.47	26.85	4.38	6:07:09	0	0	0	0	TPDEPLOY	CXON
12	1022	2:37:06	8353	C	F	N	-14.22	26.84	4.38	6:07:10	0	0	0	0	TPDEPLOY	CXON
13	1022	2:37:07	8354	C	F	N	-13.72	26.78	4.39	6:07:11	0	0	0	0	TPDEPLOY	CXON
14	1022	2:37:09	8355	C	F	N	-14.31	26.83	4.25	6:07:12	0	0	0	0	TPDEPLOY	CXON
15	1022	2:37:10	8356	C	F	N	-14.39	26.83	4.39	6:07:14	0	0	0	0	TPDEPLOY	CXON
16	1022	2:37:11	8357	C	F	N	-13.13	26.74	4.38	6:07:15	0	0	0	0	TPDEPLOY	CXON
17	1022	2:37:12	8358	C	F	N	-14.31	26.83	4.3	6:07:16	0	0	0	0	TPDEPLOY	CXON
18	1022	2:37:13	8359	C	F	N	-5.84	26.18	4.31	6:07:18	0	0	0	0	TPDEPLOY	CXON
19	1022	2:37:14	8360	C	F	N	-14.22	26.83	4.38	6:07:19	0	0	0	0	TPDEPLOY	CXON
20	1022	2:37:15	8361	C	F	N	-14.39	26.84	4.38	6:07:20	0	0	0	0	TPDEPLOY	CXON
21	1022	2:37:16	8362	C	F	N	-13.22	26.77	4.38	6:07:21	0	0	0	0	TPDEPLOY	CXON
22	1022	2:37:17	8363	C	F	N	-13.22	26.75	4.38	6:07:22	0	0	0	0	TPDEPLOY	CXON
23	1022	2:37:18	8364	C	F	N	-14.06	26.82	4.39	6:07:23	0	0	0	0	TPDEPLOY	CXON
24	1022	2:37:19	8365	C	F	N	-13.97	26.82	4.39	6:07:24	0	0	0	0	TPDEPLOY	CXON
25	1022	2:37:20	8366	C	F	N	-13.13	26.77	4.38	6:07:25	0	0	0	0	TPDEPLOY	CXON
26	1022	2:37:21	8367	C	F	N	-13.64	26.78	4.37	6:07:26	0	0	0	0	TPDEPLOY	CXON
27	1022	2:37:22	8368	C	F	N	-14.47	26.82	4.38	6:07:27	0	0	0	0	TPDEPLOY	CXON
28	1022	2:37:23	8369	C	F	N	-14.06	26.83	4.39	6:07:28	0	0	0	0	TPDEPLOY	CXON

Flight_1022_C

MQTT Integration

Publish

Topic

MQTT Broker

Publish

Subscribe

GCS running Python

CanSat

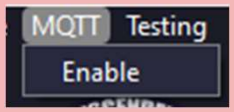
cansat.info/plot.html

Selected language: Python

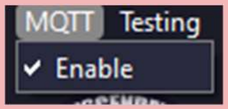
Selected MQTT library: paho-mqtt (also suggested in the MQTT guide)

MQTT feature can be toggled in the UI action menu

When disabled



When enabled



We have tested with cansat.info

CanSat Integration and Test

Thasvarit Krueklai

CanSat Integration and Test Overview (1/3)

Test Overview

- **Subsystem Level Testing**
  - Sensor
  - CDH
  - EPS
  - Radio Communication
  - FSW
  - Mechanical
  - Descent Control
- **Integrated Level Function Testing**
  - Descent Testing
  - Communication
  - Mechanism
  - Deployment
- **Environmental Testing**
  - Drop Test
  - Thermal Test
  - Vibration Test
  - Fit Test
  - Vacuum Test
- **Simulation Test Plan**
  - Flight Mode
  - Simulation Mode

Subsystem Level Testing Plan

SS	• Sensors Calibration and Reliability test
CDH	• Timing test • SD card storage test
EPS	• Power Sufficiency Test • Current Leakage and Inefficiency Test
RC	• XBEE Communication Test • GCS Software and CSV File generation Test • Antenna Range test • Interference Test with 900 MHz signal
FSW	• Parachute and payload deployment algorithm • Last Memory Recovery after Unexpected Shutdown or Reset • Camera Test
MS	• Container & TP mass control • Parachute ejection test • Payload release mechanism • Camera stabilization
DC	• Descent velocity test • Container parachute drop test • Separation test

CanSat Integration and Test Overview
(3 / 3)

Integrated Level Function Testing

Descent Tests	• Container parachute, TP Descent test
Communication	• XBee communication test • Communication between components on the PCB will be tested
Mechanics	• Container lid opening mechanism
Deployment	• Release TP from the container using brake system

Environmental Testing

Drop Test	• Survivability of CanSat after deployment from rocket • Mounting components tests • 30 Gs shock durability test of the overall system
Thermal Test	• CanSat's performance in hot environment
Vibration Test	• This test will be conducted to make sure that overall components are fine at 30G
Fit Check	• Check that the dimensions of the CanSat meet the requirement
Vacuum Test	• Check the operation of CanSat in vacuum

Subsystem Level Testing Plan (1/3)

CDH	
Processors	Test receiving and transmitting of data of processors and executing calculation
Real Time Clock	Verify accuracy of time stamping by comparing to atomic clock and GPS time receiver
Camera	Verify that the recorded video is stored in SD card
SD card	Verify that the measured numerical data is stored in SD card connected to Teensy
XBee & Antenna	Verify that all operation meets CDH and GCS requirements

EPS

- Test the operation current draw of all the electronics at different stages of the mission
- Verify that the CanSat can operate for at least two hours on internal power
- Verify the stated efficiency of the step up regulator by measuring the output
- Verify that the battery can provide the peak current level without major consequences on the battery capacity ,which will occur during the descent of the payload
- Verify the voltage levels are as expected under all loads and all components are powered

Subsystem Level Testing Plan
(2 / 3)

Sensors	
Air Pressure	Measuring altitude at location where altitude is known
Air Temperature	Compare mearured temperature with thermometer
GPS	Compare location with other devices and Aerial image
Voltage Divider	Measure and compare battery with Voltmeter
Camera	Verify that module works as expected (640x480 30fps color video)

FSW

- Processor Resets: Simulate each sensors shutdown or complete shutdowns and ensure that it recovers from last state and not stuck in loops or functions.
- Sensor Accuracy Check
- Test Output data with randomly corrupted sensor data and check its ability to handle

Subsystem Level Testing Plan
(3 / 3)

Mechanisms

- Test the 2nd parachute release mechanism
- Test operation of the camera orientation mechanism.
- Test the payload release mechanism
- Test resistance of mounting methods of components
- Test the structure's stresses and deformations when the forces and accelerations indicated in the competition guide are applied.

