CanSat 2022
Preliminary Design Review (PDR) Outline
Version 3.0

Team # 1022
Descendere

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
3D	Three dimensional
A	Ampere
ABS	Acrylonitrile butadiene styrene
°C	Celsius
CAD	Computer-aided design
CDH	Communication and Data Handling Subsystem
CI	Communication Interface
CI	Communication Interface
C_m	Pitching moment coefficient
cm	Centimeters
CONOPS	Concept of Operation
COTS	Commercial-off-the-shelf
CRQ	Competition requirement
csv, CSV	Comma Separated Value

Acronyms	Definition
dB	Decibel
dBi	Decibel relative to isotropic
DC	Descent control
EEPROM	Electrically Erasable Programmable Read-Only Memory
EPS	Electrical Power Subsystem
FME	For Mobile Equipment
Fps	Frames per second
FSW	Flight Software
g	Grams
g/cm^3	Gram per cubic centimeter
GB	Gigabytes
GCS	Ground Control System
GHz	Gigahertz
GPIO	General-Purpose Input Output

Acronyms (2/3)

Acronyms	Definition
GPRS	General Packet Radio Service
GPS	Global Positioning System
Gs	Gravitational Force
GS	Ground station
GSM	Global System for Mobile
h, hrs	Hour
H	Height
hPa	hectopascal
Hz, hz	Hertz
I^2C	Inter-Integrated circuit
kB	Kilobytes
kg	Kilograms
L	Length
LED	Light-emitting diode

Acronyms	Definition
Li-ion	Lithium ion
m	Meters
m/s	Meter per second
m/s^2	Meter per second squared
m^2	Square meter
mA	Milliampere
mA·h	Milliampere hour
MCU	Microcontroller
MHz	Megahertz
mm	Millimeters
MS	Mechanical Subsystem
mV	Millivolts
N/A	Not applicable/Not available
PCB	Printed circuit board

Acronyms (3/3)

Acronyms	Definition
PETG	Polyethylene terephthalate glycol
PFR	Post Flight Review
PLA	Polylactic acid
PP	Polypropylene
RAM	Random Access Memory
RP	Reverse Polarity
RPM, rpm	Revolutions per minute
RTC	Real-time clock
s	seconds
SMA	Sub-Miniature Version A
SPI	Serial Peripheral Interface
TP	Tethered Payload
µA	Microampere
UART	Universal asynchronous receiver-transmitter

Acronyms	Definition
UI	User Interface
UTC	Universal Time Coordinated
V	Volts
Vcc	Voltage at the Common Collector
W	Watts/Width
W∙h	Watts hour

Acronyms	Verification Methods
A	Analysis
D	Demonstration
I	Inspection
T	Test

Systems 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 .

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.

System Requirement Summary (1/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
1.	Total mass of the CanSat (science payloads and container) shall be 600 grams +/- 10 grams.	CRQ	Very High				
2.	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 400 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.	CRQ	Very High				
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.	CRQ	Very High				
4.	The container shall be a fluorescent color; pink, red or orange.	CRQ	Very High				
5.	The container shall be solid and fully enclose the science payloads. Small holes to allow access to turn on the science payloads are allowed. The end of the container where the payload deploys may be open.	CRQ	Very High				

System Requirement Summary (2/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
6.	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	CRQ	Very High				
7.	The rocket airframe shall not be used as part of the CanSat operations.	CRQ	Very High				
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.	CRQ	Very High				
9.	The Parachutes shall be fluorescent Pink or Orange	CRQ	Very High				
10.	The descent rate of the CanSat (container and science payload) shall be 15 meters/second +/- 5m/s after deployment while above 400 meters.	CRQ	Very High				

System Requirement Summary (3/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
11.	The descent rate of the CanSat shall be reduced to 5 meters/second +/-2 m/s when the CanSat descends below 400 meters.	CRQ	Very High				
12.	0 altitude reference shall be at the launch pad.	CRQ	Very High				
13.	All structures shall be built to survive 15 Gs of launch acceleration.	CRQ	Very High				
14.	All structures shall be built to survive 30 Gs of shock.	CRQ	Very High				
15.	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	CRQ	Very High				

System Requirement Summary (4/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
16.	All mechanisms shall be capable of maintaining their configuration or states under all forces.	CRQ	Very High				
17.	Mechanisms shall not use pyrotechnics or chemicals.	CRQ	High				
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.	CRQ	Very High				
19.	Both the container and payload shall be labeled with team contact information including email address.	CRQ	Very High				
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.	CRQ	Very High				

System Requirement Summary (5/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
21.	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE radios are also allowed.	CRQ	Very High				
22.	XBEE radios shall have their NETID/PANID set to their team number	CRQ	Very High				
23.	XBEE radios shall not use broadcast mode.	CRQ	High				
24.	The container shall include electronics to receive sensor payload telemetry.	CRQ	Very High				
25.	The container shall include electronics and mechanisms to release the science payload on a tether.	CRQ	Very High				

System Requirement Summary (6/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
26.	The container shall include a GPS sensor to track its position.	CRQ	Very High				
27.	The container shall include a pressure sensor to measure altitude.	CRQ	Very High				
28.	The container shall measure its battery voltage	CRQ	Very High				
29.	The container shall transmit its telemetry once per second (1 Hz) in the formats described in the Telemetry Requirements section.	CRQ	Very High				
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.	CRQ	Very High				

System Requirement Summary (7/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
31.	The container shall stop polling and transmitting telemetry when it lands.	CRQ	Very High				
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.	CRQ	Very High				
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.	CRQ	Very High				
34.	An audio beacon is required for the container. It shall be powered after landing.	CRQ	Very High				
35.	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	CRQ	High				

System Requirement Summary (8/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
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.	CRQ	Very High				
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.	CRQ	Very High				
38.	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	CRQ	Very High				
39.	The CanSat must operate during the environmental tests laid out in Section 3.5.	CRQ	Very High				
40.	The CanSat shall operate for a minimum of two hours when integrated into the rocket.	CRQ	Very High				

System Requirement Summary (9/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
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.	CRQ	Very High				
42.	The science payload shall transmit sensor telemetry to the container when polled.	CRQ	Very High				
43.	-	-	-				
44.	The science payload shall include a pressure sensor, temperature sensor and rotation sensor.	CRQ	Very High				
45.	The science payload shall include a video camera pointing 45 degrees up from the payload NADIR direction.	CRQ	Very High				

System Requirement Summary (10/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
46.	The science payload shall maintain orientation so the camera always faces south within +/- 20 degrees.	CRQ	Very High				
47.	The payload shall be connected to the container with a 10 meter tether.	CRQ	Very High				
48.	At 300 meters, the payload shall be released from the container at a rate of .5 meters per second.	CRQ	Very High				
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.	CRQ	Very High				
50.	The container shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	CRQ	Very High				

System Requirement Summary (11/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
51.	The container shall have its time set to UTC time to within one second before launch.	CRQ	High				
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.	CRQ	Very High				
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.	CRQ	Very High				
54.	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands	CRQ	Very High				
55.	The ground station shall command the CanSat to start transmitting telemetry prior to launch.	CRQ	Very High				

System Requirement Summary (12/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
56.	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	CRQ	Very High				
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.	CRQ	Very High				
58.	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	CRQ	Very High				
59.	Each team shall develop their own ground station.	CRQ	Very High				
60.	All telemetry shall be displayed in real time during descent on the ground station.	CRQ	Very High				

System Requirement Summary (13/14)

Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
61.	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	CRQ	Medium				
62.	Teams shall plot each telemetry data field in real time during flight.	CRQ	Very High				
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.	CRQ	Very High				
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.	CRQ	Very High				
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.	CRQ	Very High				

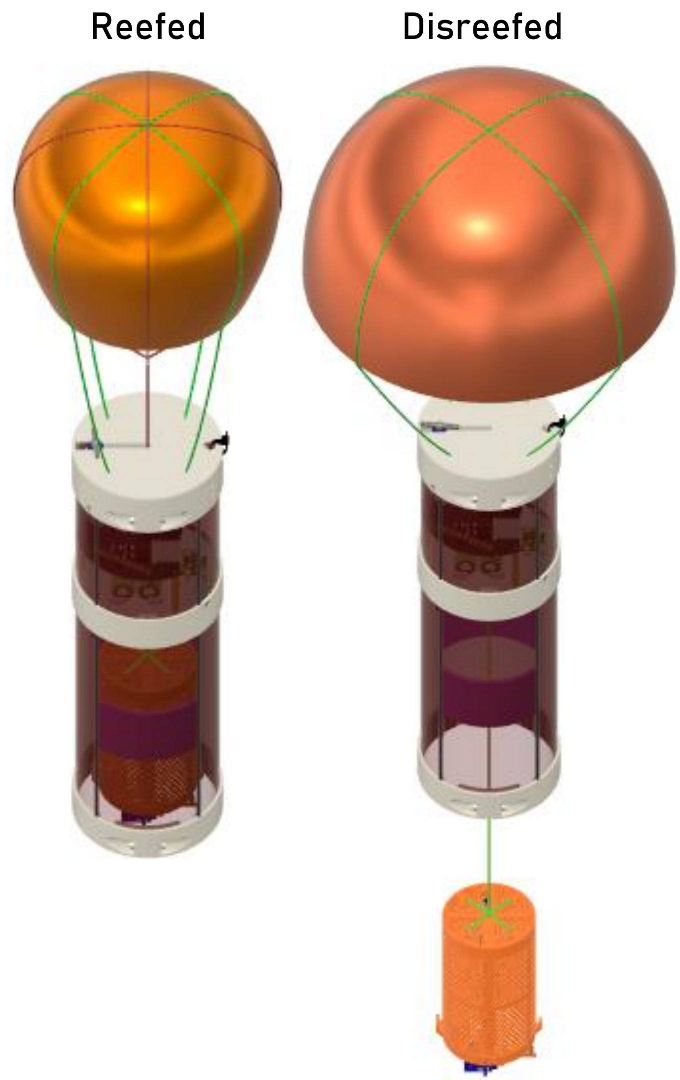
System Requirement Summary (14/14)

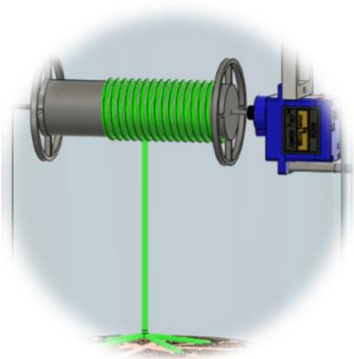
Number	Requirement	Rationale	Priority	Verification			
				A	I	T	D
66.	When in simulation mode, the ground station shall transmit pressure data from a csv file provided by the competition at a 1 Hz interval to the container.	CRQ	Very High				
67.	The science payloads shall not transmit telemetry during the launch, and the container shall command the science payloads to begin telemetry transmission upon release from the container	CRQ	Very High				
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.	CRQ	Very High				

System Level CanSat Configuration Trade & Selection (1/4)

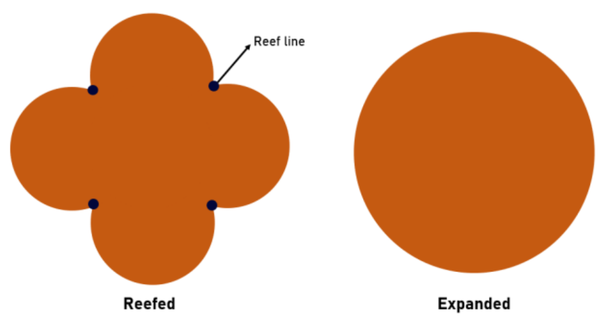
Configuration 1: Reef Parachute, Reel System

- The system will use only one parachute.
- The parachute will have reefing lines to control the effective area of the parachute.
- The reefing lines which are pulling the parachute to decrease the effective area will be melted by nichrome wire to reduce the descent rate to 5 m/s.
- The deploy system will use a reel connected to an actuator to release the tethered payload.
- Once the CanSat reaches 300 m, the actuator will start rotating the reel and release the tethered payload within 20 seconds.



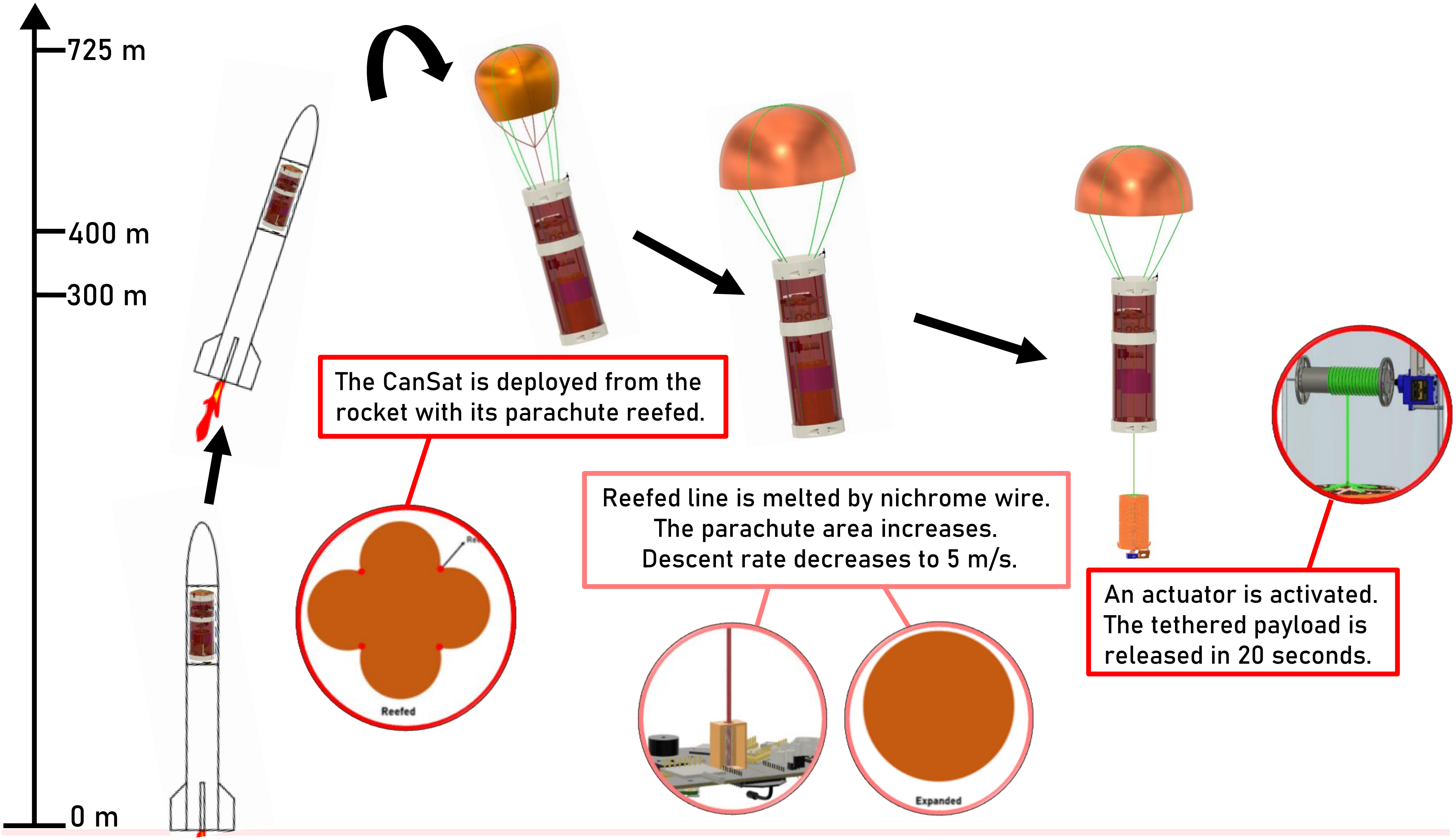


Reel mechanism



Change of parachute area

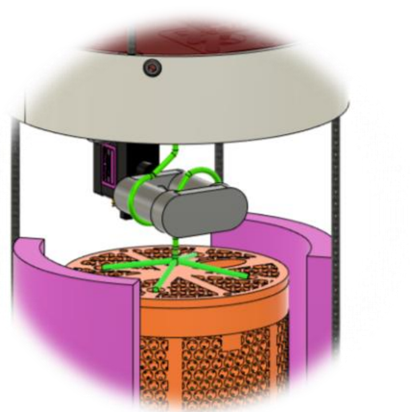
- Configuration 1 CONOPS



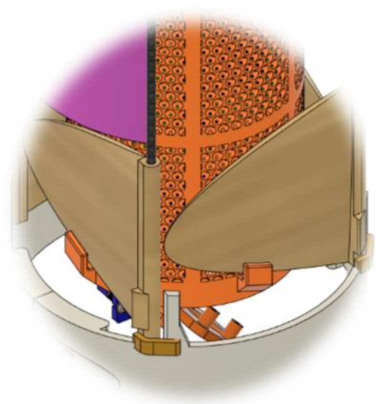
System Level CanSat Configuration Trade & Selection (3/4)

Configuration 2: Two-Stage Parachute, Brake System

- The system will descend by using two different parachutes at different altitudes.
- The deploy system will use a servo attached to two cylinders that has a middle gap between it to let the tether spooling down. It can both deploy payload and reduce the spooling rate by rotating to fold and unfold the tether.
- The container has retractable fins which are going to be deployed when the tethered payload is unspooling down.