Radio Communication

- Test the reception of the transmitted telemetry
- Test the ground station's ability to store telemetry data.
- Test the creation of a.csv file.

Descent Control

- CanSat's falling velocity will be tested using both parachutes.
- Ensure the payload stabiltiy

Integrated Level Functional Test Plan (1/2)

Communication Test

- Communication between components on the PCB will be tested to identify any failure on circuits and short circuits by supplying umbilical power to the PCB.
- XBee will be tested for signal range, quality drop, data health, and any interference with other XBees or 900 MHz alternatives.
- Telemetry transmission will be tested up to 1.5 km range for determining antenna couple range which will provide the distance like field competition.
- Check that the GCS software can handle real-time data from the antenna and XBee

Descent Test

- The overall descent of CanSat will be tested with rocket to make sure that system functions at corresponding altitude levels.
- Descent of TP will be tested by being deployed from the drone to test if the TP brake system and stability control work properly 10 meters in 20 seconds).

Integrated Level Functional Test Plan (2 / 2)

Mechanical Test

- To test whether the lid of the container will open
- The second parachute release mechanism will be tested in a controlled environment to make sure that the deployment of tethered payload can be easily performed.

Deployment Test

- To test whether TP can be deployed from the Container
- To test whether the parachute can be ejected from Container (immediately after deployed from simulated rocket) and tethered payload (brake mechanism) with ease

Environmental Test Plan (1/2)

Drop Test

- Attach Parachute to the ceiling hole with non stretching cord using hot glue.
- Drop CanSat from different heights of the building Drop CanSat from 700 m height using a drone and deployer, DC subsystem will function.
- Damage assessment will be done after touching down and recovery.

Thermal Test

- Thermal tests will be conducted in both the university's thermal machine and custom-built chamber to see the effect and tolerance in extreme temperature of both electronic and mechanical components.
- The CanSat will be held in the machine for 60ºC for 2 hours.
- Any mechanical and electrical damaged will be checked after the test.

Thermal Machine
Suitable for 55-60°C, 2 hrs.

Environmental Test Plan
(2 / 2)

Vacuum Test

- A vacuum chamber will be constructed for the test.
- The CanSat will be in the vacuum for 1-2 minutes.
- The data sent from TP will be monitored from start pulling a vacuum until retrieving the CanSat.

Fit Check

- A measuring tool will be designed as a diameter of the envelope (125 mm diameter x 400 mm length) in CAD program and printed using a 3D printer with PLA plastic.
- The accuracy of the hole will be checked using a vernier caliper.
- If the CanSat can fit the tool and drop out easily, it will be considered a success.

Vibration Test

- Vibration tests will be performed using the random orbit sander.
- The rate will be set to around 12,000-14,000 rpm. The machine will be set on for 2 seconds and off for 2 seconds. This will be repeated in 2-3 minutes duration.
- Any mechanical and electrical damage will be checked after the test.

Test Procedures Descriptions (1/5)

Sensor Test

Part	Objective	Requirements	Pass / Fail Criteria	Status
Air Pressure sensor Test	Each sensor is mounted on the breadboard to ensure precision and stability of sensor readings (plus the camera's functionality to record video at 640*480 resolution).	27	Altitude data based on sensor reading stable and equal to actual established altitude	✓
Air Temperature Sensor Test		-	Temperature data equal to actual temperature	✓
GPS Sensor Test		26	GPS data show correct location and time data	✓
Voltage Divider Test		-	-	✓
Camera		45, 46, 68	Video output must be 640*480 pixels	✓
Rotation Sensor		44	Electronic board angle of inclination, measured in relation to gravity	✓

Mechanical and Environmental Test

Part	Objective	Requirements	Pass / Fail Criteria	Status
Thermal Test	Observing the CanSat structural integrity and functionality in high temperature environments	-	If structure survives without damage and remain functional after the test	-
Vibration Test	To ensure all mechanical systems are run proof to vibrations	15, 16	If system is working properly when the system is under vibration	-
Drop Test	Verifying that the parachute, attachment point, release mechanism, component and battery mounts will survive the deployment from the rocket payload section	15,16	If structure and electronics survive without damage and remain functional after the test	✓
Dimension Verification Test	To ensure probe size is available for rocket.	2	If its dimension less than the dimension of rocket's payload section	✓
G Test	To ensure all mechanical systems are resistant to G shock	15, 16	If system is working properly under G force.	-
Strength Test	To ensure all electronics are resistant to impacts it can face	-	If system is working properly when the system is facing impacts	-
Descent Test	Checking if the system descends with estimated descent rates	10, 11	If the system descends with estimated descent rates	✓

Test Procedures Descriptions
(3 / 5)

Electrical and Power Test

Part	Objective	Requirements	Pass / Fail Criteria	Status
G Test	To ensure all electronics are resistant to G shock.	13, 14	If system is working properly under G force.	-
Strength Test	To ensure all electronics are resistant to impacts it can face	15, 16	If system is working properly when the system is facing impacts	-
Vibration Test	To ensure all electronics are runproof to vibrations	15, 16	If system is working properly when the system is under vibration	-
Thermal Test	Observing the CanSat structural integrity and functionality in high temperature environments	-	If electronics survive without damage and remain functional after the test	-

Test Procedures Descriptions
(4 / 5)

Electrical and Power Test

Part	Objective	Requirements	Pass / Fail Criteria	Status
Regulator Test	To ensure regulators are working properly at the own range.	-	If output voltage of regulators are voltages that is required.	
PCB Circuit Test	To ensure there is no short circuit	-	If no short circuit., PCB will work properly.	
Battery Test	To ensure the battery runs the system for a sufficient period of time.	-	If system works at least two hours.	
Extreme Conditions Test	To ensure even high temperature and even high current power circuit is working robust	-	If system operate in extreme conditions.	-

Test Procedures Descriptions
(5 / 5)

Communication Test

Part	Objective	Requirements	Pass / Fail Criteria	Status
I^2C Conneciton Test	To ensure all I2C devices are connected.	-	If all data is received succesfully.	✔
SPI Connection Test	To ensure all SPI device is connected and working properly.	-	If all data is received succesfully	✔
Range Test	To ensure at the distance 3km, datalink is working properly	-	If at 3km datalink is connected.	-
Release Override Command Execution Test	To ensure while CanSat communicating with ground station, parachute relase and override command is working properly.	-	If no frame lost	✔
Communicati -on Test with XBee	To have valid XBee communication	21, 22, 23	A data package that transmitted from transmitter XBee is received from receiver XBee	✔
EEPROM Test	To ensure have properly write and read operations.	-	If all data can be legibility from EEPROM or writability to EEPROM.	✔
UART Connection Test	To check data are sent properly.	-	If all data received succesfully	✔

Simulation Test Plan

Flight Mode	Simulation
• CanSat will operate as the mission. • The actual sensor data will be used to locate any error.	• The simulated barometric pressure from GCS will be sent to container via command. • Those values will be substituted for the actual pressure data from sensor. • Flight software logic will calculate the altitude from those data. • This will be used to find any error in the software logic.

Mission Operations & Analysis

Thasvarit Krueklai

Overview of Mission Sequence of Events (1/2)

Arrival

- Arrival at Launch Site
- Integrity of CanSat will be checked for any damage or unexpected malfunctioning that might occur during flight and travelling.
- GCS & Antenna are ready and prepared.

Pre-launch

- TP will be loaded into the container.
- Assembly will be done.
- The electronic components will be tested as integrated system.
- Wireless Communication will be initiated & tested.
- Checklist for Pre-launch procedures

Installation

- CanSat will be switched on prior to installation into rocket.
- Wireless Communication with GCS will be confirmed for continuity.
- Rocket will be delivered to team members.

CanSat Crews
, Preparation – Damage Control
Krin
Suvijak

→

Assembly Crew
Kittipon
Nuchit
Krin

→

Ground Station Crew
Krissada
Arkkhanirut

Overview of Mission Sequence of Events (2 / 2)

Launch

- Rocket will be launched after Mission Control team completes launch procedures.
- When the rocket reaches apogee, CanSat will begin to descend with parachute.

Mid-Air Operation

- The first parachute is immediately deployed.
- CanSat will continue descending.
- The second parachute will be deployed at 400 m .
- TP will be deployed at 300 m.
- Container and Tethered Payload will measure telemetry data and transmit to GCS during descent.

Recovery

- Container & TP will land with parachute.
- The latest coordinates will be used to locate the touchdown locations with help of audio beacon.
- Recovery Team will start searching when all launches are completed, and the area is safe.

Analysis

- Received telemetry data will be analyzed.
- Damage Inspection will be done.
- CSV Flight Data will be delivered to judges.
- PFR

Mission Control Officers:
Kittipon

→

CanSat Recovery Crews:
Thasvarit
Pitiphoom
Shinakrit

→

CanSat Crew Damage Inspection:
Thasvarit
Pitiphoom
Shinakrit

Field Safety Rules Compliance

Ground station configuration → CanSat Preparation → CanSat Integration to the rocket → Launch preparation procedure → Launch procedure → Removal procedure

Development Status

- Each member team continues working on their assignments and writing the final procedures for the subsystem.
- After a launch rehearsal to inspect its efficiency and ensure that no steps are missing, the final version of mission operation manual will be ready by the end of May.
- Before the launch, there will be two copies of the mission operation manual file.

CanSat Location and Recovery

CanSat Recovery Strategy

- The last coordinates of both Container and TP will be used to track the approximate touchdown locations of Container and both TP with the help of sound from buzzer for exact location.
- The recovery team will be tracing the location of CanSat.
- Color of container is fluorescent red, and payload is fluorescent orange so they can be easily spotted and visually tracked in the sky or field.
- Both of the parachutes are fluorescent orange.
- Our team must not walk into the field until it is safe.

CanSat Label

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Bang Rak, Bangkok,
, Thailand, 10500.
+66988899311 , (USA Mobile No.)
phachara@spaceac.net
kittipon_am@outlook.co.th

Mission Rehearsal Activities

Ground System Radio Link Check	Check XBee settings from the software interface, antenna – XBee communications and calibration command software
Powering On / Off CanSat	CanSat is turned on by turning on the on/off switch
Launch Configuraion Preparations	All CanSat components are placed and checked to ensure that CanSat is ready to receive data
CanSat Loading in Launch Vehicle	CanSat is placed in a rocket envelope that has the same dimensions as the one used in the competition
Telemetry processing archiving and analysis	The data from the CanSat was saved and then analyzed by the members during the testing of the ground station's software
Recovery	GPS and a buzzer are used to track and recover the CanSat if possible

Requirements Compliance

Kittipon Amornprasertkij

Requirement Compliance Overview

Comply

- All Competition Requirements have been calculated, simulated, and tested theoretically.

Partial

- Some of the requirements that must be examined include survivability against specified shock or acceleration effects, correct operability at specific altitudes, and activities activated by electronics.
- The ability of the cansat to withstand environmental testing will be examined.

No Comply

- There are no requirements that do not meet the criteria.

Upcoming Stages of Development.

- It is necessary to test the design to ensure Requirements Compliance, following the steps outlined in this document's CanSat Integration and Test section.