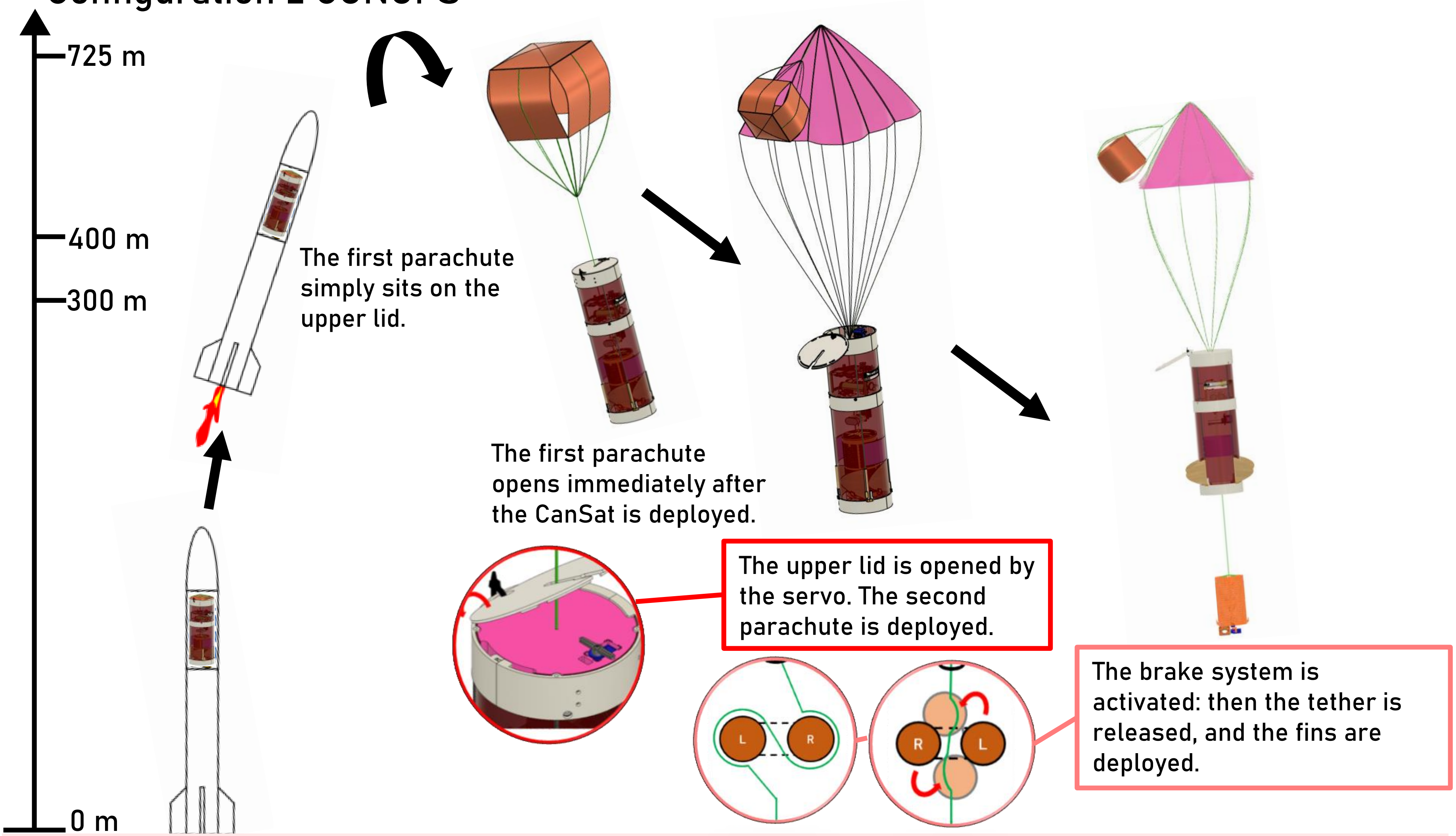
Brake mechanism



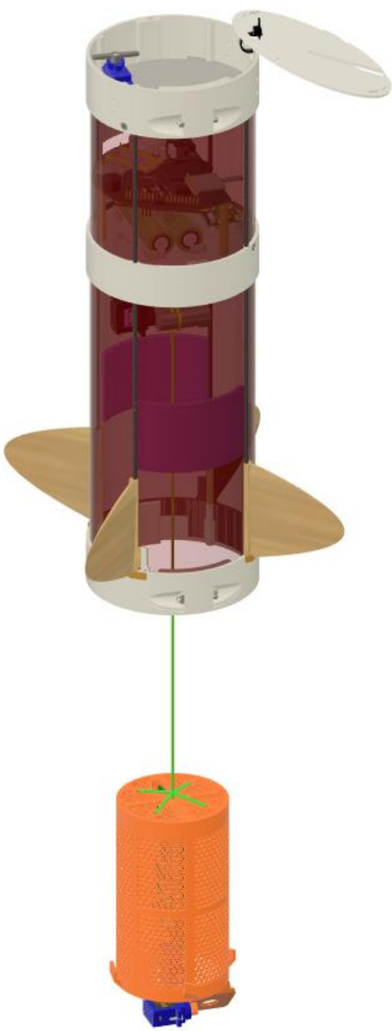
Retractable Fins

System Level CanSat Configuration Trade & Selection (4/4)

- Configuration 2 CONOPS



System Level CanSat Configuration Selection

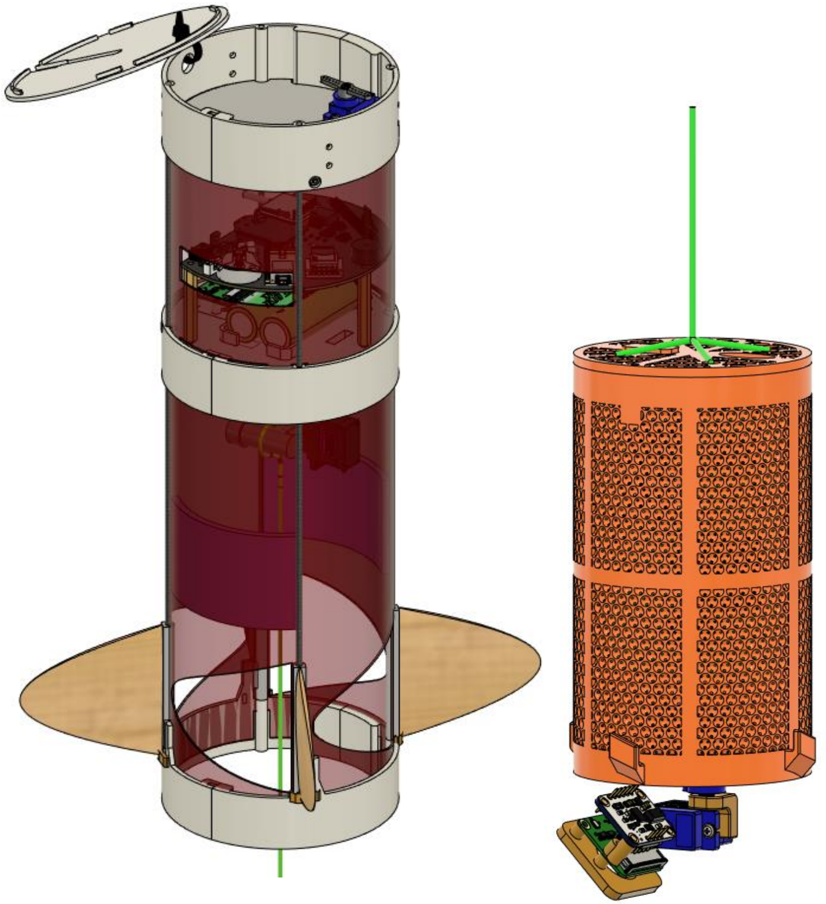


Configuration	Advantages	Disadvantages
Configuration 1: Reef Parachute, Reel System	• Consume less space • Less weight • Less complex deployment mechanism	• Complicated descent rate calculation (Parachute) • Disposable cords
Configuration 2: Two-Stage Parachute, Brake System	• Easy to manufacture • Simple descent rate calculation	• Additional servo mass • Consume more space • Additional calculation for brake system

Selected Design	Rationales
Configuration 2: Two-Stage Parachute, Brake System	• Easier to assemble on site • Could be tested many times

Physical Layout (1/6)

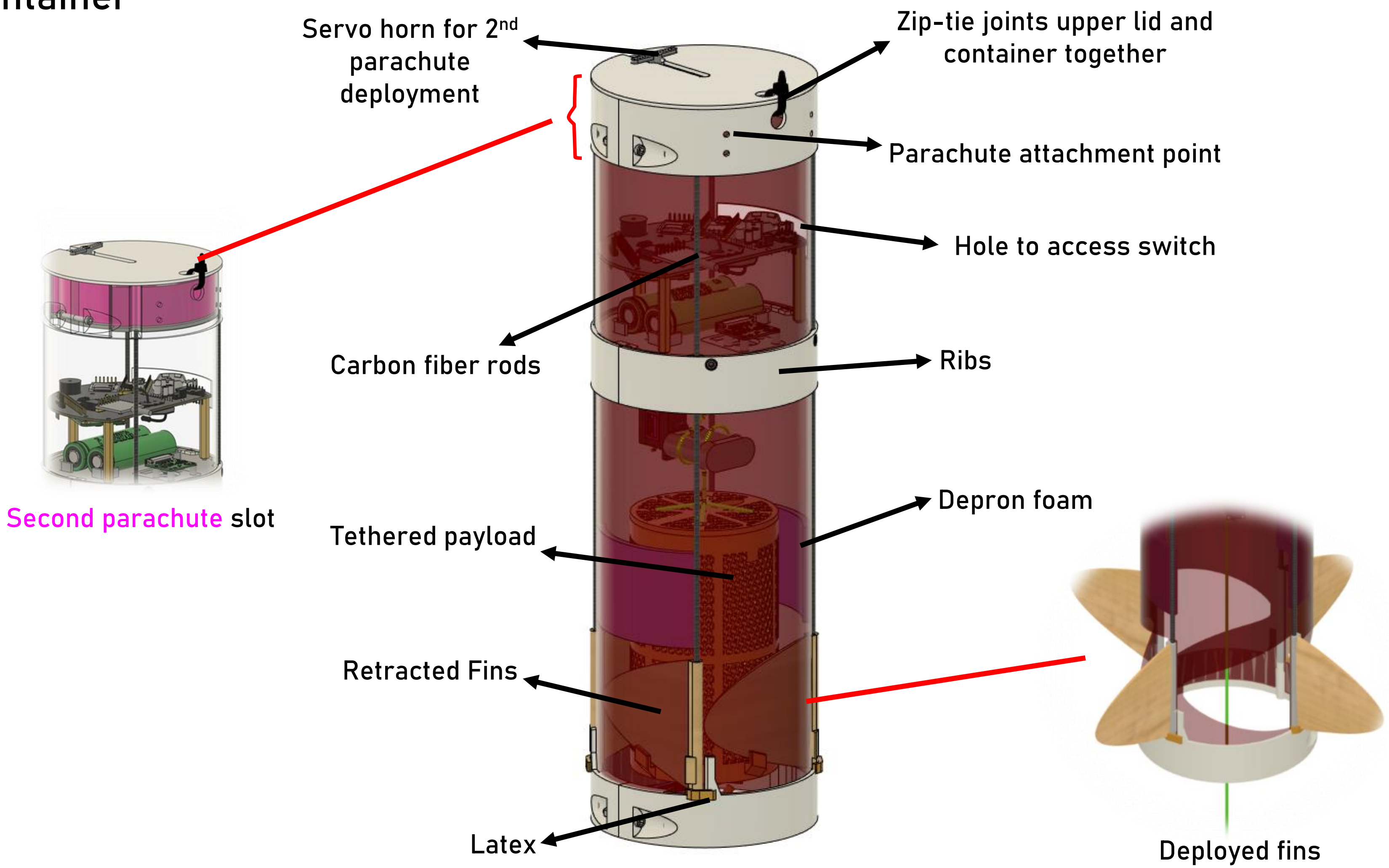
Launch Configuration



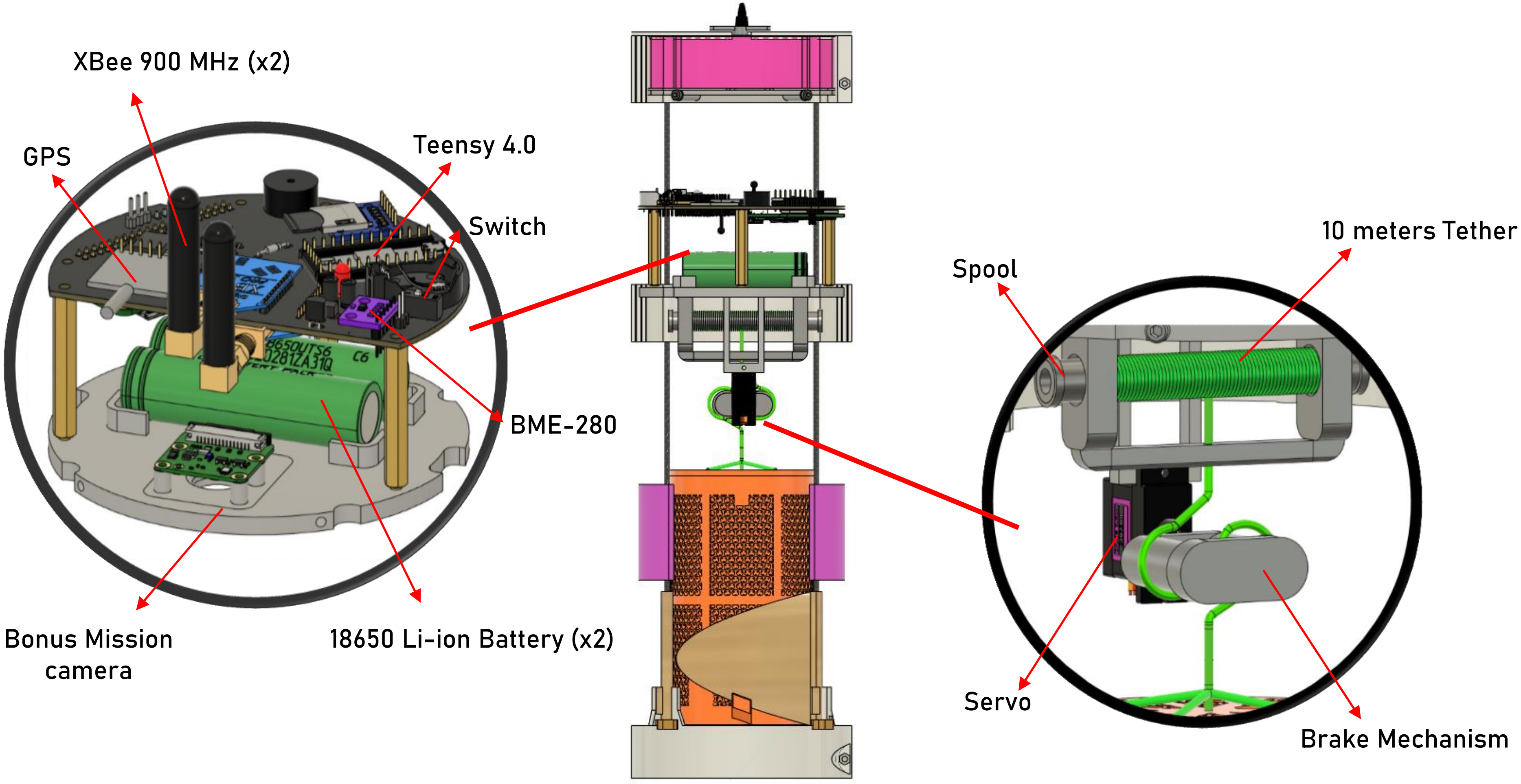
Deployed Configuration

Physical Layout (2/6)

Container



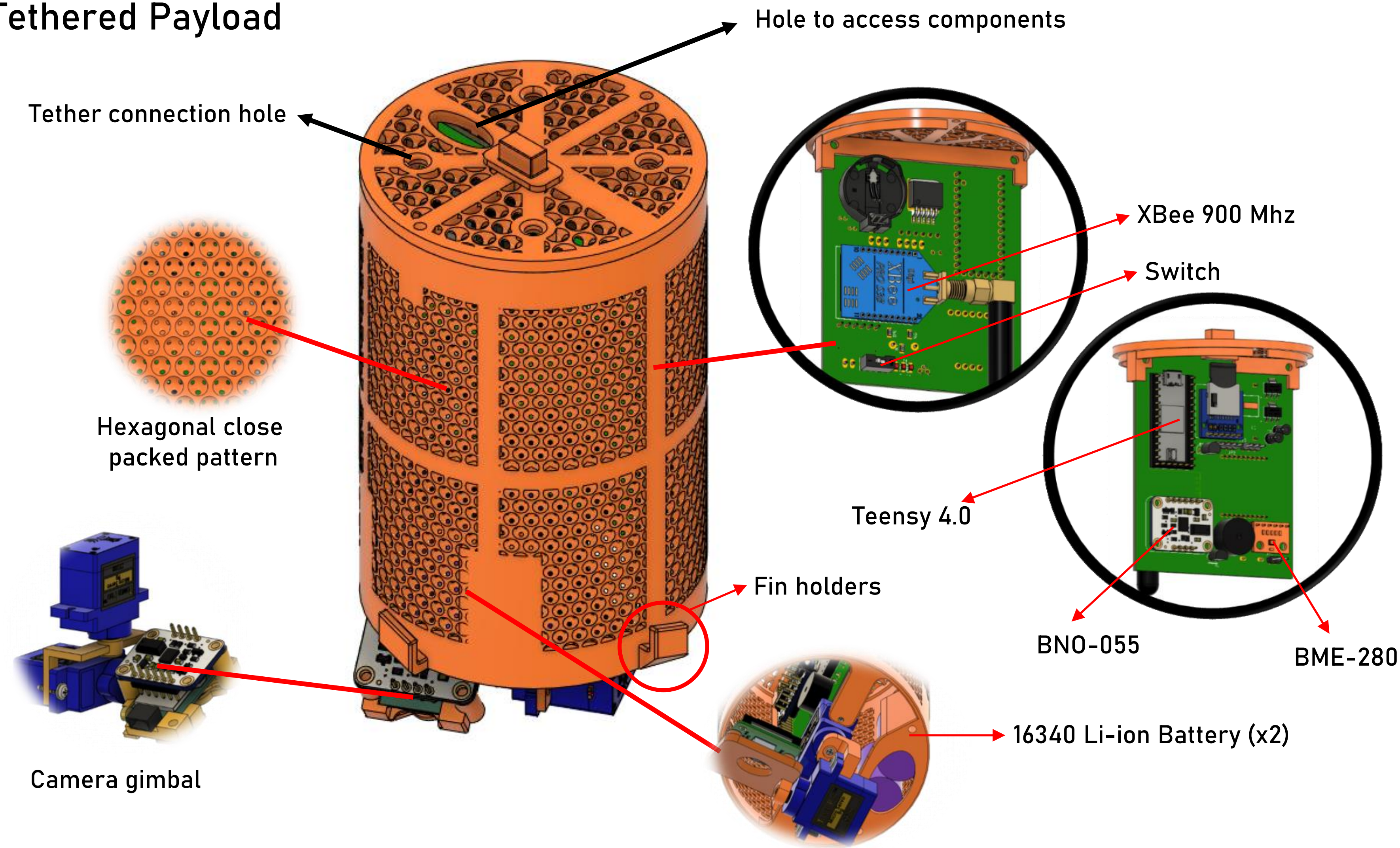
Container



XBee 900 MHz (x2)
GPS
Teensy 4.0
Switch
BME-280
Bonus Mission camera
18650 Li-ion Battery (x2)
Spool
10 meters Tether
Servo
Brake Mechanism

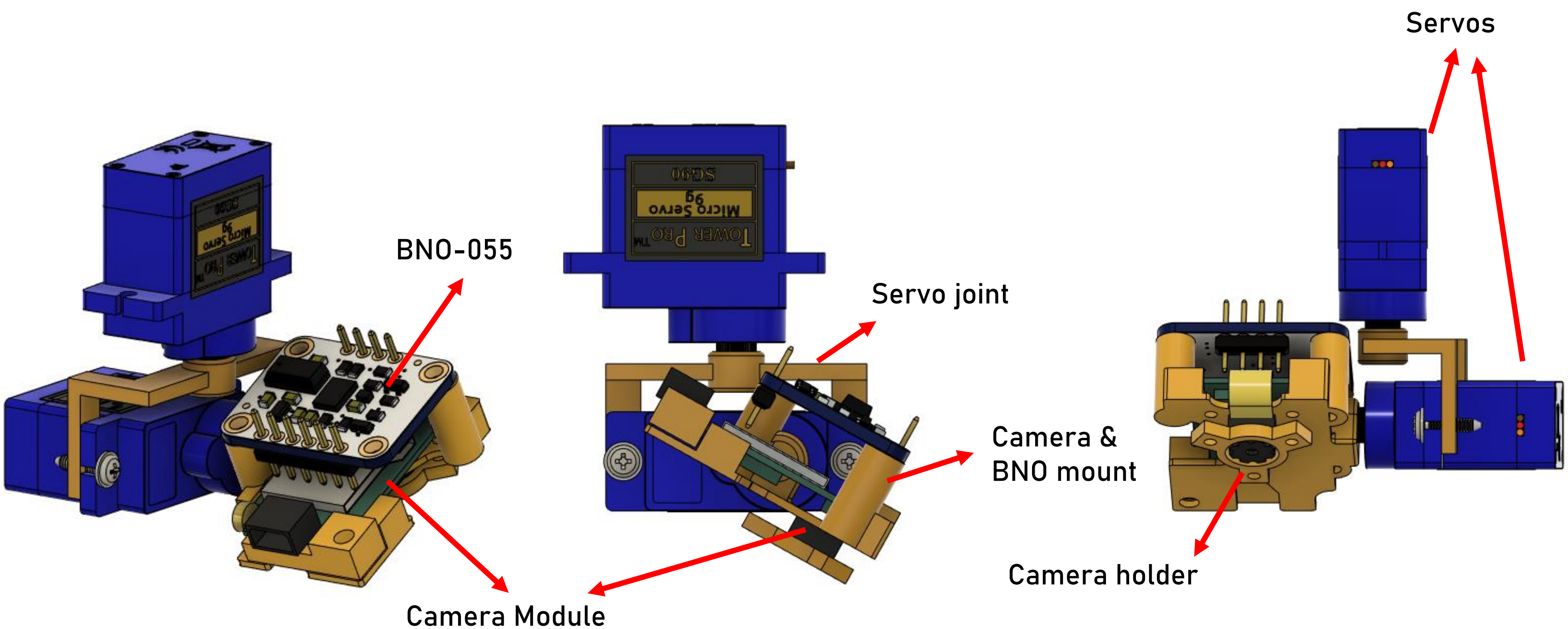
Physical Layout (4/6)