Requirement Compliance
(1 / 7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Reference Slides	Team Comments or Notes
1	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.	Comply	89-93	Completed
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.	Comply	22	Completed
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.	Comply	16-18	Completed
4	The container shall be a fluorescent color; pink, red or orange.	Comply	22	Completed
5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	108	Completed
6	The rocket airframe shall not be used as part of the CanSat operations.	Comply	52	Completed
7	The rocket airframe shall not be used as part of the CanSat operations.	Comply	22	Completed
8	The container's first parachute shall not be enclosed in the container structure. It shall be external and attached to the container so that it opens immediately when deployed from the rocket.	Comply	108	Completed
9	The Parachutes shall be fluorescent Pink or Orange	Comply	52	Completed
10	The descent rate of the CanSat (container and science payload) shall be 15 meters/second +/- 5 m/s after deployment while above 400 meters.	Comply	54-55	Completed

Requirement Compliance
(2 / 7)

56-58	Requirement	Comply / No Comply / Partial	Reference Slides	Team Comments or Notes
11	The descent rate of the CanSat shall be reduced to 5 meters/second +/-2 m/s when the CanSat descends below 400 meters.	Comply	56-58	Completed
12	0 altitude reference shall be at the launch pad.	Comply	22	Completed
13	All structures shall be built to survive 15 Gs of launch acceleration.	Partial	161-162	Theoretically complies, awaiting test
14	All structures shall be built to survive 30 Gs of shock.	Partial	161-162	Theoretically complies, awaiting test
15	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	87	Completed
16	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Partial	161-162	Theoretically complies, awaiting test
17	Mechanisms shall not use pyrotechnics or chemicals.	Comply	60-61 , 78-79	Completed
18	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	173	Completed
19	Both the container and payload shall be labeled with team contact information including email address.	Comply	17	Completed
20	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost. Equipment from previous years should be included in this cost, based on current market value.	Comply	186-191	Completed

Requirement Compliance
(3 / 7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Reference Slides	Team Comments or Notes
21	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	Comply	96-97	Completed
22	XBEE radios shall have their NETID/PANID set to their team number.	Comply	113-114	Completed
23	XBEE radios shall not use broadcast mode.	Comply	114	Completed
24	The container shall include electronics to receive sensor payload telemetry.	Comply	97	Completed
25	The container shall include electronics and mechanisms to release the science payload on a tether.	Comply	95-97	Completed
26	The container shall include a GPS sensor to track its position.	Comply	27	Completed
27	The container shall include a pressure sensor to measure altitude.	Comply	26	Completed
28	The container shall measure its battery voltage.	Comply	28	Completed
29	The container shall transmit its telemetry once per second (1 Hz) in the formats described in the Telemetry Requirements section.	Comply	105-107	Completed
30	The container shall poll the payload for telemetry and relay that data four times per second (4 Hz) in the formats described in the Telemetry Requirements section.	Comply	105-107	Completed
31	The container shall stop polling and transmitting telemetry when it lands.	Comply	130-131	Completed

Requirement Compliance
(4 / 7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Reference Slides	Team Comments or Notes
32	The container and science payload must include an easily accessible power switch that can be accessed without disassembling the cansat and science payloads and in the stowed configuration.	Comply	70-71, 74-76	Completed
33	The container and payload must include a power indicator such as an LED or sound generating device that can be easily seen or heard without disassembling the cansat and in the stowed state.	Comply	70-71, 74-76	Completed
34	An audio beacon is required for the container. It shall be powered after landing.	Comply	130-131, 173	Completed
35	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Comply	95-97	Completed
36	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. Coin cells are allowed..	Comply	123, 127	Completed
37	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	70-71, 74-76	Completed
38	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	121-122, 125-126	Completed
39	The CanSat must operate during the environmental tests laid out in Section 3.5.	Partial	161-162	Theoretically complies, awaiting test

Requirement Compliance
(5 / 7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Reference Slides	Team Comments or Notes
40	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	Comply	124, 128	Completed
41	The science payload shall have their NETID/PANID set to their team number plus 5000. If the team number is 1000, sensor payload NETID is 6000.	Comply	104, 113	Completed
42	The science payload shall transmit sensor telemetry to the container when polled.	Comply	114-116	Completed
44	The science payload shall include a pressure sensor, temperature sensor and rotation sensor.	Comply	28-29, 32	Completed
45	The science payload shall include a video camera pointing 45 degrees up from the payload NADIR direction.	Comply	20	Completed
46	The science payload shall maintain orientation so the camera always faces south within +/- 20 degrees.	Comply	20	Completed
47	The payload shall be connected to the container with a 10 meter tether	Comply	78-79	Completed
48	At 300 meters, the payload shall be released from the container at a rate of .5 meters per second.	Partial	67-68	Payload is released with variable velocity by brake system [average velocity ≈ .5 m/s]
49	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	130-137	Completed
50	The container shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	134, 136	Completed

Requirement Compliance (6 / 7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Reference Slides	Team Comments or Notes
51	The container shall have its time set to UTC time to within one second before launch.	Comply	105-107, 114-116	Completed
52	The container flight software shall support simulated flight mode where the ground station sends air pressure values at a one second interval using a provided flight profile csv file.	Comply	138	Completed
53	In simulation mode, the flight software shall use the radio uplink pressure values in place of the pressure sensor for determining the container altitude.	Comply	138	Completed
54	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	105-107	Completed
55	The ground station shall command the CanSat to start transmitting telemetry prior to launch.	Comply	130-131, 149	Completed
56	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	105-107	Completed
57	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	108	Completed
58	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	Comply	105-107, 114-116	Completed
59	Each team shall develop their own ground station.	Comply	142-152	Completed

Requirement Compliance
(7 / 7)

Rqmt Num	Requirement	Comply / No Comply / Partial	Reference Slides	Team Comments or Notes
60	All telemetry shall be displayed in real time during descent on the ground station.	Comply	148-151	Completed
61	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	148-151	Completed
62	Teams shall plot each telemetry data field in real time during flight.	Comply	148-151	Completed
63	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	142-147	Completed
64	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	142-147	Completed
65	The ground station software shall be able to command the container to operate in simulation mode by sending two commands, SIMULATION ENABLE and SIMULATION ACTIVATE.	Comply	108	Completed
66	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the container.	Comply	107	Completed
67	The science payloads shall not transmit telemetry during the launch, and the container shall command the science payloads to begin telemetry transmission upon release from the container.	Comply	136-137	Completed
68	All video cameras shall be in color, have a resolution of at least 640x480 and record at a minimum of 30 frames a second.	Comply	33-34	Completed

Management

Kittipon Amornprasertkij

Status of Procurements

Procurement	Status
SD Card, XBee, and Camera have all been purchased and received.	✓
All mechanisms were created using a 3D printer.	✓
Antennas were ordered and delivered in order to evaluate the communication system's range.	✓
Components for the RF module were ordered and received.	✓

CanSat Budget – Hardware (1/6)

Components	Status	Price ($)	Quantity	Total Price ($)	Type
Carbon fiber rods	New	3.50	3	11.67	Actual
Nylon Standoffs	New	20.53	3	62.37	Actual
Velcro Tape	New	5.17	2	10.34	Actual
Rubber Sheet	New	5.67	2	12.10	Actual
ePLA-LW	New	41.63	1	41.63	Actual
Polypropylene	New	75.15	1	75.15	Actual
ABS	New	32.94	1	32.94	Actual
Magigoo Adhesive	New	3.50	3	11.67	Actual
PETG	New	20.53	2	41.00	Actual
M3x25	New	5.17	2	11.07	Actual

CanSat Budget – Hardware
(2 / 6)

Components	Status	Price ($)	Quantity	Total Price ($)	Type
Cable tie	New	1.33	2	2.66	Actual
Adafruit 3202	New	23.50	3	70.50	Actual
LM2596S	New	0.59	30	17.70	Actual
Capacitor	New	0.28	30	8.26	Actual
Resistor	New	0.04	40	1.66	Actual
Fin	New	2.00	4	8.00	Actual
Laminated Paper	New	2.50	2	5.00	Actual
Magigoo Adhesive	New	3.50	3	11.67	Actual
M3x25	New	5.17	2	11.07	Actual
DIP Switch	New	0.20	30	6.05	Actual

CanSat Budget – Hardware
(3 / 6)

Components	Status	Price ($)	Quantity	Total Price ($)	Type
Diode	New	0.08	30	2.32	Actual
Buzzer	New	0.42	20	8.40	Actual
BME-280	New	7.00	2	14.00	Actual
Teensy 4.0	New	19.95	2	39.90	Actual
BNO055	New	100.00	1	100.00	Actual
CR2032	New	8.33	2	16.66	Actual
Vapcell 18350 F14	New	13.90	2	27.80	Actual
Vapcell 16650 M20	New	4.50	2	9.00	Actual
Yagi-Uda antenna	New	6.00	1	6.00	Actual
ATGM336H	New	2.33	3	7.00	Actual

CanSat Budget – Hardware
(4 / 6)

Components	Status	Price ($)	Quantity	Total Price ($)	Type
Servo SG90	New	2.33	5	11.67	Actual
Servo MG90D	New	2.50	5	12.50	Actual
MINI micro SD Card module	New	2.00	8	16.00	Actual
GPS Antenna	New	12.00	2	24.00	Actual
SanDisk Extreme PRO	New	16.0	2	32.00	Actual
Container PCB	New	7.70	2	15.40	Actual
Nano cord	New	10.50	2	22.80	Actual
Duct tape	New	0.66	5	4.10	Actual
M2.5x6	New	0.17	25	5.50	Actual
Payload PCB	New	2.20	2	4.40	Actual

CanSat Budget – Hardware
(5 / 6)

Components	Status	Price ($)	Quantity	Total Price ($)	Type
GNSS	New	2.21	3	6.65	Actual
Soldering cramp	New	9.37	1	9.37	Actual
clamp meter	New	41.00	1	41.00	Actual
ESD Wrist Strap	New	2.67	2	5.34	Actual
Solder paste	New	3.20	1	3.20	Actual
Digital Meter	New	7.43	3	22.30	Actual
Shrinking tube	New	0.20	3	0.60	Actual
Wire	New	5.90	3	17.70	Actual