Tethered Payload



Physical Layout (5/6)

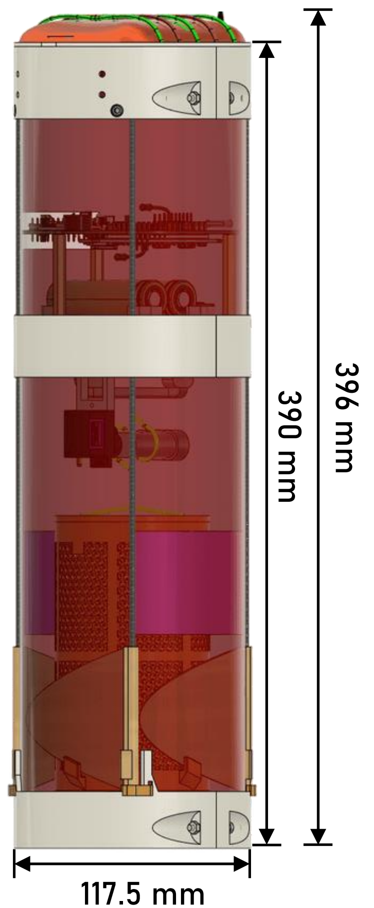
Camera Gimbal



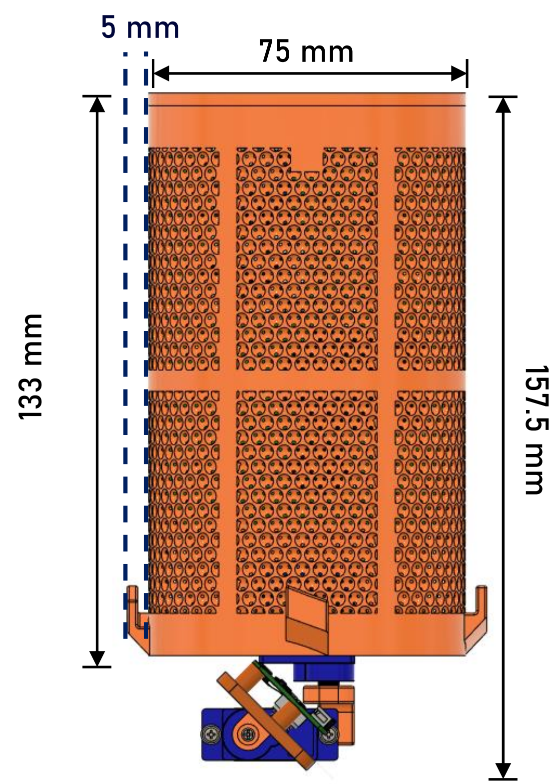
Front view

Side view

Dimension



Container Dimension



Tethered Payload Dimension

System Concept of Operations (1/2)

Pre-launch Check

- Flight day planning
- Arrival at competition area
- Final pre-launch integration and operations check
- Powering-up and loading CanSat into the rocket
- Launch and Descent Operations

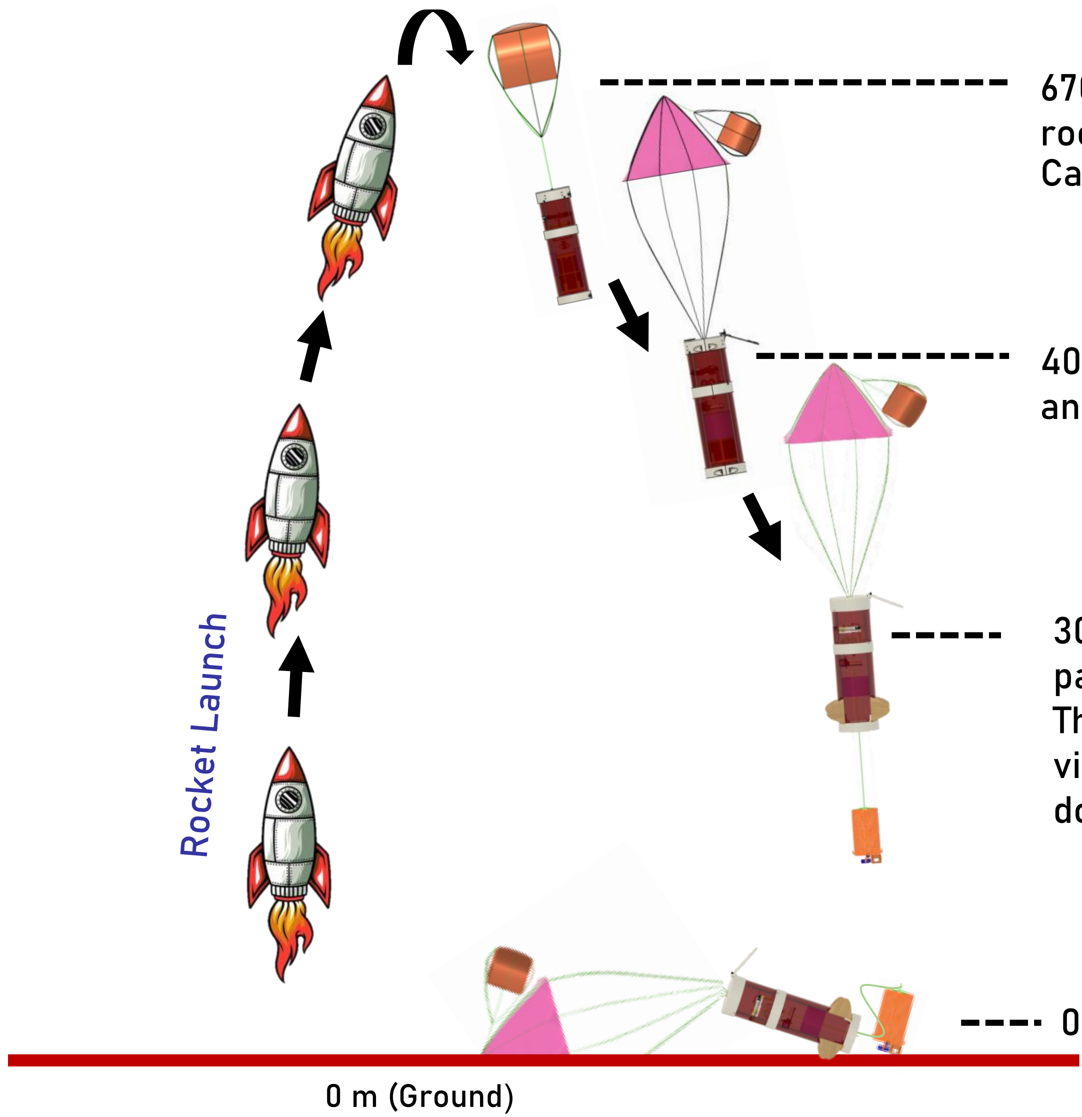
Launch and Descent operation

- CanSat insertion in rocket payload bay
- Rocket launches into the atmosphere
- Separation and Descent Control Phase
- Obtaining Telemetry Data and CSV File
- Generation via GCS software

Post-Launch operation

- Container and Tethered Payload
- Inspection of CanSat damage
- Analysis of measured data
- PFR preparation
- PFR presentation to judge

System Concept of Operations (2/2)



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 reduce the descent rate to 5 m/s.

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

0 m - CanSat landed, ready for recovery.

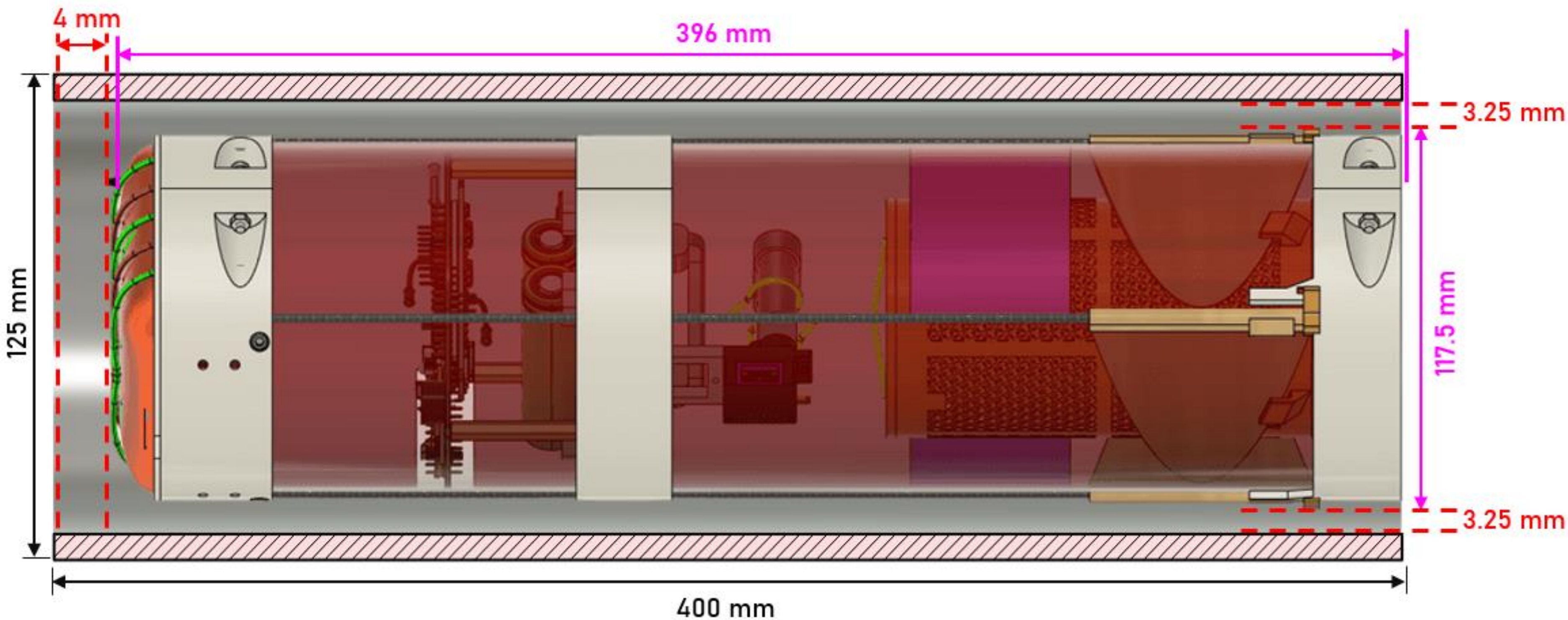
Launch Vehicle Compatibility

Container Dimension
- Height - 390 mm
- Height with stowed parachute - 396 mm
- Diameter - 117.5 mm

Tethered Payload Dimension
- Height (Gimbal Included) - 157.75 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

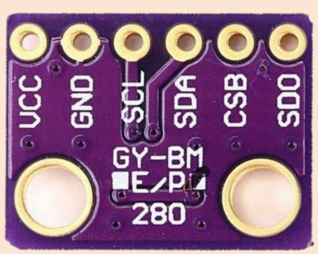
Suvijak Piyanopharoj

Sensor Subsystem Overview

NO	Sensor type	Sensor model	Purpose	Section
1.	Air Pressure Sensor	BME-280	Measuring air pressure for altitude calculation	TP and Container
2.	Air Temperature Sensor	BME-280	Measuring air temperature	TP
3.	Battery Voltage Sensor	Teensy Analog Pin	Measuring Battery Voltage of TP and container	TP and Container
4.	Rotation Sensor	BNO-055	Measuring rotational motion	TP
5.	Camera	Adafruit 3202	Recording video during the mission process	TP
6.	GPS	MAX-M8Q	Container position tracking	Container
7.	Bonus Camera	Raspberry Pi Camera v2.1	Recording video for bonus mission	Container

Container Air Pressure Sensor Trade & Selection

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
BMP388	I²C, SPI	300.00~1250.00	±0.50	21.6 x 16.6 x 3.0	1.2	3.3 V, 5 V (Module)	3.4	9.95

Selected Container Air Pressure Sensor		Rationale
BME-280		• Highly accessible Library • Smaller size compared to BMP388 • Less weight • More affordable in our country • Familiarity with the sensor

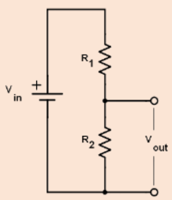
Container GPS Sensor Trade & Selection

Sensor Model	CI (s)	Accuracy (m)	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
MAX-M8Q	UART	±2.0	22 x 22 x 1.6	8.5	3.3 V (Module)	25	26.39
NEO-M8N	UART	±2.0	25 x 35 x 3	17	3.3 V (Module)	23	32.49

Selected Container GPS Sensor	Rationale
MAX-M8Q 	• High accuracy for ±2.0 m • More affordable in Thailand • Lower price • Smaller size compared to NEO-M8N • Less weight • Highly accessible library

Container Battery Voltage Sensor Trade & Selection

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
Arduino Voltage Sensor	Analog	0.00~5.00	±0.1%	20	4.8 mV	1.49

Selected Container Battery Voltage Sensor	Rationale
Teensy 4.0 Analog Pin 	• Included with Teensy • No external area occupation needed • No extra cost • No I^2C, SPI or UART interfaces needed • Easy to calculate

Payload Air Pressure Sensor Trade & Selection

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
BMP388	I^2C, SPI	300.00~1250.00	±0.50	21.6 x 16.6 x 3.0	1.2	3.3 V, 5 V (Module)	3.4	9.95

Selected Payload Air Pressure Sensor	Rationale
BME-280 	• Highly accessible Library • Smaller size compared to BMP388 • Less weight • More affordable in our country • Familiarity with the sensor

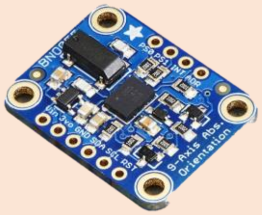
Payload Air Temperature Sensor Trade & Selection

Sensor Model	CI (s)	Range (°C)	Accuracy (°C)	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
BME-280	I^2C, SPI	-40.0~85.0	±1.0	15.5 x 11.5 x 3.0	1.0	3.3 V (Module)	3.6×10^{-3}	3.25
DHT22	I^2C	-40.0~85.0	±0.5	27.7 x 59.7 x 14.7	2.4	3.3 V (Module)	2.5	4.42
DHT12	I^2C	-20.0~60.0	±0.5	12.3 x 7.5 x 4.7	8.0	3.3 V (Module)	1.0	1.49

Selected Payload Air Temperature Sensor	Rationale
BME-280 	• Higher accuracy for ±1.0 °C with 0.1 °C Resolution • More affordable in our country • Lowest weight from all • Highly accessible Library • Familiarity with the sensor

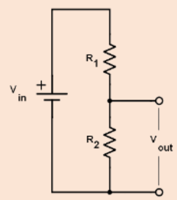
Payload Rotation Control Sensor Trade & Selection

Sensor Model	CI (s)	Resolution (degree)	Accuracy (degree)	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
BNO-055	I^2C, 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
BMX-055	SPI, I^2C	±1.00	±1.00	3.0 x 4.5 x 1	10.0	3.3 V (Module)	5	7.72

Selected Payload Rotation Sensor	Rationale
BNO-055 	• High accuracy and Resolution for ± 1 degree • Less weight • Compatible for the mission • More affordable in our country

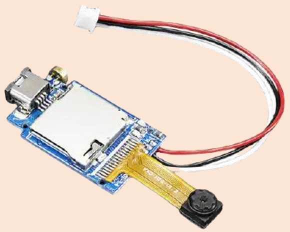
Payload Battery Voltage Sensor Trade & Selection

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
Arduino Voltage Sensor	Analog	0.00~5.00	±0.1%	20	4.8 mV	1.49

Selected Payload Battery Voltage Sensor	Rationale
Teensy 4.0 Analog Pin 	• Included with Teensy • No external area occupation needed • No extra cost • No I^2C, SPI or UART interfaces needed • Easy to calculate

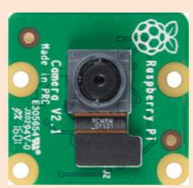
Payload Camera Trade & Selection

Sensor Model	CI (s)	Maximum Video Resolution	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
Raspberry Pi Camera v2.1	Camera Serial Interface	1920x1080 @30fps	25.0 x 23.0 x 9.0	3.00	5.0 V	250	25.00
Adafruit 3202	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

Selected Camera		Rationale
Adafruit 3202		• Small size • Eliminate the problem of microcontrollers taking up more space, weight and power consumption • Inexpensive • The resolution meets mission requirement