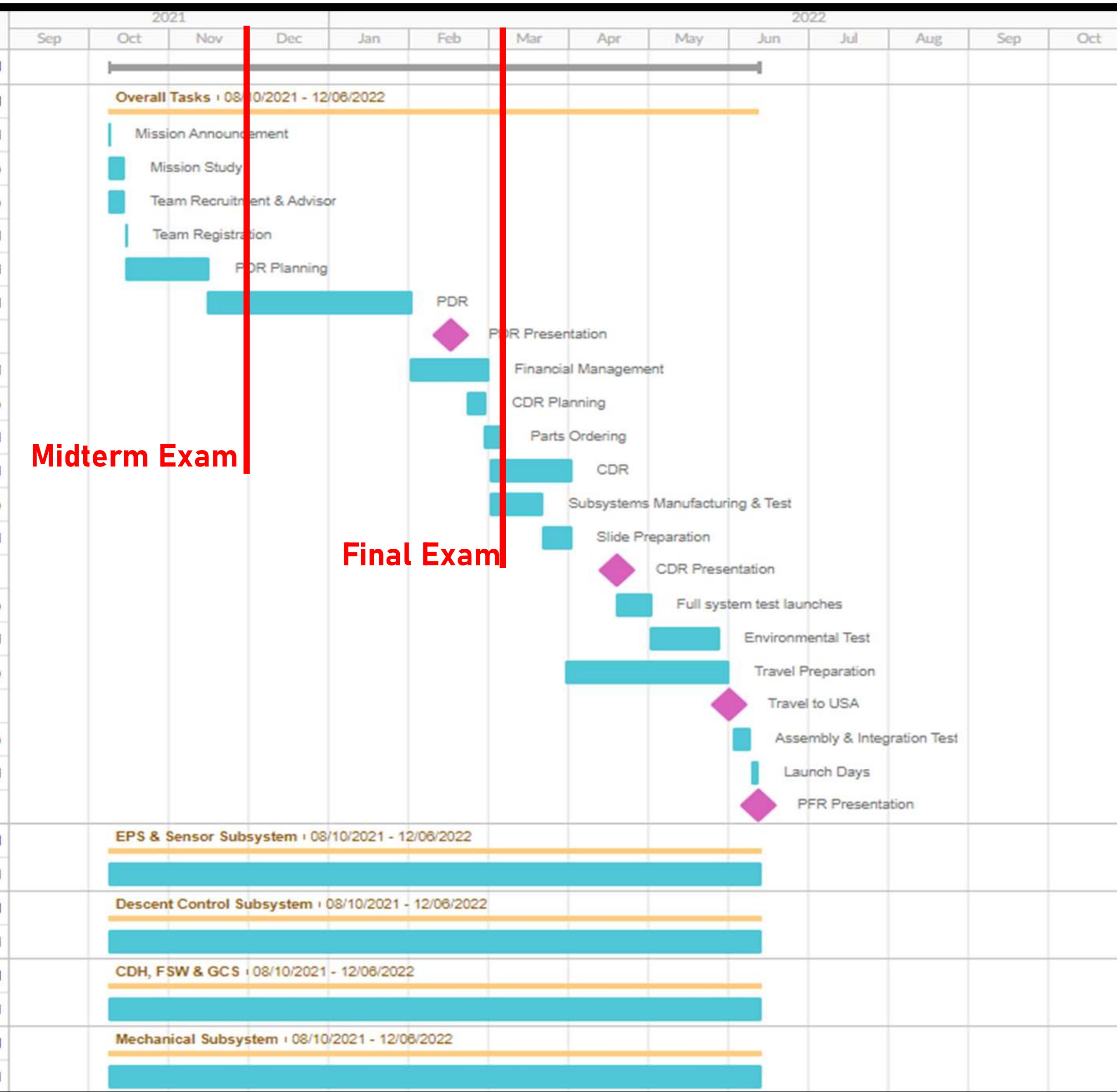
CanSat Budget – Other Costs (6 / 6)

Components	Price ($)	Quantity	Total Price ($)	Justification
Experimental Tools	-	-	-	Provided
Antenna Holder	-	-	-	Provided
Airline Ticket	1,700	10	17,000	Estimate
Travel Costs in USA	170	10	1,700	Estimate
Prototyping	150	2	300	Estimate
Registration Fee	200	1	200	Actual
Rental Fee	800	5	4,000	Estimate
Insurance Fee	34	10	3,400	Estimate
Visa Fee	160	10	1,600	Actual
Internet in USA	120	2	240	Actual

Components	Price ($)
Hardware Total Cost	454.71
Travel Costs in USA	28,440

Program Schedule Overview

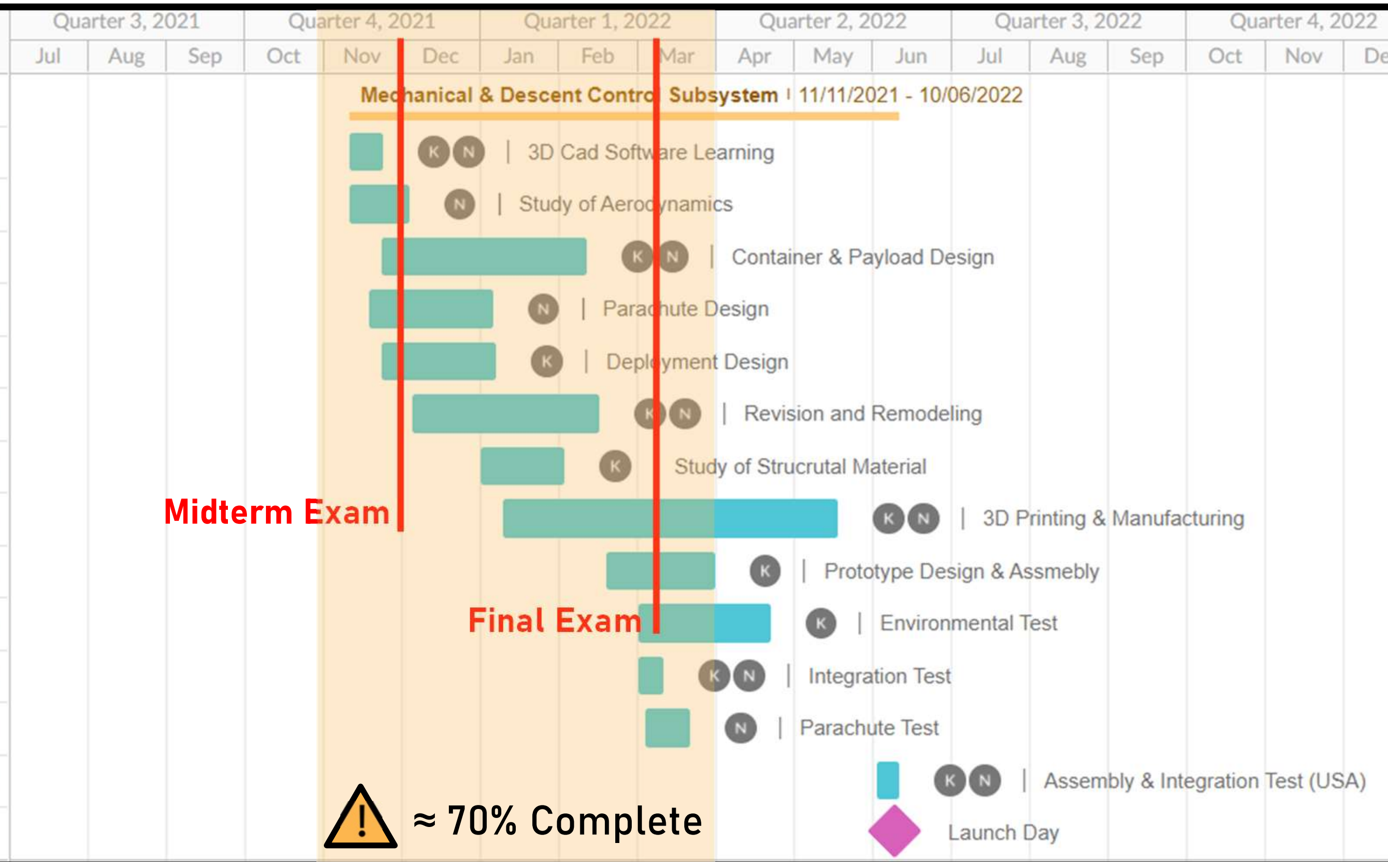
	Task name	Start date	End date	Duration
		08/10/2021	**12/06/2022**	**8M 3w 3d**
1	**Overall Tasks**	**08/10/2021**	**12/06/2022**	**8M 3w 2d**
1.1	Mission Announcement	08/10/2021	08/10/2021	1d
1.2	Mission Study	08/10/2021	14/10/2021	1w
1.3	Team Recruitment & Advisor	08/10/2021	14/10/2021	1w
1.4	Team Registration	15/10/2021	15/10/2021	1d
1.5	PDR Planning	15/10/2021	15/11/2021	1M 4d
1.6	PDR	15/11/2021	01/02/2022	2M 3w 2d
1.7	PDR Presentation	15/02/2022	15/02/2022	
1.8	Financial Management	01/02/2022	28/02/2022	1M
1.9	CDR Planning	21/02/2022	27/02/2022	1w
1.10	Parts Ordering	27/02/2022	06/03/2022	1w 1d
1.11	CDR	01/03/2022	01/04/2022	1M 4d
1.12	Subsystems Manufacturing &...	01/03/2022	21/03/2022	3w
1.13	Slide Preparation	21/03/2022	01/04/2022	1w 5d
1.14	CDR Presentation	19/04/2022	19/04/2022	
1.15	Full system test launches	18/04/2022	01/05/2022	2w
1.16	Environmental Test	01/05/2022	27/05/2022	3w 6d
1.17	Travel Preparation	30/03/2022	31/05/2022	2M 1w
1.18	Travel to USA	01/06/2022	01/06/2022	
1.19	Assembly & Integration Test	02/06/2022	08/06/2022	1w
1.20	Launch Days	09/06/2022	11/06/2022	3d
1.21	PFR Presentation	12/06/2022	12/06/2022	
2	**EPS & Sensor Subsystem**	**08/10/2021**	**12/06/2022**	**8M 3w 3d**
2.1		08/10/2021	12/06/2022	8M 3w 3d
3	**Descent Control Subsystem**	**08/10/2021**	**12/06/2022**	**8M 3w 3d**
3.1		08/10/2021	12/06/2022	8M 3w 3d
4	**CDH, FSW & GCS**	**08/10/2021**	**12/06/2022**	**8M 3w 3d**
4.1		08/10/2021	12/06/2022	8M 3w 3d
5	**Mechanical Subsystem**	**08/10/2021**	**12/06/2022**	**8M 3w 3d**
5.1		08/10/2021	12/06/2022	8M 3w 3d



Detailed Program Schedule
(1/3)

Mechanical & Descent Control Subsystem

Task name	Duration
Mechanical & Descent Contro…	**7M 2w 2d**
3D Cad Software Learning	1w 5d 4h
Study of Aerodynamics	3w 2d
Container & Payload Design	2M 3w 3d
Parachute Design	1M 3w
Deployment Design	1M 2w 3d
Revision and Remodeling	2M 2w 2d
Study of Strucrutal Material	1M 5d
3D Printing & Manufacturing	4M 2w 2d
Prototype Design & Assmebly	1M 1w 6d
Environmental Test	1M 3w 3d
Integration Test	1w 3d
Parachute Test	2w 4d
Assembly & Integration Test (…	1w 2d
Launch Day	