Bonus Camera Trade & Selection

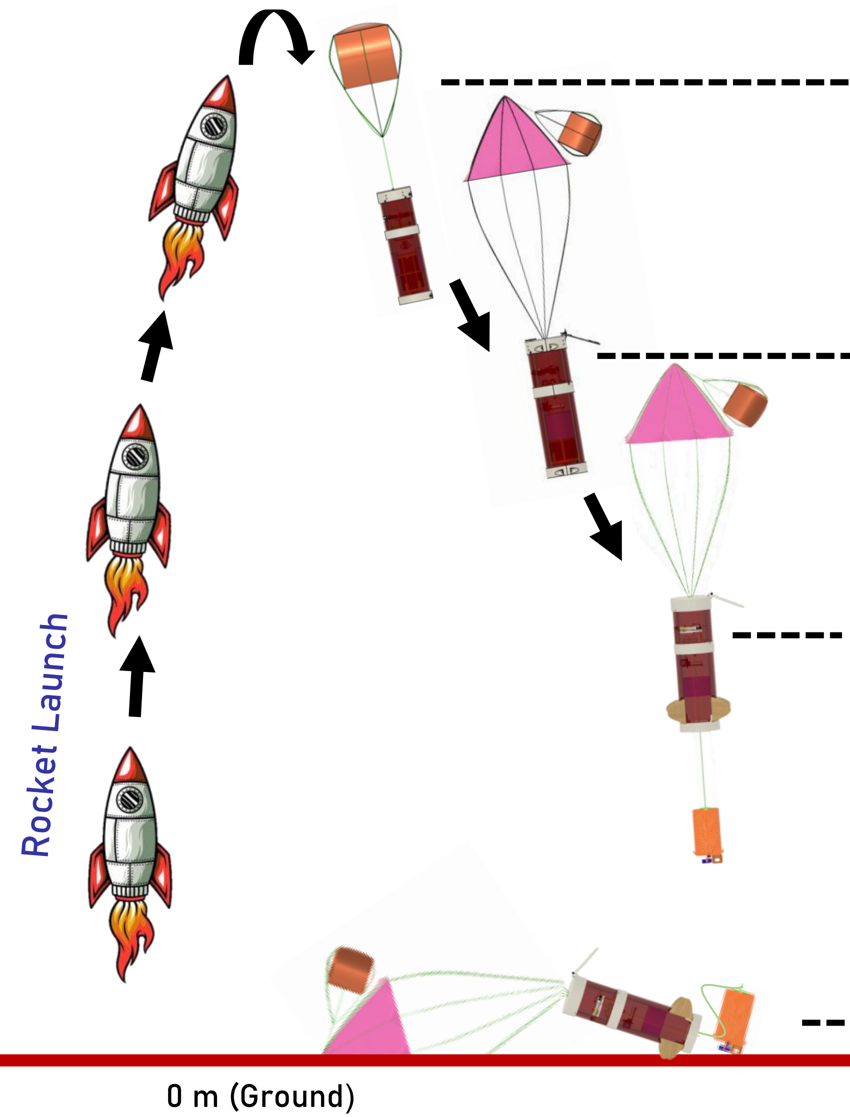
Sensor Model	CI (s)	Maximum Video Resolution	Size (mm)	Mass (g)	Supply Voltage	Current (mA)	Cost ($)
Raspberry Pi Camera v2.1	Camera Serial Interface	1920x1080 @30fps	25.0 x 23.0 x 9.0	3.00	5.0 V	250	25.00
OV7670	Serial Camera Control Bus	640x480 @30fps	33.0 x 33.0 x 20.0	15.00	3.3 V	N/A	14.00

Selected Camera		Rationale
Raspberry Pi Camera v.2.1		• Video resolution meets mission requirement • Able to record the video according to specification in Mission Guide • Less weight • Smaller size

Descent Control Design

Nuchit Vichitkijja, Thasvarit Krueklai

Descent Control Overview (1/5)



670-725 m - CanSat is deployed from rocket. First parachute will be deployed, the CanSat descends with a rate of 15 m/s

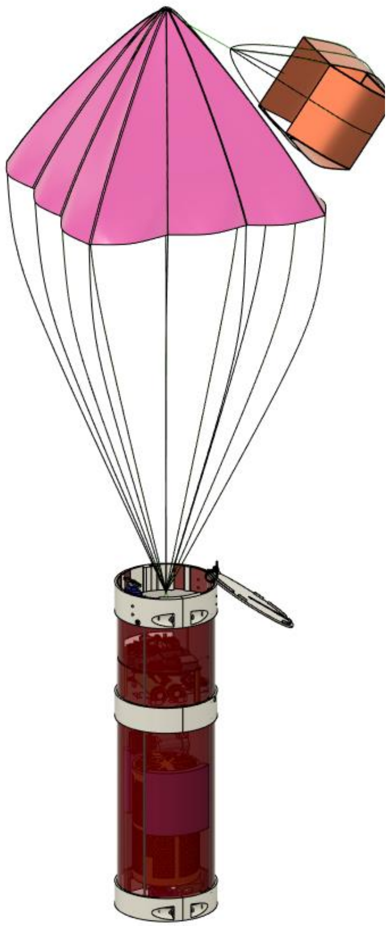
400 m - Second parachute will be deployed and reduce the descent rate to 5 m/s.

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

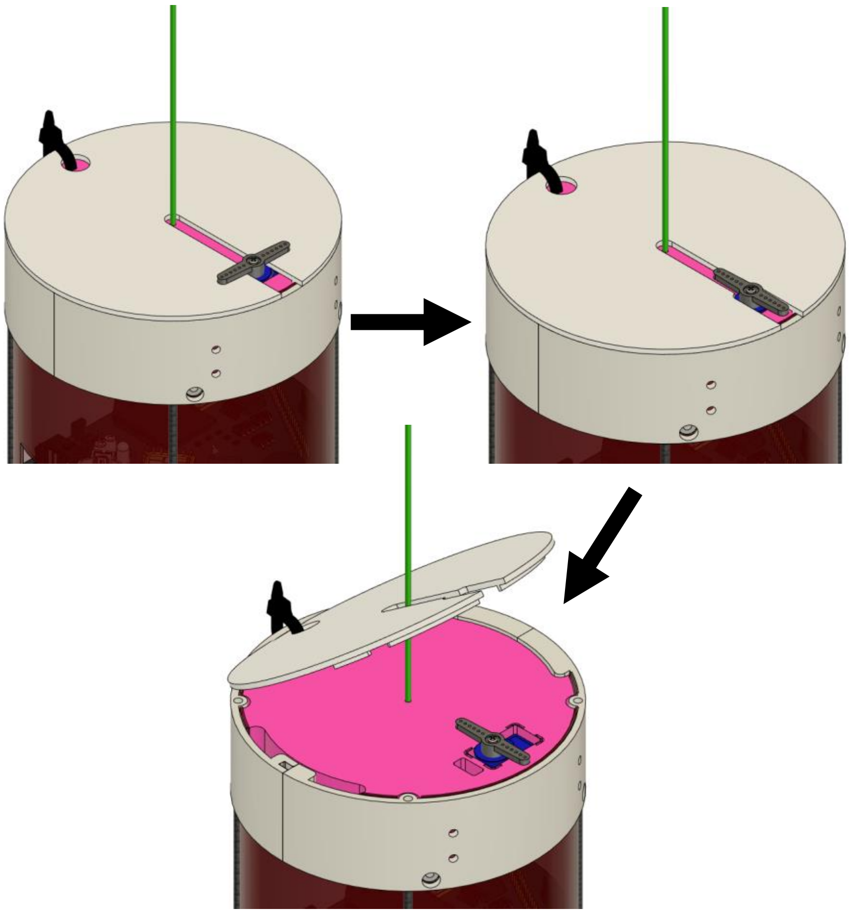
0 m - CanSat landed, ready for recovery.

Container Descent control system [Two-Stage Parachute]

1^{st} Stage



2^{nd} Stage

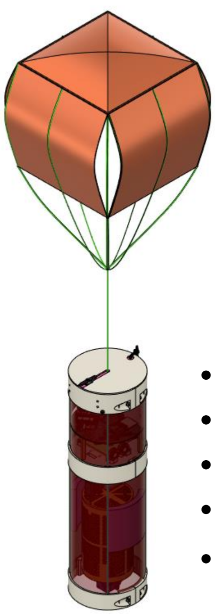


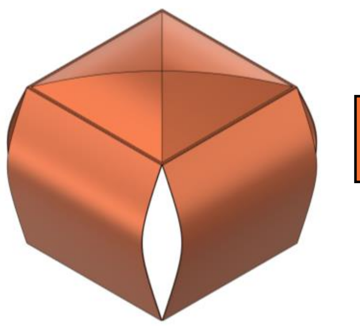
Detailed view on parachute deploy system

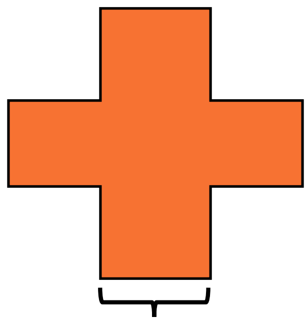
Descent Control Overview (3/5)

Container Descent control system [Two-Stage Parachute]

First Parachute: Cube Parachute

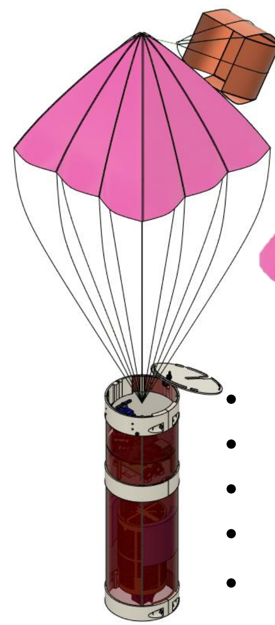


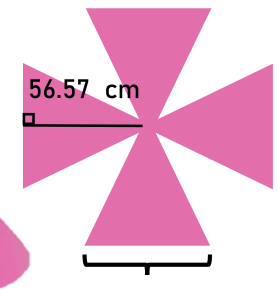




- Drag Coefficient : 0.54
- Material Used : Nylon
- Color : Fluorescent orange
- Effective Area : 0.0791 m^2
- It will control the descent of the CanSat at a rate of 15 m/s.

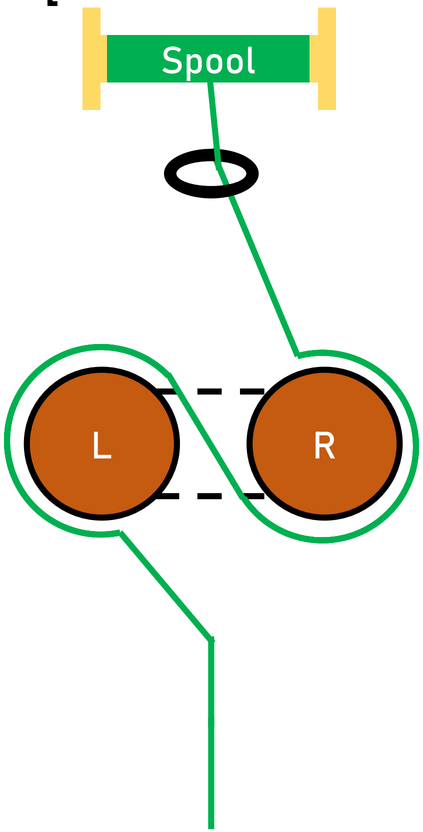
Second Parachute: da Vinci’s Parachute



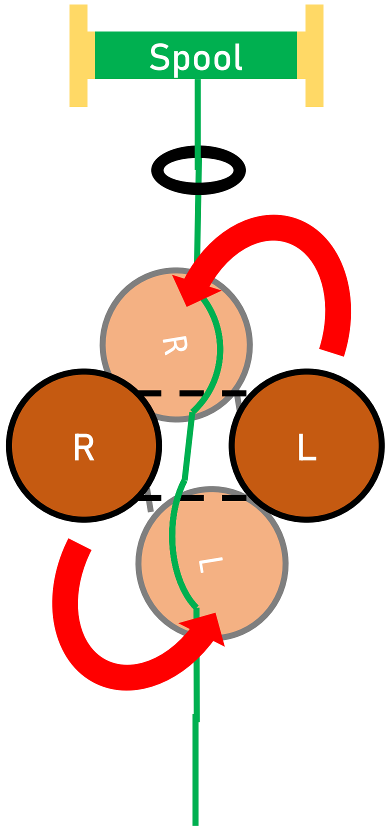


- Drag Coefficient : 0.9
- Material Used : Nylon
- Color : Fluorescent pink
- Effective Area : 0.4267 m^2
- It will control the descent of the CanSat at a rate of 5 m/s.

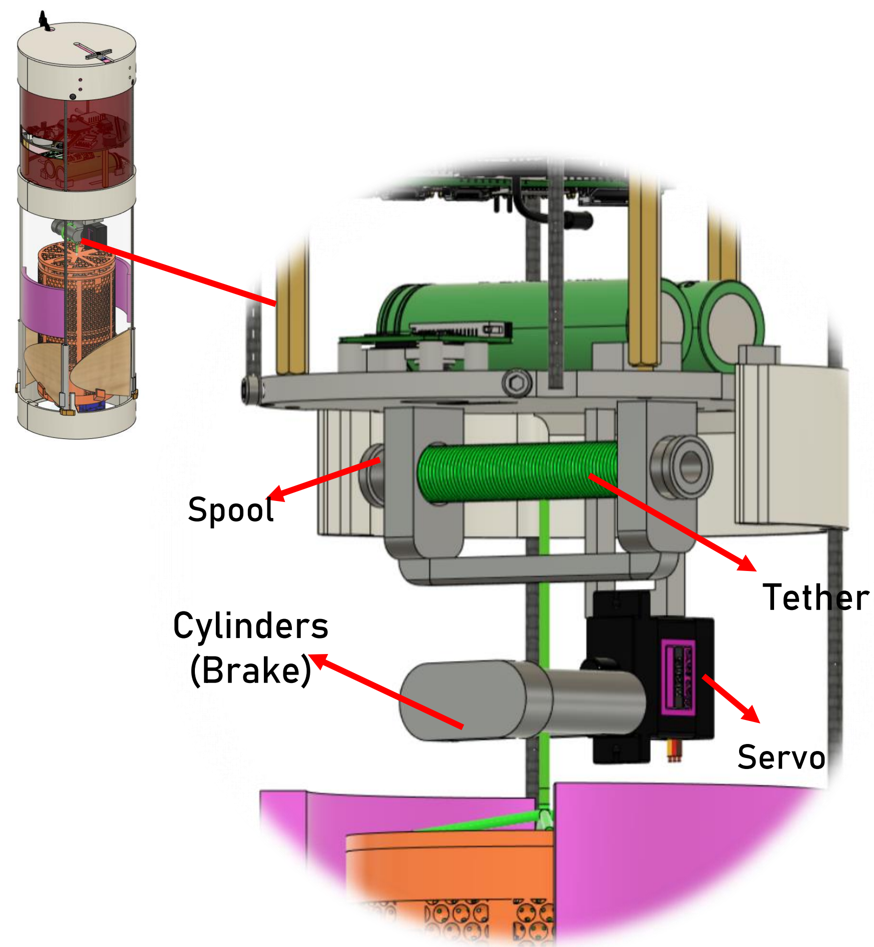
Payload Descent control system [Brake Mechanism]



The cylinders restrict the tether from spooling down



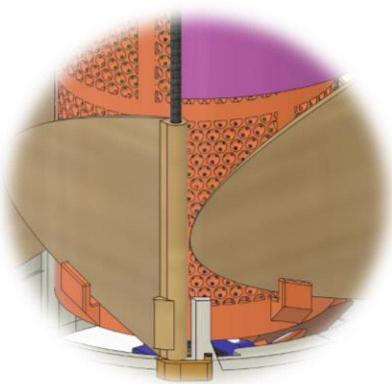
Once the CanSat reaches 300 m, the servo will be triggered and tilts the break. The tether is unfolded.



Descent Control Overview (5/5)

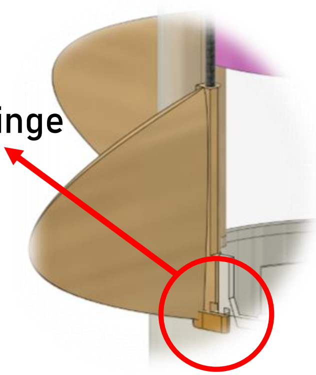
Container and Payload Descent Stability Control [Elliptical Fin]

- The retractable elliptical fins are attached at the bottom of the container.
- The fins are deployed when the payload starts to spool down.

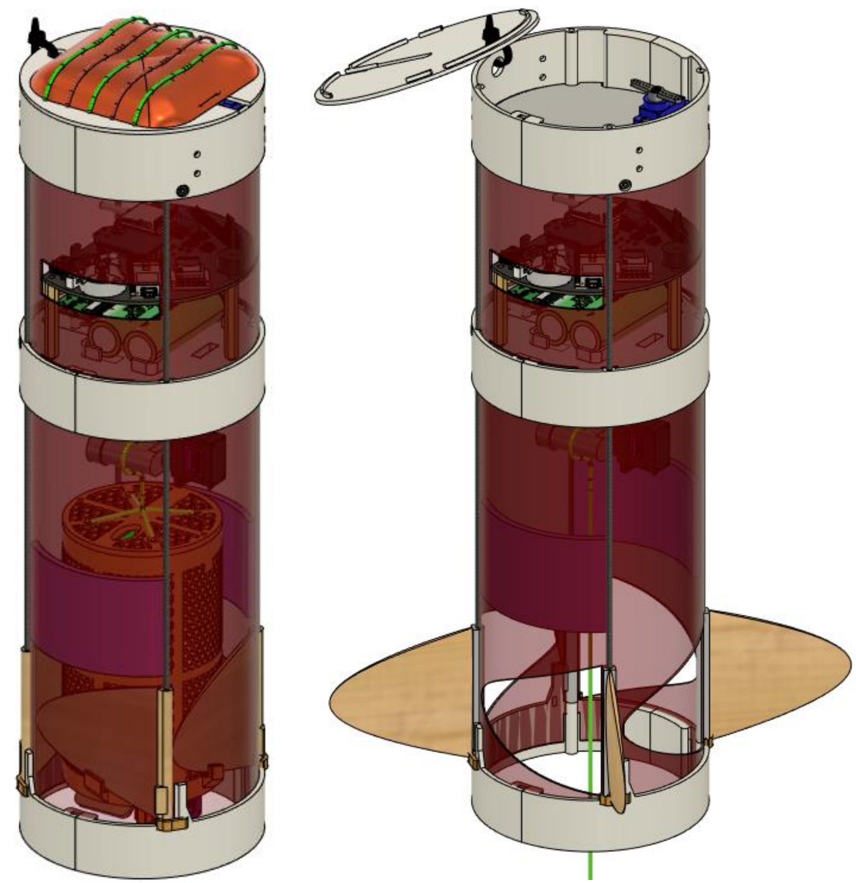


Fins retracted with payload hooks

Latex hinge



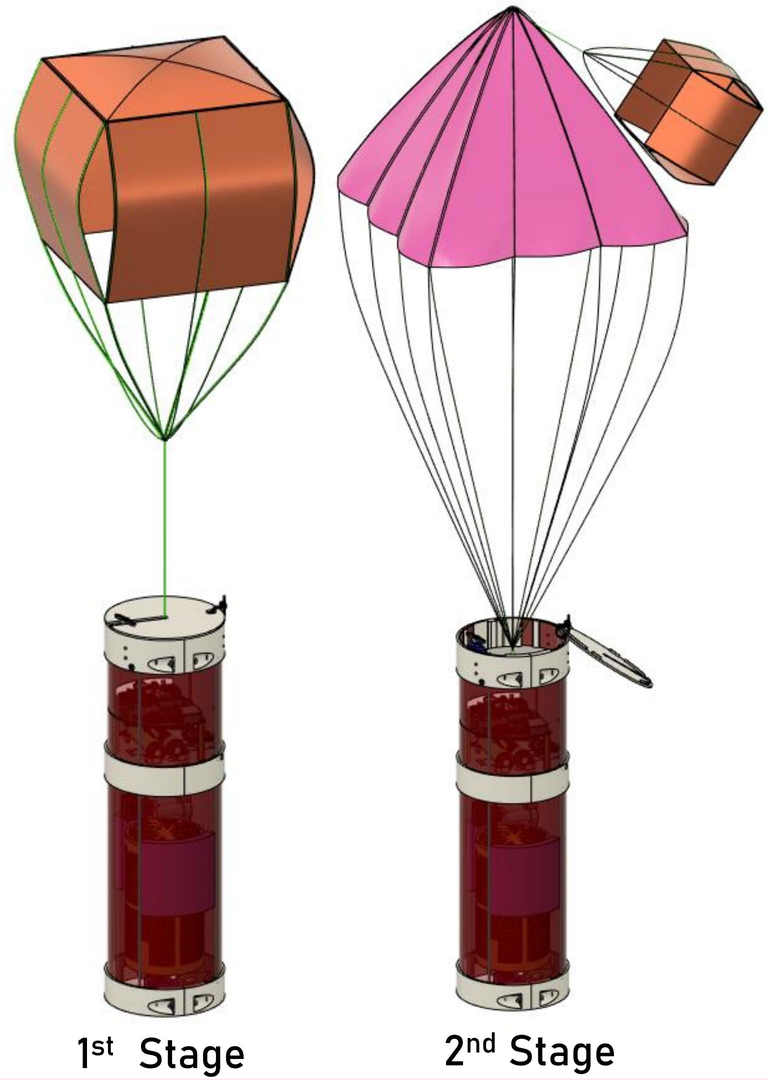
Fins deployed



Stowed Configuration Deployed Configuration

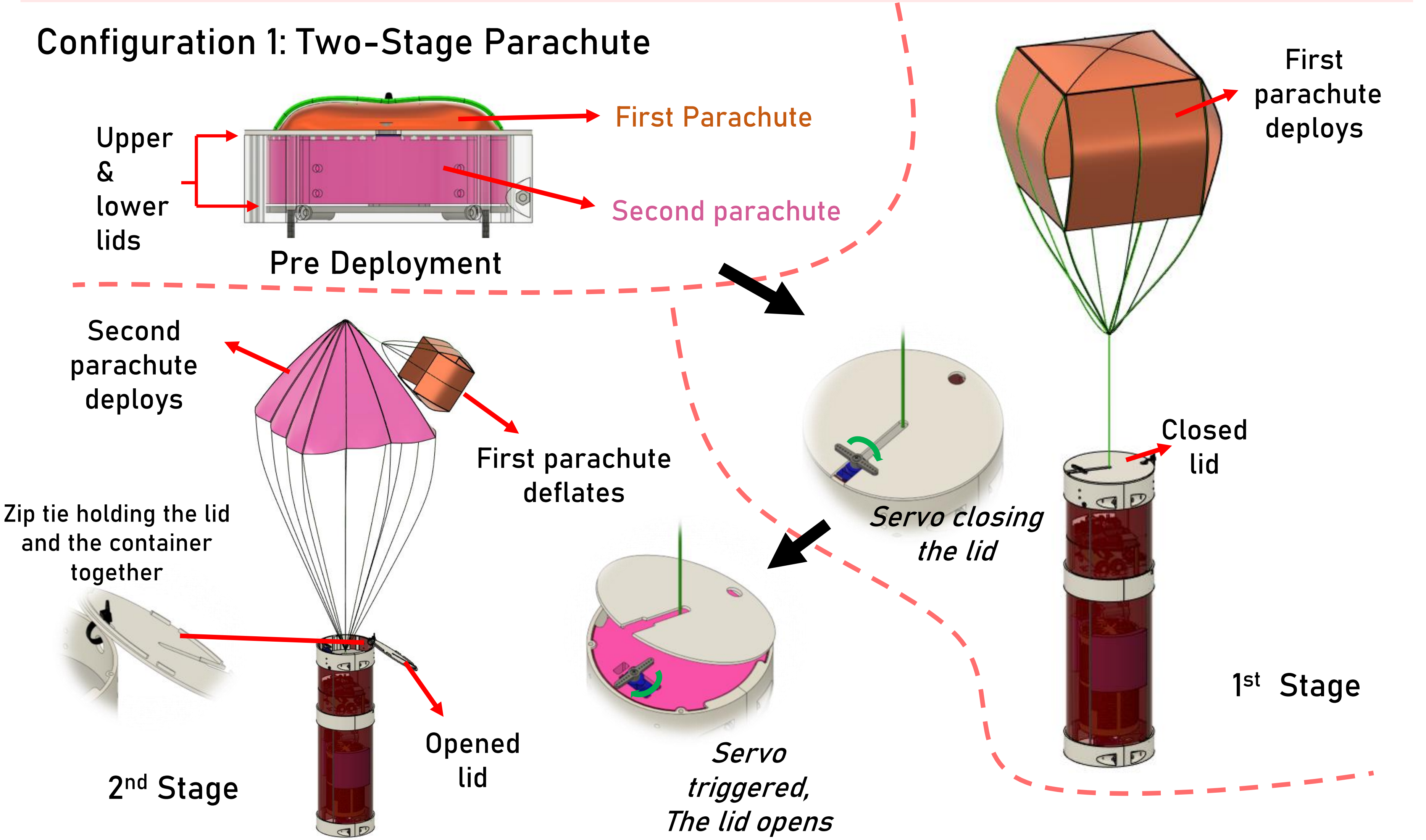
Configuration 1: Two-Stage Parachute

- The CanSat has two parachutes for different altitudes.
- Two Parachutes are sewn to each other. The second parachute is stowed between the lids of the CanSat
- The first parachute will be deployed immediately after ejected from the rocket.
- The CanSat will descend at a rate of 15 m/s with the first parachute. 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.
- The second parachute will reduce the descent rate to 15 m/s.
- After second parachute is deployed, the first parachute will still be attached to it. We have already tested that it won't affect CanSat descent rate.



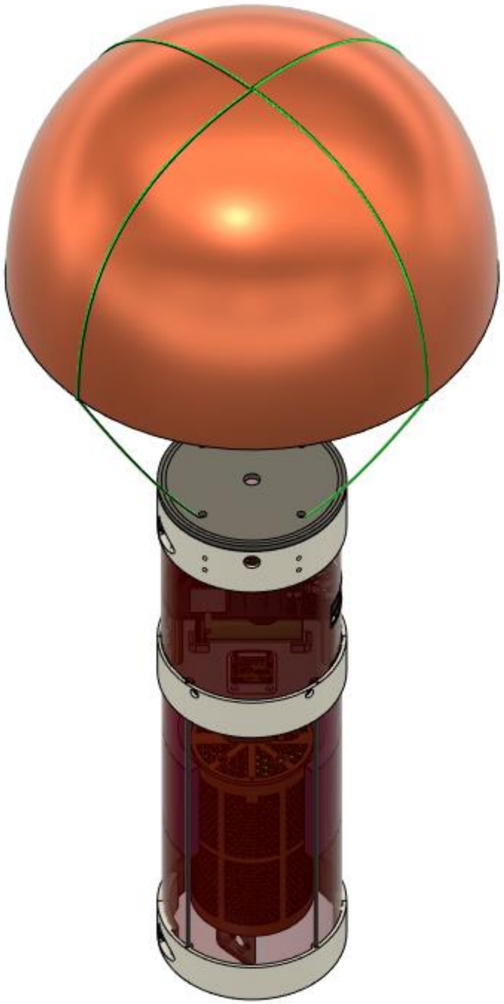
Container Descent Control Strategy Selection and Trade (2/10)

Configuration 1: Two-Stage Parachute



Container Descent Control Strategy Selection and Trade (3/10)

Reefed

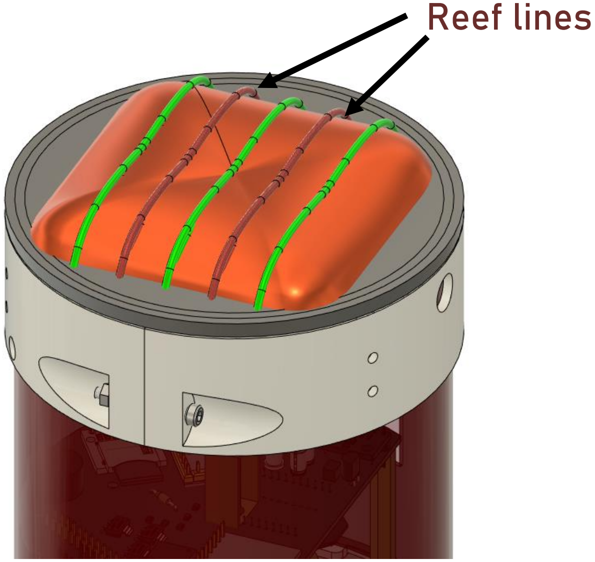


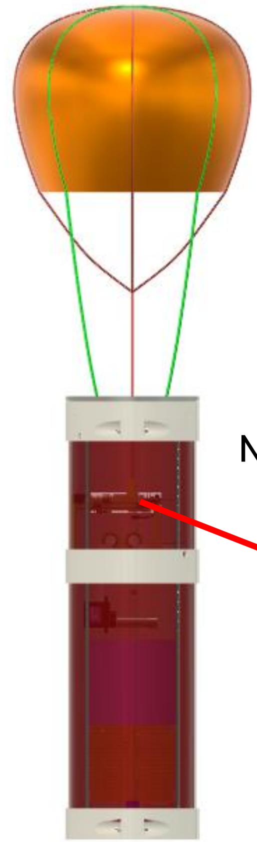
Fully Expanded

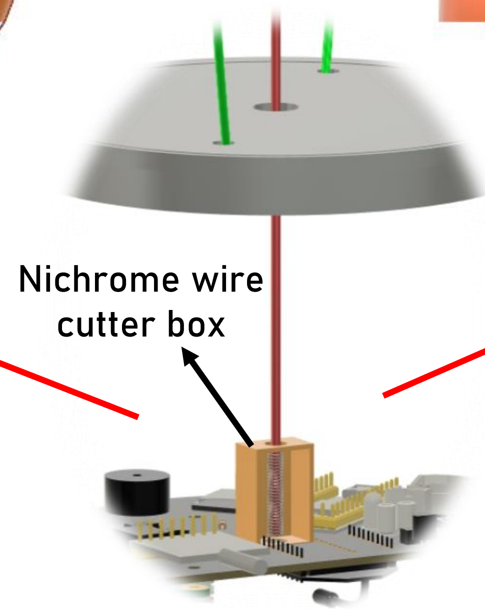
Configuration 2: Reefing Parachute

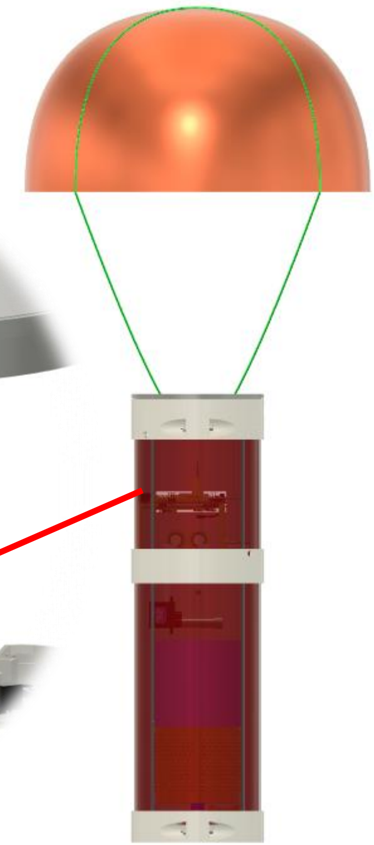
- The CanSat has only one parachute.
- The parachute has reef lines that can restrict the area of the parachute.
- When the CanSat is loaded into the rocket, the parachute is already reefed.
- Once the CanSat is ejected from the rocket, the reefed parachute will reduce the descent rate to 15 m/s.
- When the CanSat reaches 400 meters, the reef lines will be melted by heat generated by the nichrome wire. The parachute area will increase afterward.
- The expanded parachute will reduce the descent rate to 5 m/s.

Configuration 2: Reefing Parachute



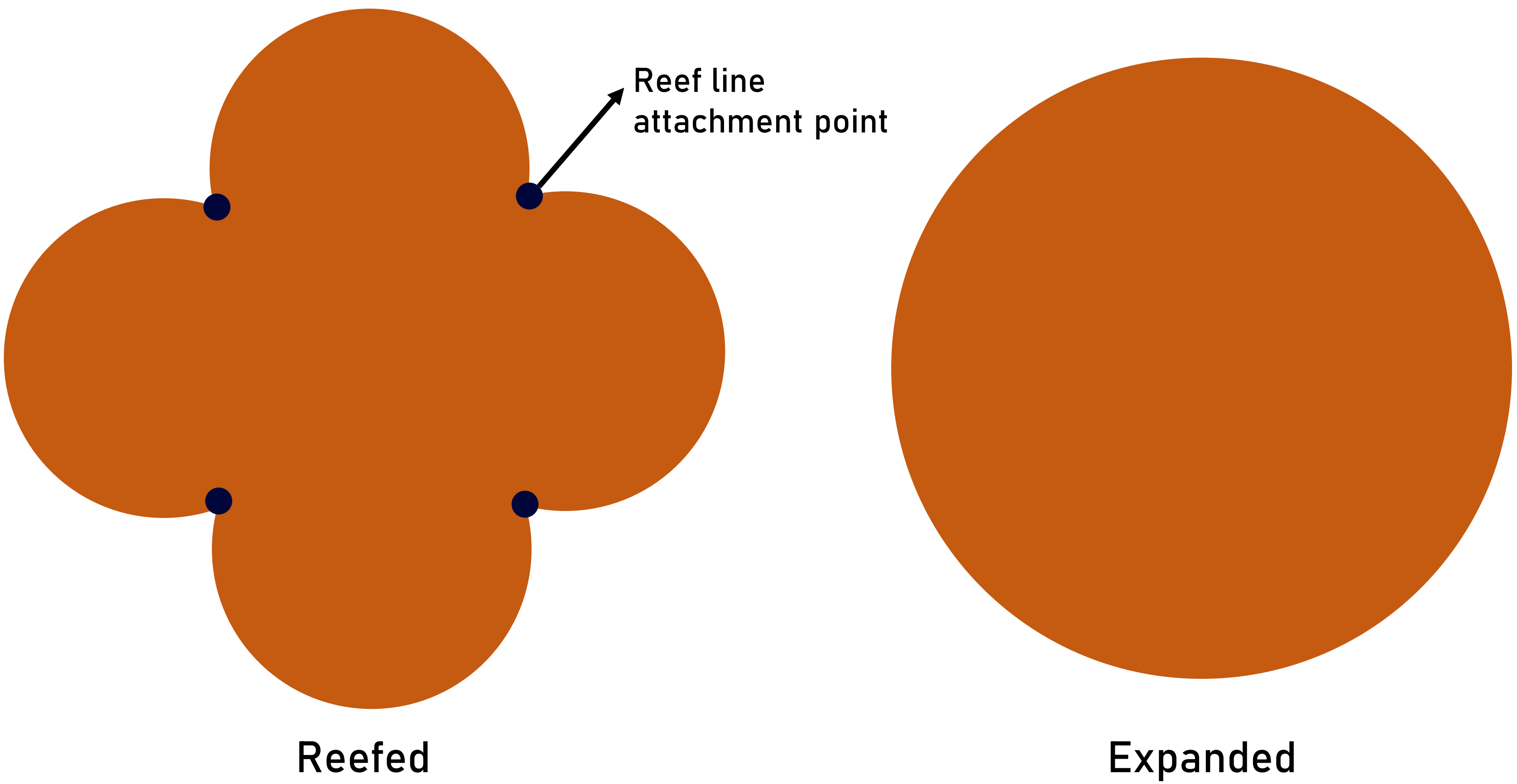






Pre Deployment	→	700 m -Reefed	→	400 m - Expanded
Parachute with reef lines folded sits on the lid.		Reefed parachute make the CanSat descend with a rate of 15 m/s.		The nichrome wire is heated at 400 m, melting the reef lines. The parachute fully expands and reduces the descent rate to 5 m/s.

Configuration 2: Reefing Parachute



Bottom view of the parachute

Container Descent Control Strategy Selection and Trade (6/10)

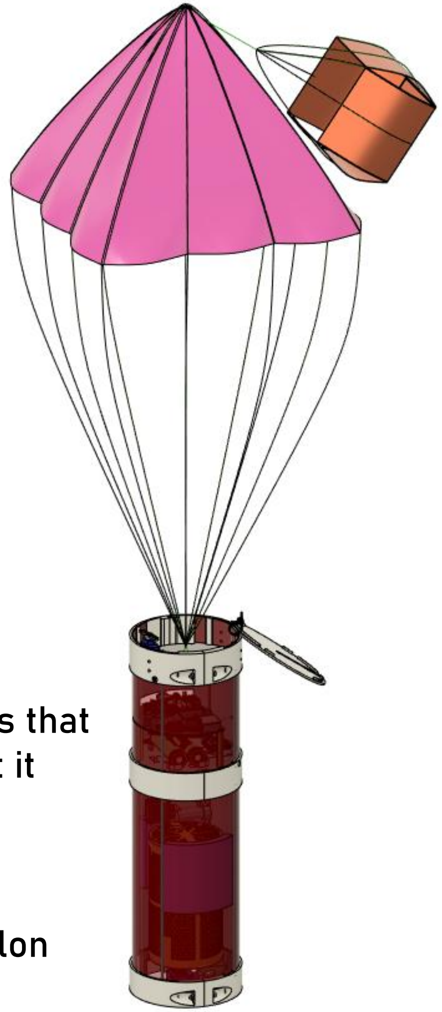
Configuration	Advantages	Disadvantages
Config. 1: Two-Stage Parachute	• Simple mechanism • Easy to manufacture and assemble • Simple descent rate calculation • More Stability	• Bulkier • Small chance of parachute getting stuck inside
Config. 2: Reefing Parachute	• Consume less space	• Complex calculation of the parachute area • Disposable (Reef line) • Hard to assemble on site • Less stability

Selected Design	Rationales
Config. 2: Two-Stage Parachute	• Easier to assemble on site • Simple Mechanism • We have more experience with servo than nichrome wire.