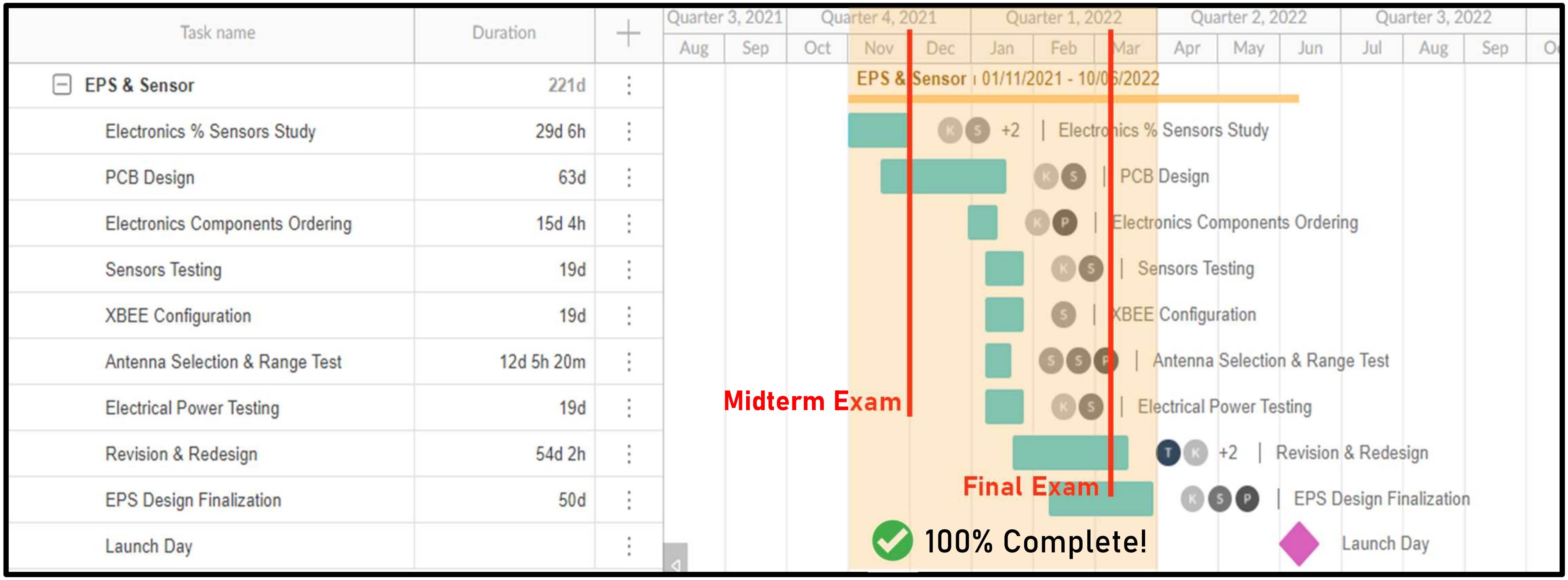


K — Kittipon Amornprasertkij

N — Nuchit Vichitkijja

Detailed Program Schedule
(2 / 3)

EPS & Sensor Subsystem



S — Suvijak Piyanopharoj

K — Krin Kaweewonsonthorn

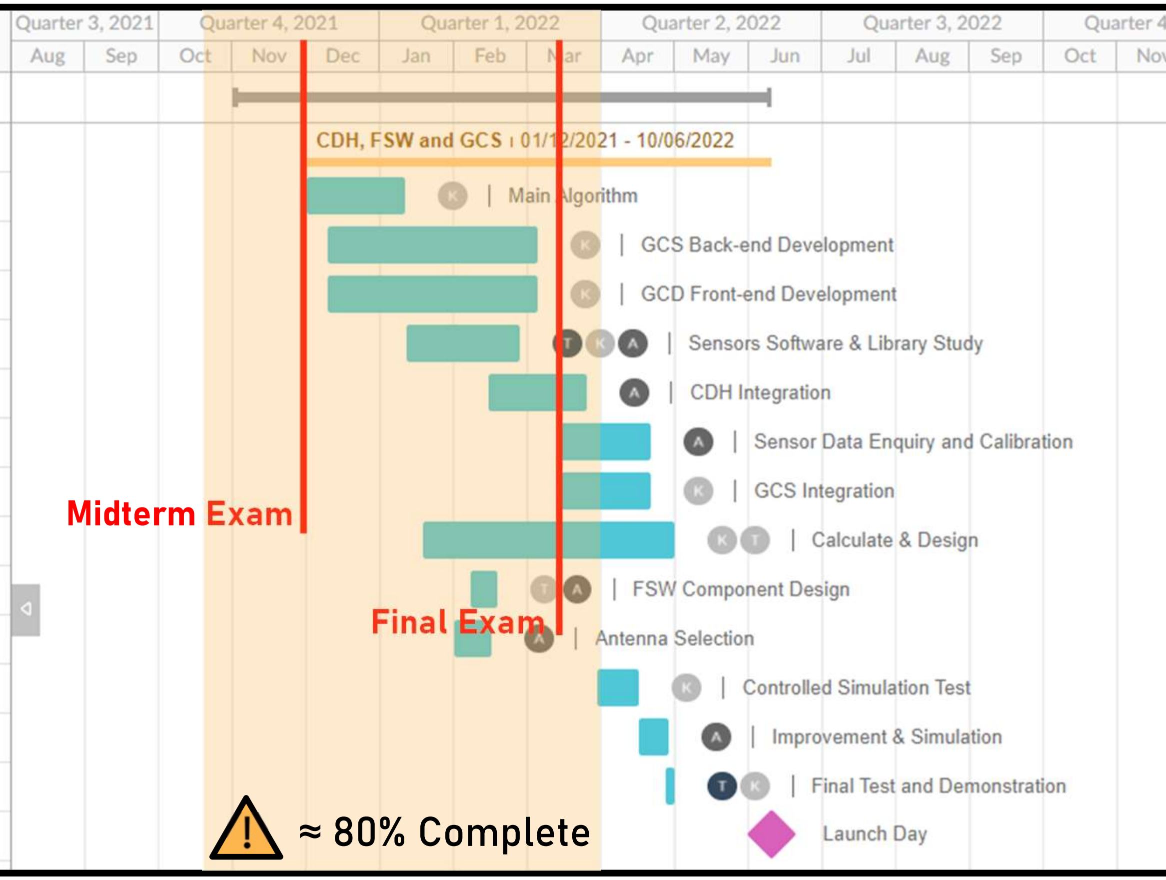
S — Shinakrit Laokittichai

P — Pitiphoom Achapramote

Detailed Program Schedule
(3 / 3)

CDH, FSW, and GCS

Task name	Duration
	221d
CDH, FSW and GCS	191d
Main Algorithm	41d
GCS Back-end Development	85d
GCD Front-end Development	85d
Sensors Software & Library Study	45d
CDH Integration	40d
Sensor Data Enquiry and Calibration	38d
GCS Integration	38d
Calculate & Design	102d
FSW Component Design	10d
Antenna Selection	14d
Controlled Simulation Test	17d
Improvement & Simulation	12d
Final Test and Demonstration	4d
Launch Day	



K — Krissada Singhakachain

T — Thasvarit Kruerklai

A — Arkkhanirut Pandej

Shipping and Transportation

- We'll put the probe in Pelican cases that's the appropriate size. In the cases, we'll keep important equipments, including CanSat, payload, electronics components and antenna.

- We will ensure that our items are securely packed and delivered to the plane's cargo section during America's flight
- In USA, all equipment will be transported in a rented car.

Conclusions

Major accomplishments

- CanSat Prototype is made and is also under weight limit.
- Most of the subsystems are manufactured and functional.
- Financial management is secured.
- Schedules are created.

Major unfinished work

- Member Visas have not been applied yet.

Testing to complete

- Environmental Test
- Long-range Communication Test
- Full system test launches

Flight software status

- FSW is already functional.