Detail on Selected configuration: Parachutes

First Parachute : Cube Parachute

- The reason why we choose the cube parachute as our first parachute is its stability. It is incredibly stable compared with other types of parachutes.
- We used it the most for our past projects.
- The material is nylon; the color is fluorescent orange.
- The suspension line is also made up of nylon and sewn to the top of the second parachute,



Second Parachute : da Vinci's parachute

- The reason why we choose da Vinci's parachute as our second parachute is that it is slightly less stable than cube but it consumes less space.
- The material is nylon; the color is fluorescent pink.
- The suspension line is made up of nylon

Parachute calculation: Cube parachute

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

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

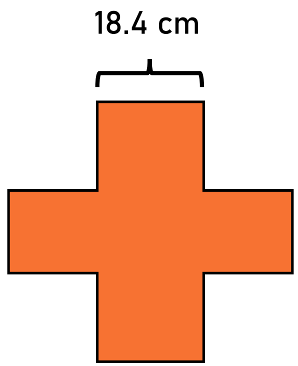
$$kl^2 = \frac{2mg}{c_{cube}\rho v^2}$$

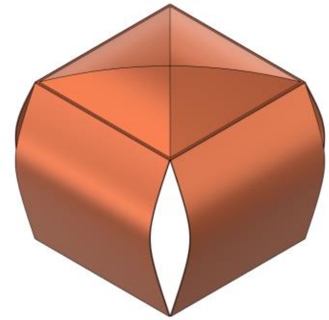
$$l = \sqrt{\frac{2mg}{kc_{cube}\rho v^2}}$$

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

$$l = 0.184\ m$$

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



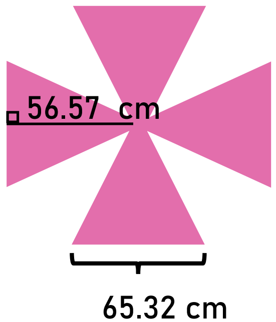


A_{eff}	Effective area of cube parachute
l	Length of cube parachute
$g = 9.81\ \frac{m}{s^2}$	Gravity acceleration
$c_{cube} = 0.54$	Cube parachute drag coefficient
$\rho_{atm} = 1.225\ \frac{kg}{m^3}$	Average air density
$k = \frac{7}{3}$	The effective area of cube parachute coefficient
m	CanSat mass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

Parachute calculation: da Vinci's parachute

$$A_{eff} = \frac{2mg}{c_{Da\ vinci}\rho v^2}$$
$$A_{eff} = kl^2$$
$$kl^2 = \frac{2mg}{c_{Da\ vinci}\rho v^2}$$
$$l = \sqrt{\frac{2mg}{kc_{Da\ vinci}\rho v^2}}$$
$$l = \sqrt{\frac{2(0.6)(9.81)}{(1)(0.9)(1.225)(5)^2}}$$
$$l = 0.6532\ m$$

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



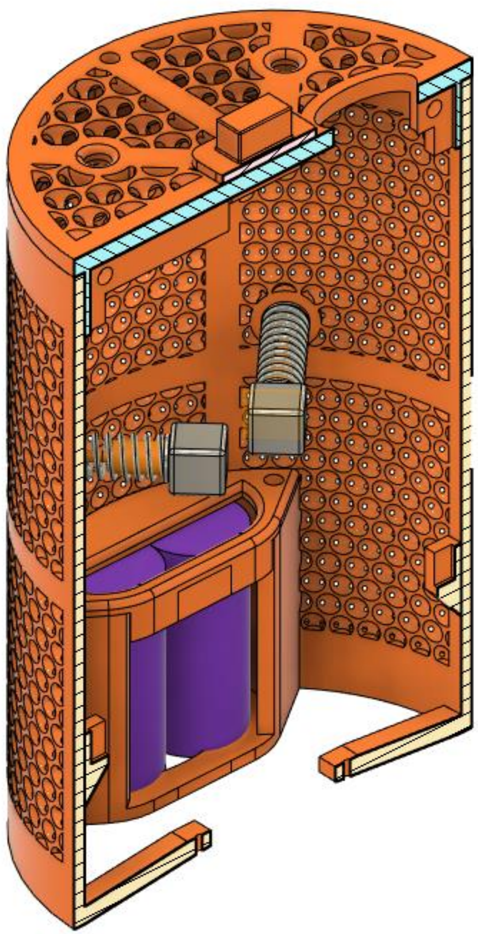
A_{eff}	Effective area of da Vinci's parachute
l	Length of da Vinci's parachute
$g = 9.81\ \frac{m}{s^2}$	Gravity acceleration
$c_{\text{Da vinci}} = 0.9$	da Vinci's parachute drag coefficient
$\rho_{atm} = 1.225\ \frac{kg}{m^3}$	Average air density
$k = 1$	The effective area of da Vinci's parachute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

Detail on Selected configuration: Drop Test Pictures

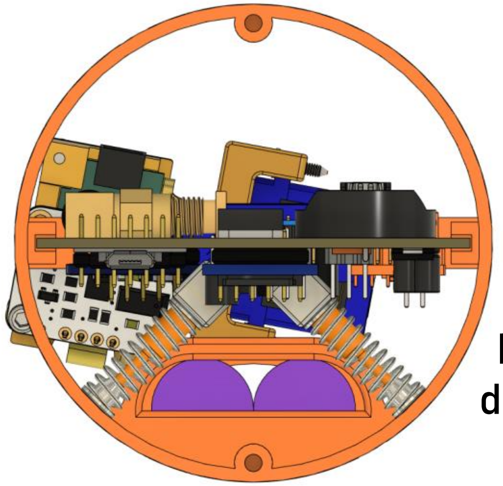
- Drop tests were performed to verify that the first parachute won’t affect the second parachute if they are connected.

Cube Parachute (deflated and didn't affect the bigger parachute)

Configuration 1: Mass Damper (Passive Control)

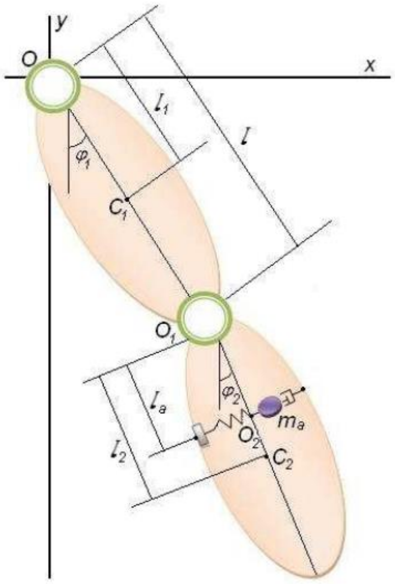


- The damper will be installed in the payload.
- It will reduce the swaying by using dashpot and spring.
- The dashpot will change the kinetic energy to heat energy.
- The spring will absorb the kinetic energy and convert it to elastic potential energy. Some of the elastic potential energy will be converted again to kinetic energy and release it to the dummy mass.

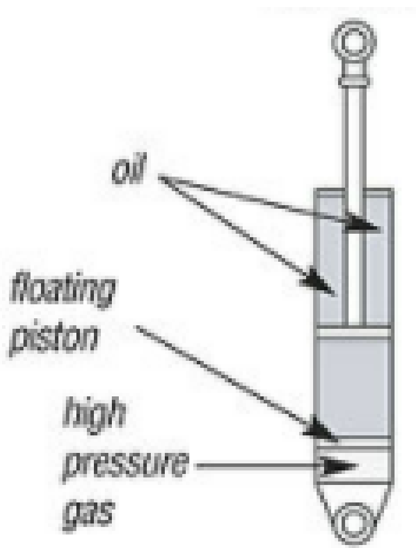


Position of mass damper in payload

Configuration 1: Mass Damper (Passive Control)



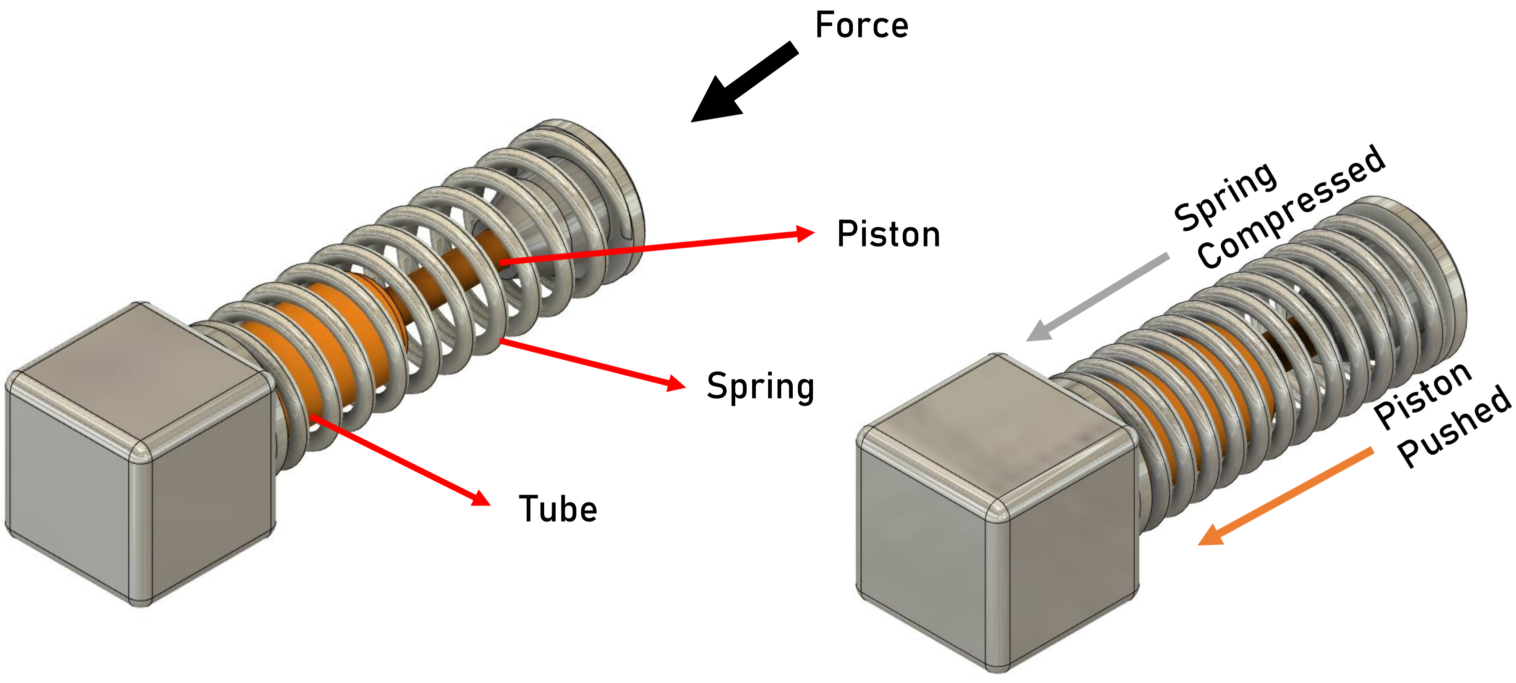
Reference : V.E. Puzyrev and N.V. Savchenko, Using Dynamic Vibration Absorber for Stabilization of a Double Pendulum Oscillations , Pages 407



Reference : https://commons.wikimedia.org/wiki/File:Shock_Absorbers_Detail.jpg

- When the container sways, the air pressure is increased from the piston that is getting pushed. That air pressure is going to counter the movement of the CanSat by pushing the piston back.
- Elastic potential energy is stored in spring as a result of swaying payload which means that potential energy in the system is reduced every time the payload sways.
- The total movement of the system is decreased from the system's decreased potential energy.

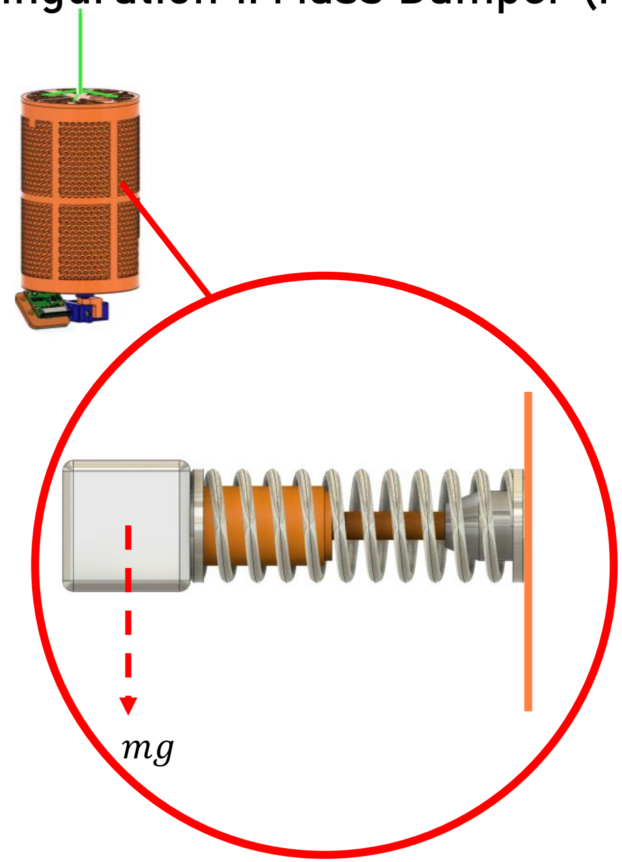
Configuration 1: Mass Damper (Passive Control)

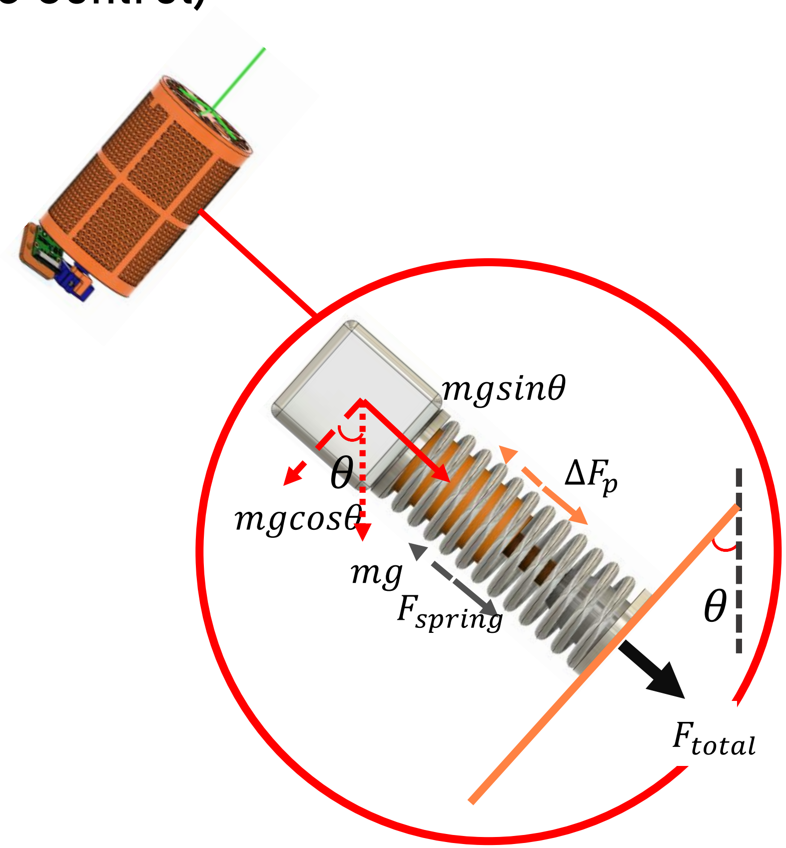


Before

After

Configuration 1: Mass Damper (Passive Control)





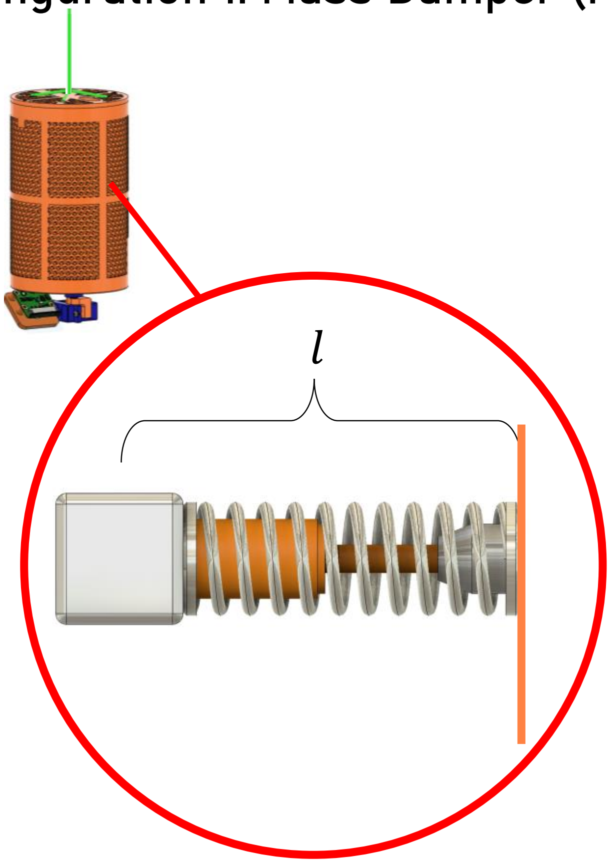
Perpendicular force act on the payload

$$F_2 = 0$$

Perpendicular force act on the payload

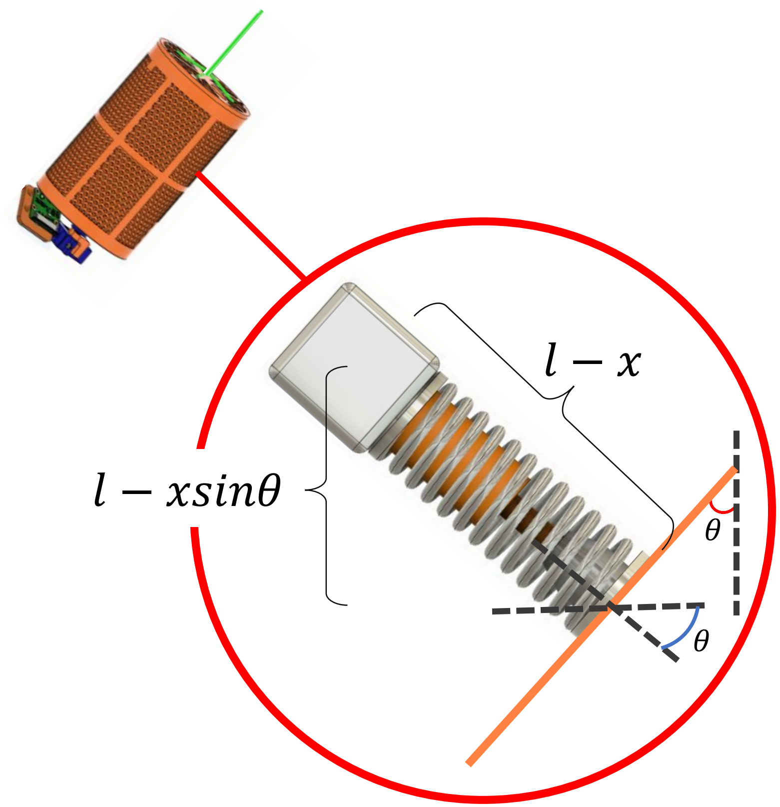
$$F_2 = mgsin\theta + \Delta F_{pressure} + F_{spring}$$

Configuration 1: Mass Damper (Passive Control)



Total energy 1

E_1

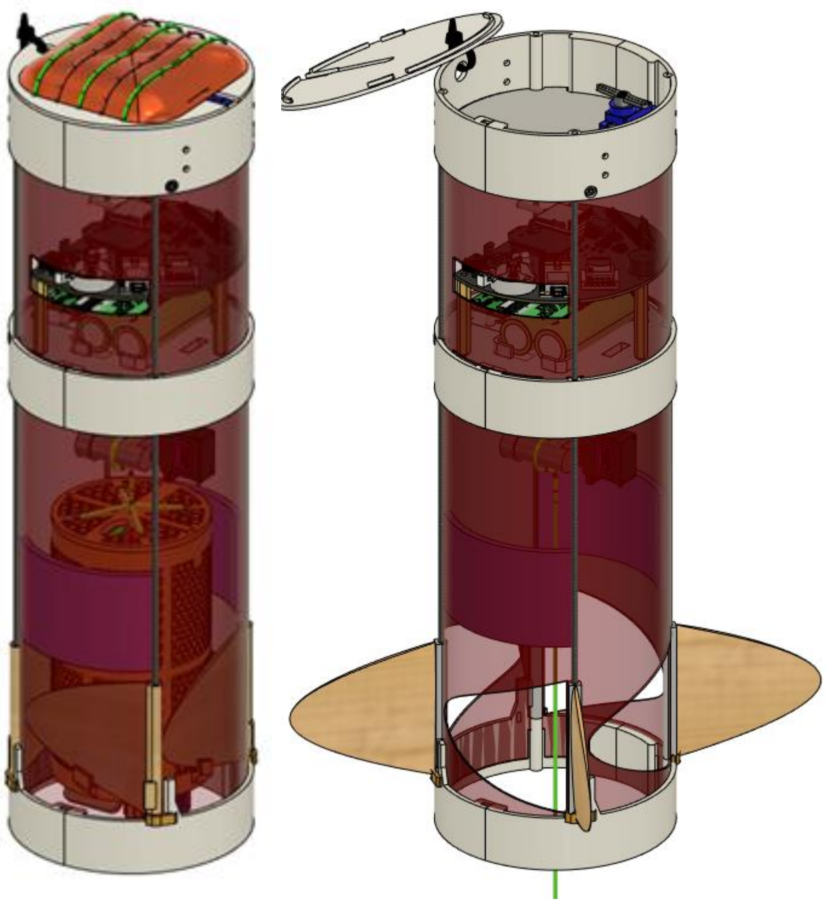


Total energy 2

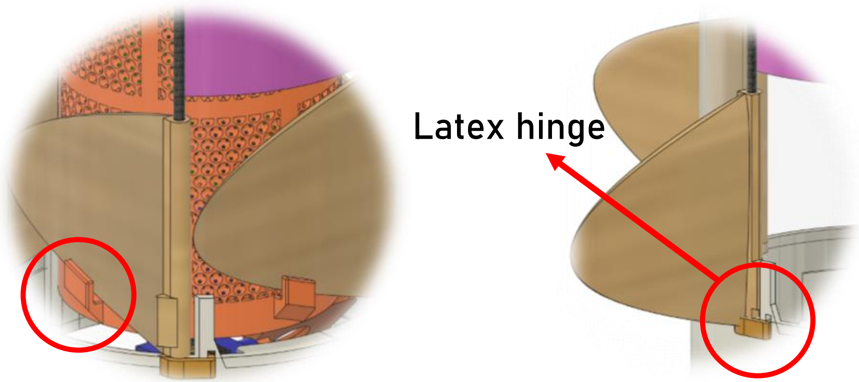
$$E_2 = E_1 + E_p + E_s - E_{heat}$$

$$E_p = mg(l - x) \quad E_s = \frac{1}{2}kx^2 \quad E_{heat} = W_{friction} + Q_{pressure}$$

Configuration 2: Fins (Passive Control)



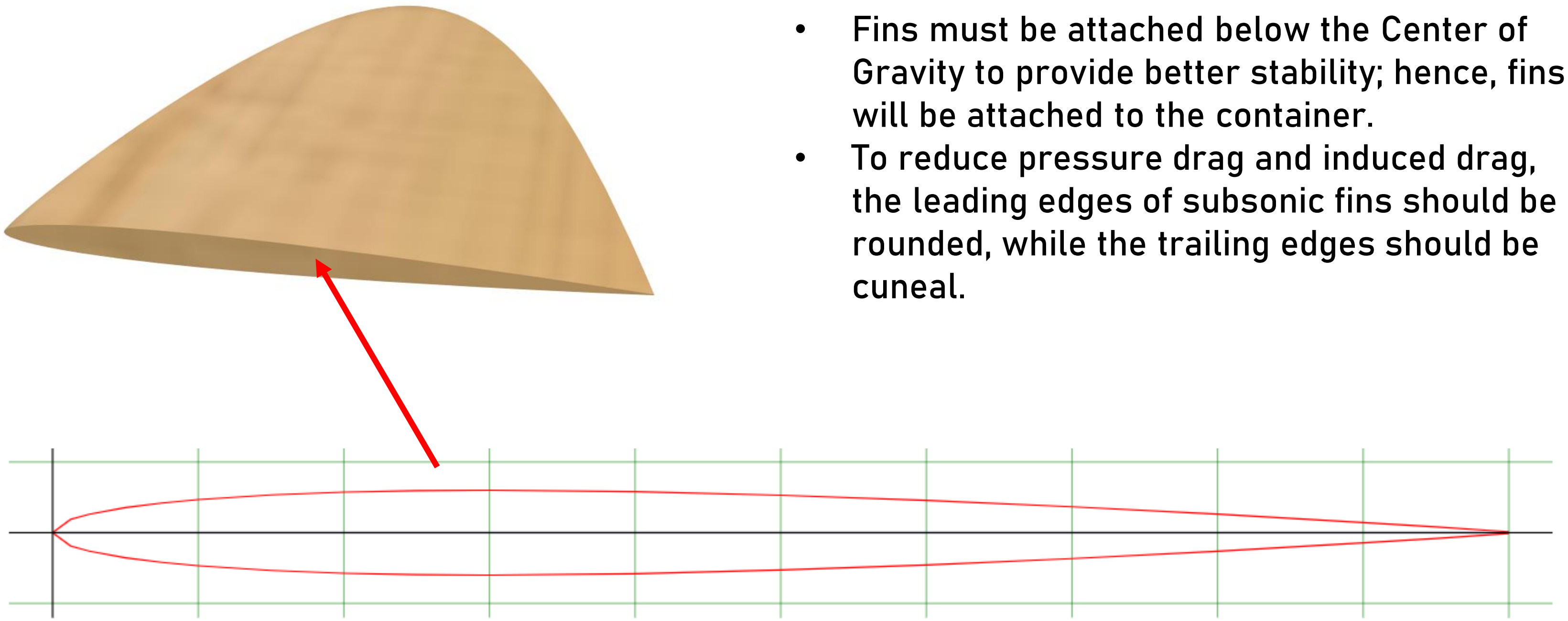
- The fins will prevent the whole CanSat from swaying. They also prevent the container and payload from spinning around themselves.
- The fins will be retracted in the container to prevent sharp protrusion.
- The payload has tiny hooks to lock the fin in an appropriate position.
- Once the payload unspools, the fins are deployed with a help of latex hinges.



Fins retracted with payload hooks

Fins deployed

Configuration 2: Fins (Passive Control)

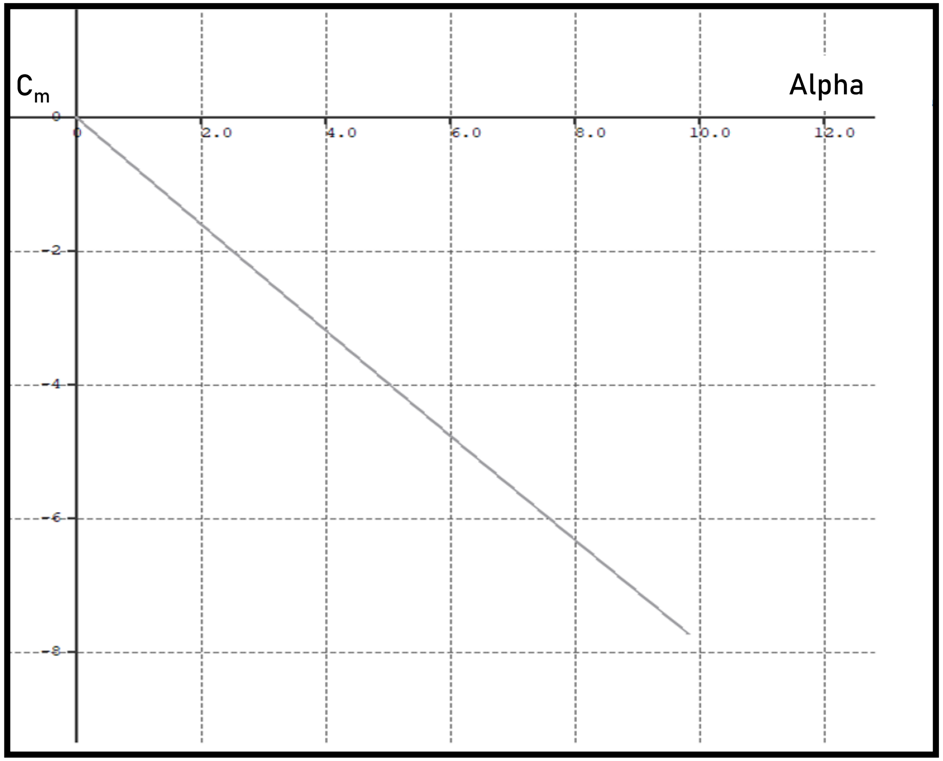


- Fins must be attached below the Center of Gravity to provide better stability; hence, fins will be attached to the container.
- To reduce pressure drag and induced drag, the leading edges of subsonic fins should be rounded, while the trailing edges should be cuneal.

NACA 0006 Airfoil (with rounded leading edges, cuneal trailing edges)

Configuration 2: Fins (Passive Control)

- Positive Static Stability (which means it has an "Initial Tendency" to revert to its equilibrium state) is provided by the fins.



Negative dCm/dAlpha
Slope from *xflr5* analysis

Container and Payload Descent Stability Control Strategy Selection and Trade (9/9)

Configuration	Advantages	Disadvantages
Config. 1: Mass Damper (Passive)	• Higher vibration damping capability	• Add additional mass to the CanSat • Hard to manufacture
Config. 2: Fins (Passive)	• Lightweight • Easier to manufacture	• Bulkier • Secure gap between the container and rocket is needed, so hooks on the payload have to be made.

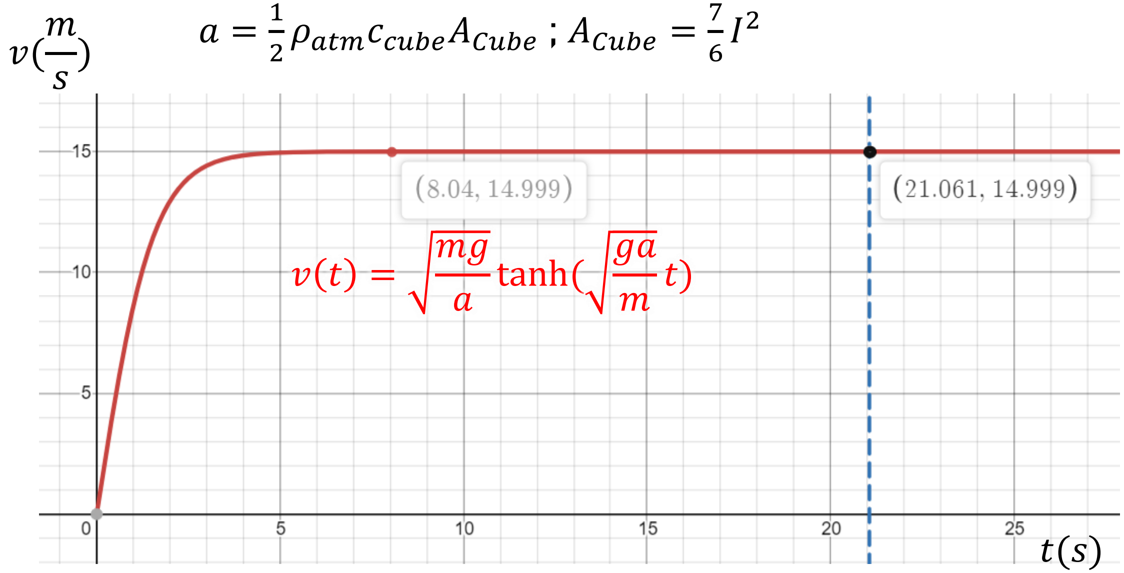
Selected Design	Rationales
Config. 2: Fins (Passive)	• Easier to manufacture • Lightweight • We have experience with fins.

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

Descent Velocity-Time Calculation for CanSat

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

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



$$v(t) = \sqrt{\frac{mg}{a}} \tanh\left(\sqrt{\frac{ga}{m}} t\right)$$

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.

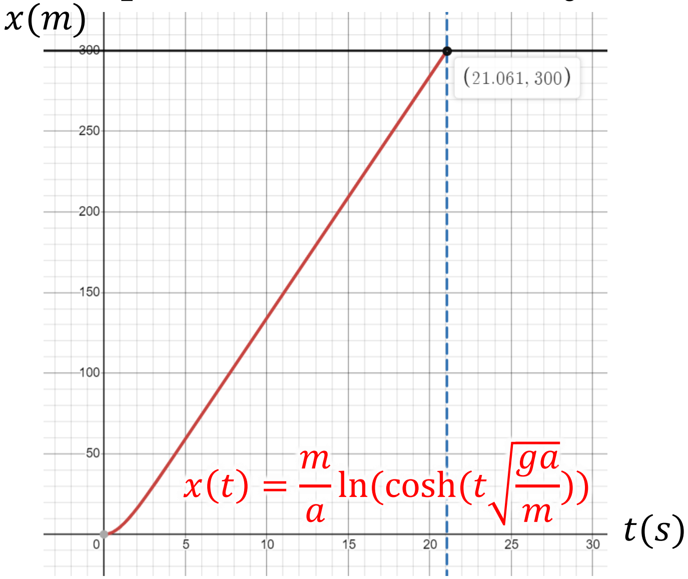
15.0 m/s in 21.1 s with Cube parachute

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

Descent Distance-Time Calculation for CanSat

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

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



Δt	Time of descent
v	Descent velocity
m	CanSat mass
l	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

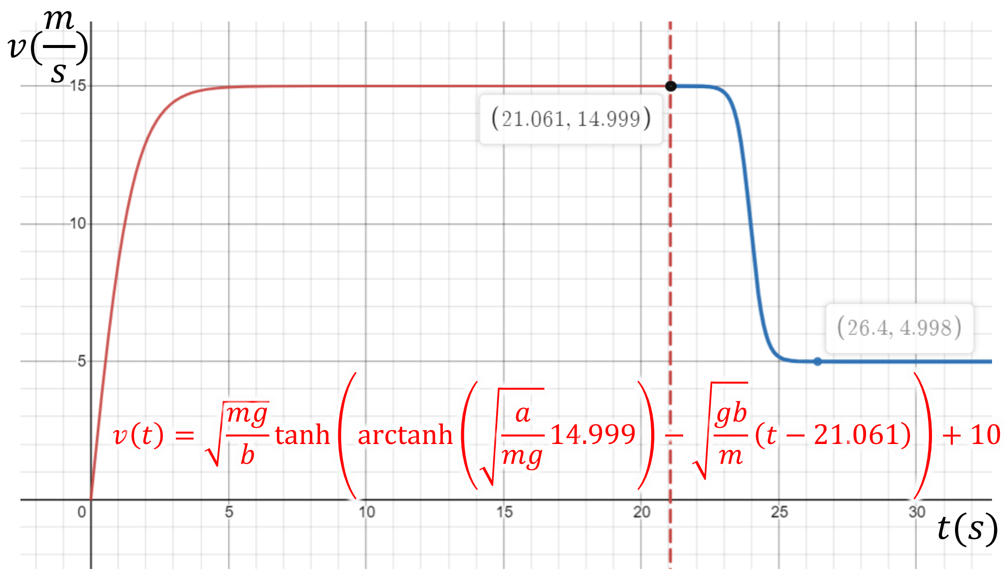
Descent Rate Estimates (3/5)

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.

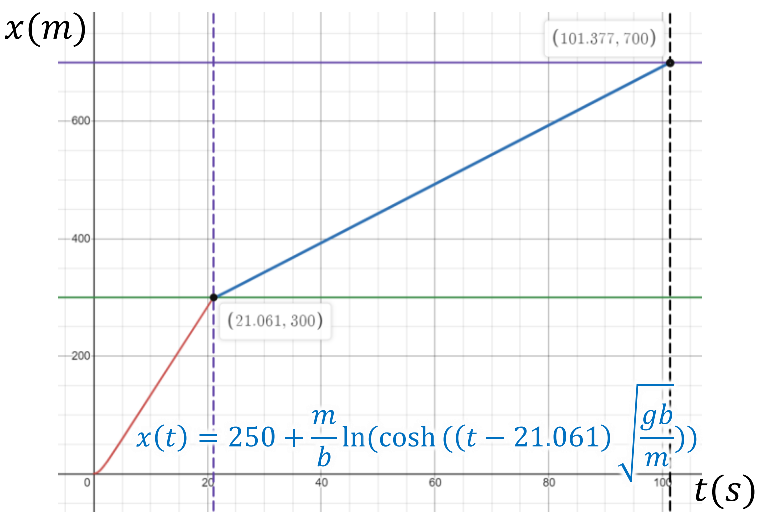
Descent Rate Estimates (4/5)

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

Descent Distance-Time Calculation for CanSat

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

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



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.

400 m in 80.4 s with da Vinci's parachute

Descent Rate Estimates (5/5)

<u>Final Result</u>

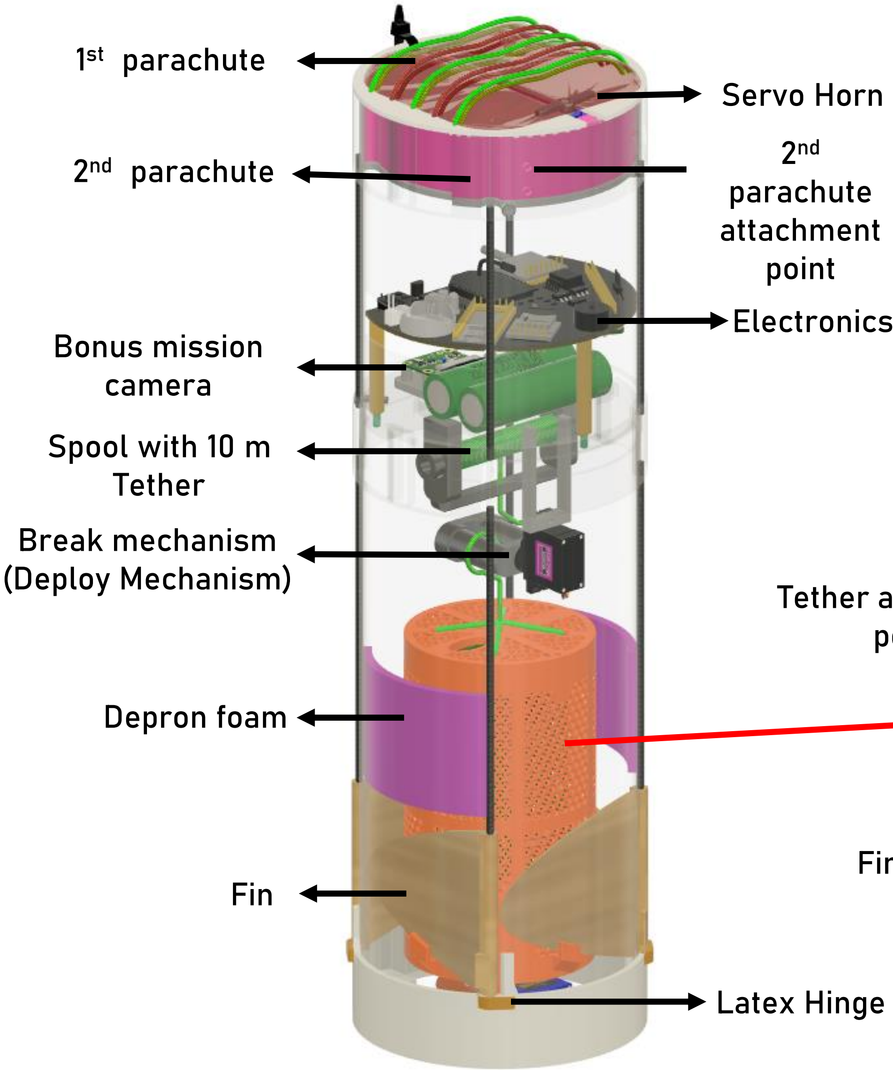
Descent Rate Estimates for CanSat

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

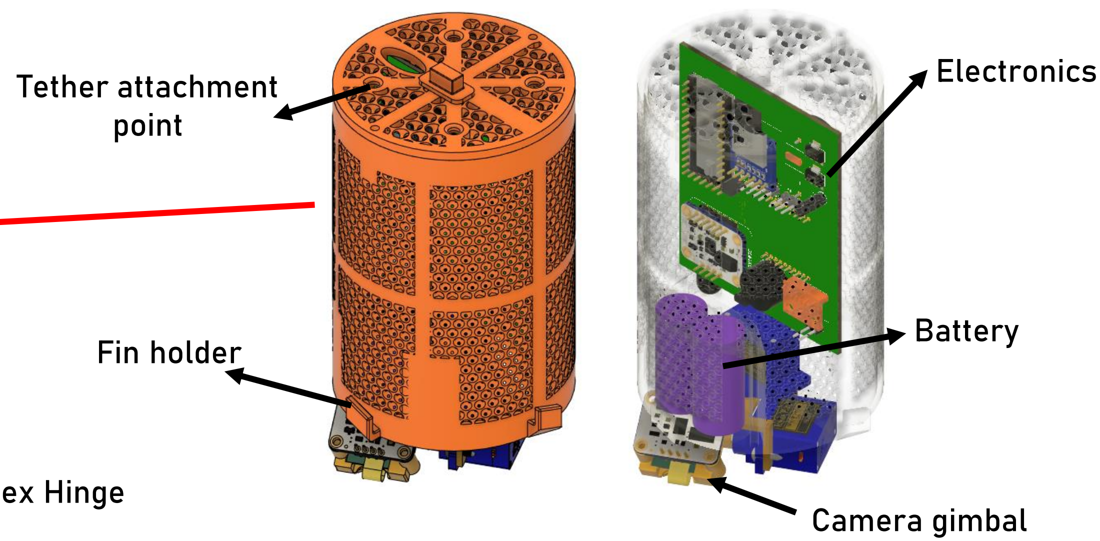
Mechanical Subsystem Design

Kittipon Amornprasertkij, Nuchit Vichitkijja

Mechanical Subsystem Overview



Structure	Material
Container Ribs	ABS
Container support column	Carbon fiber
Container coating	Laminated paper (Fluorescent red)
Payload	PETG
Tether	Nano cord (Nylon)

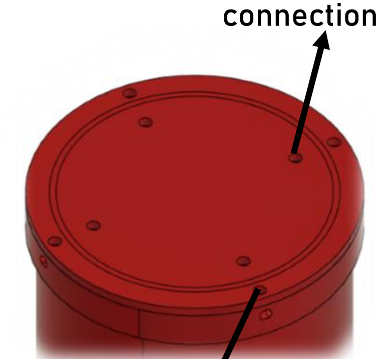


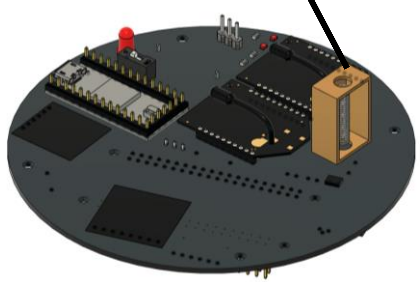
The laminated paper is made transparent for better visibility

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

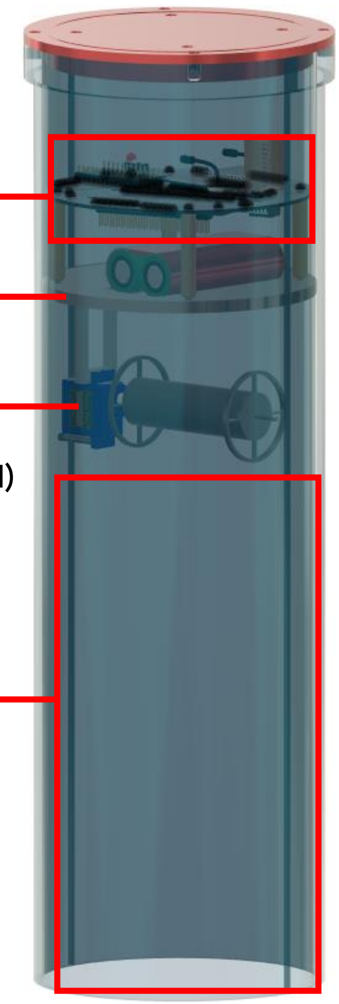
Configuration 1: One Solid Piece

- The container is manufactured in one solid piece.
- Can be opened from the top
- Circular PCB is mounted on the standoffs
- This design was initially made for reef parachute so it doesn't provide second parachute slot but has a nichrome wire box instead.



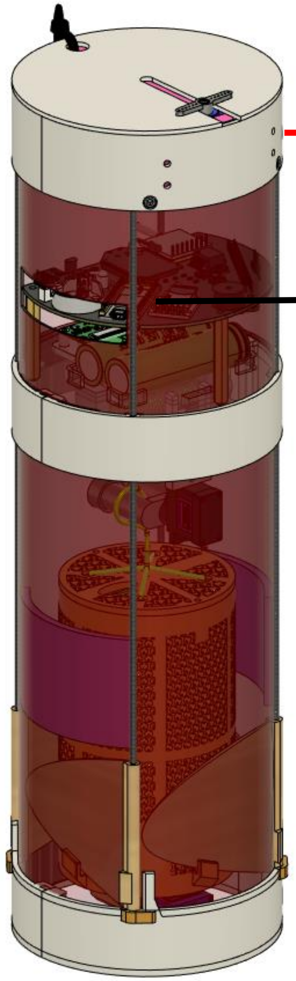


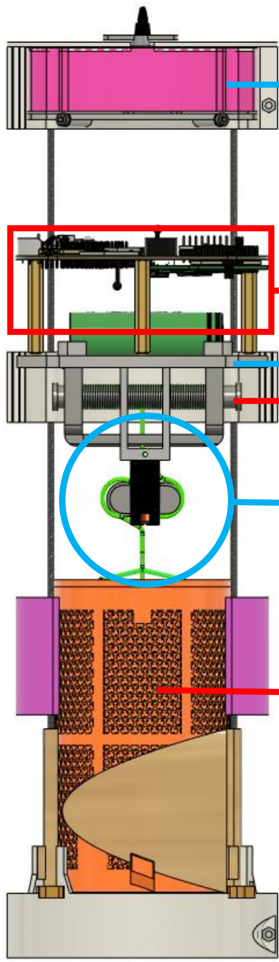
Circular PCB



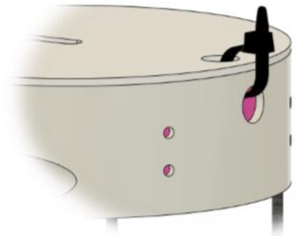
Container Mechanical Layout of Components Trade & Selection (2/5)

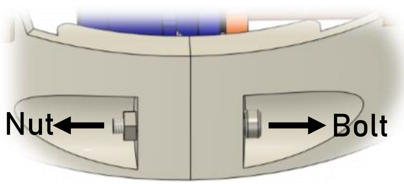
Configuration 2: Ribs with support columns



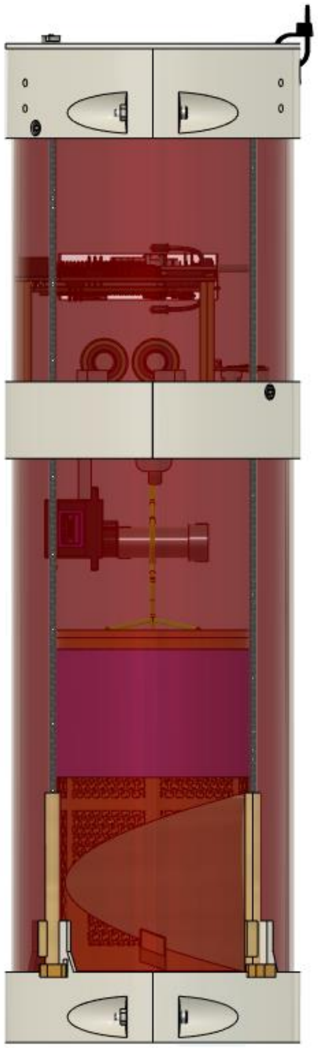


- The container ribs are attached to the carbon fiber rods and coated by laminated fluorescent paper.
- Can be opened from side to side.
- Semi-circular PCB is mounted by standoffs.





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



Configuration	Advantages	Disadvantages
Configuration 1: One Solid Piece	• Provides higher durability and strength • Easy to manufacture	• Heavy • Hard to access inner component
Configuration 2: Ribs with Support column	• Easy to access inner component • Lightweight	• Less durability and strength • Complicated manufacturing process

Selected Design	Rationales
Configuration 2: Ribs with Support column	• Lightweight • Easier to access the inner components • The support columns could be used as a part of fin deployment. • Has a second parachute slot

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

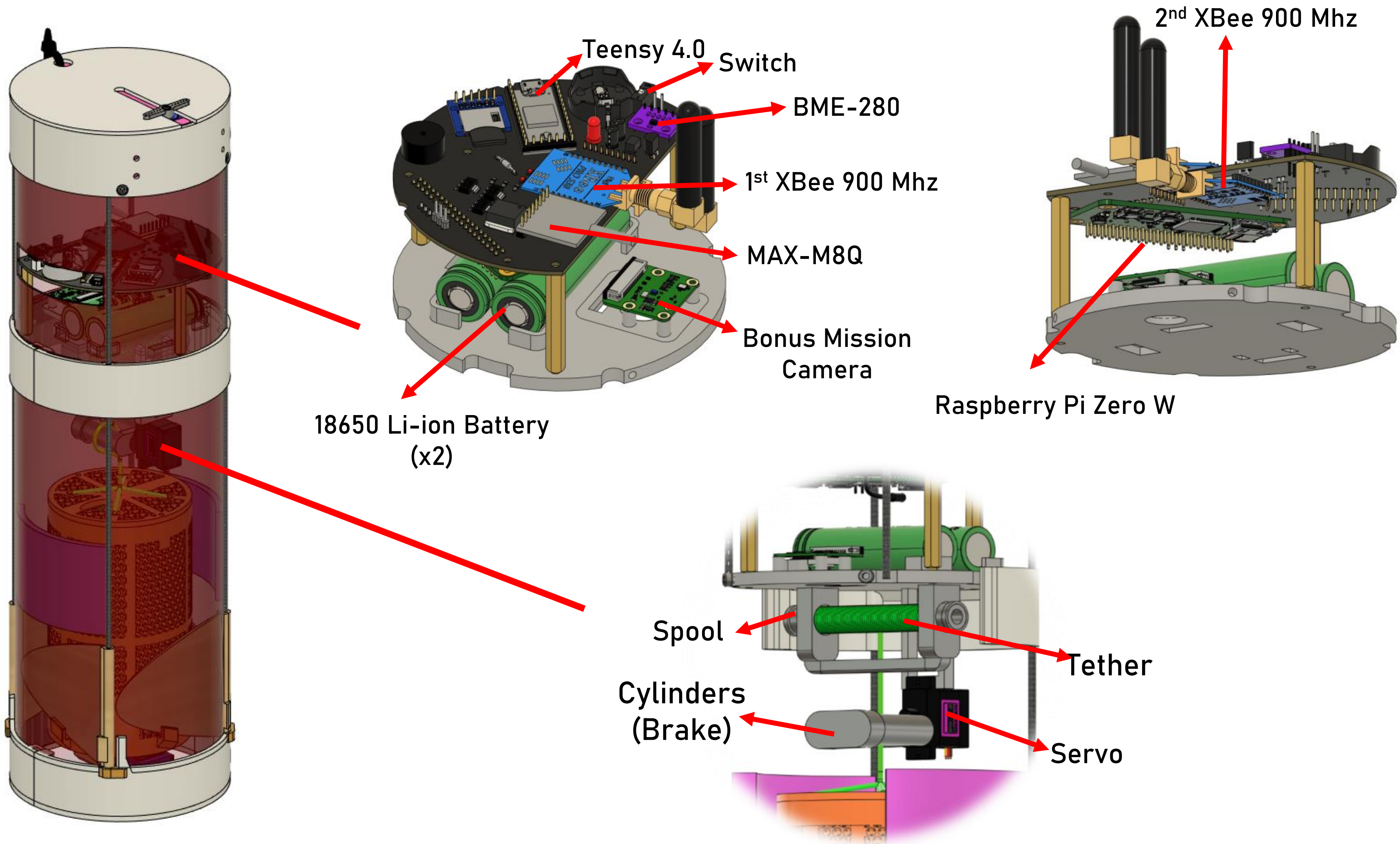
Container Structural Material Trade & Selection

Structure	Material	Density (g/cm^3)	Impact Strength	Tensile Strength	Soften Temperature (°C)	Cost ($)
Container ribs	PLA	1.24	Low	High	60	13.88
	PETG	1.27	Very High	Very High	85	21.40
	ABS	1.04	High	Low	105	15
	PP	0.89	Medium	Medium	65	40
Support column	Carbon fiber	1.75	High	High	3,652	10
	Titanium	4.5	Very High	Very High	1,668	5

Selected Material		Rationales
Container ribs	ABS	• High strength with lightweight • Can resist high temperature
Support column	Carbon fiber	• High strength with lightweight • Easy to acquire

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

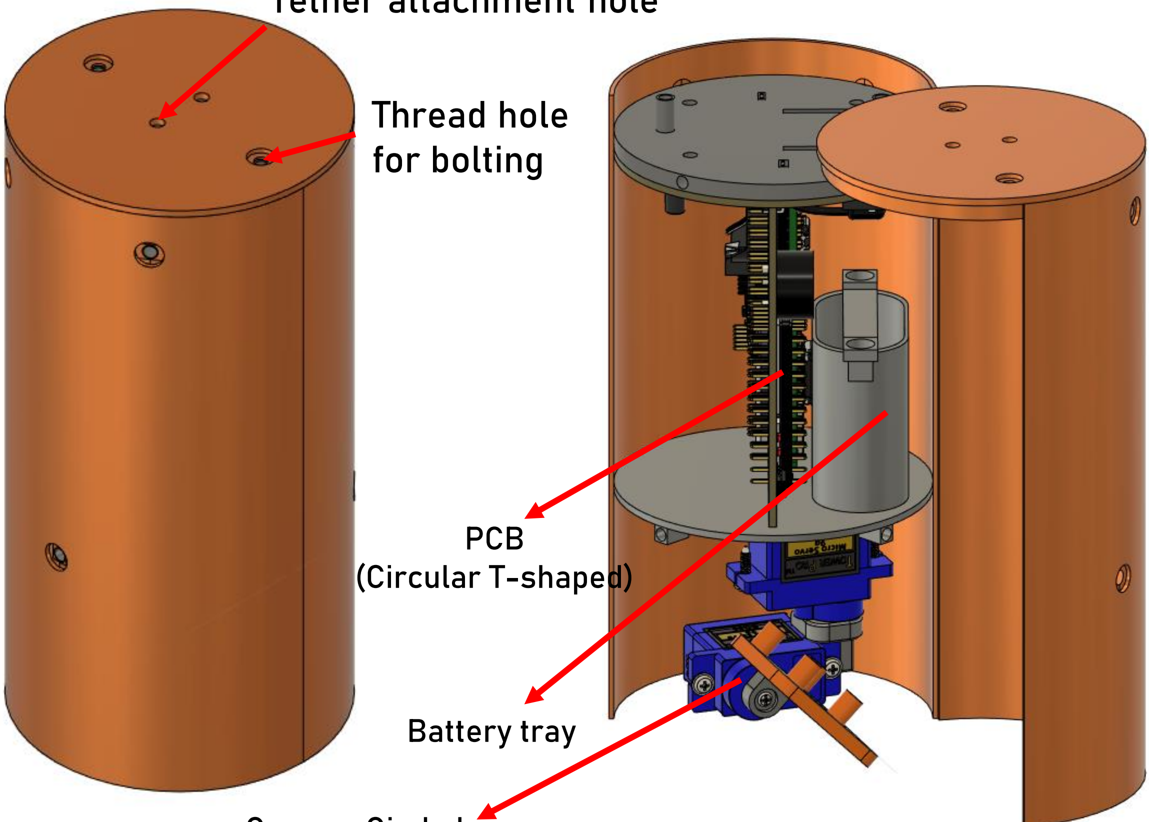
Detail on selected configuration: Location of electrical components



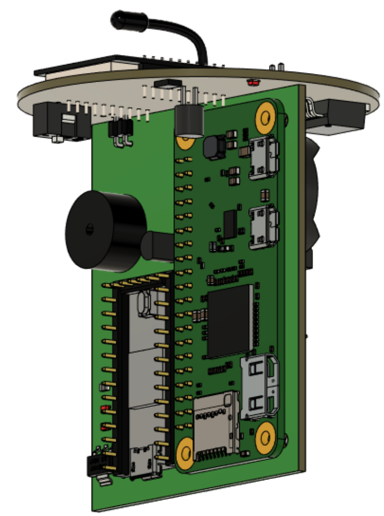
Payload Mechanical Layout of Components Trade & Selection (1/6)

Configuration 1: One Solid Piece

- The payload is manufactured in one solid piece.
- Can opened from side to side
- Circular-T PCB
- Camera gimbal is in the payload.



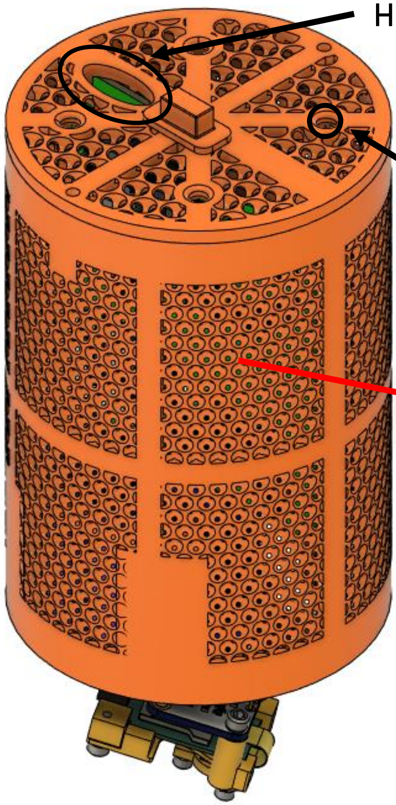
Can be opened from side to side

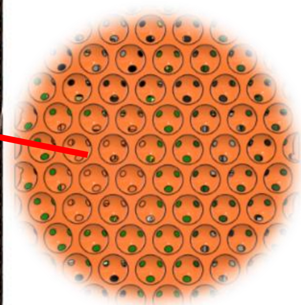


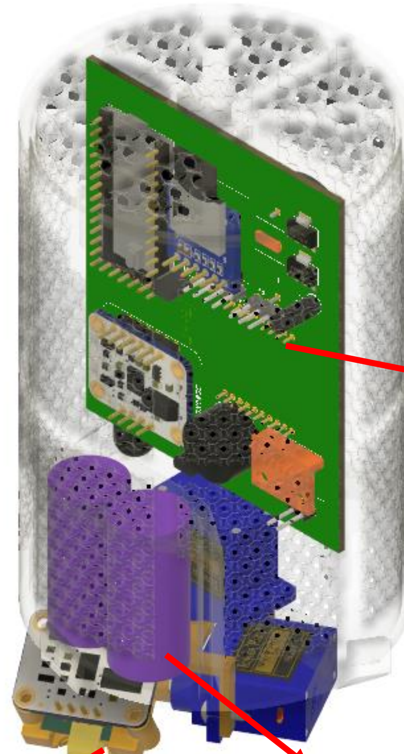
Circular-T PCB

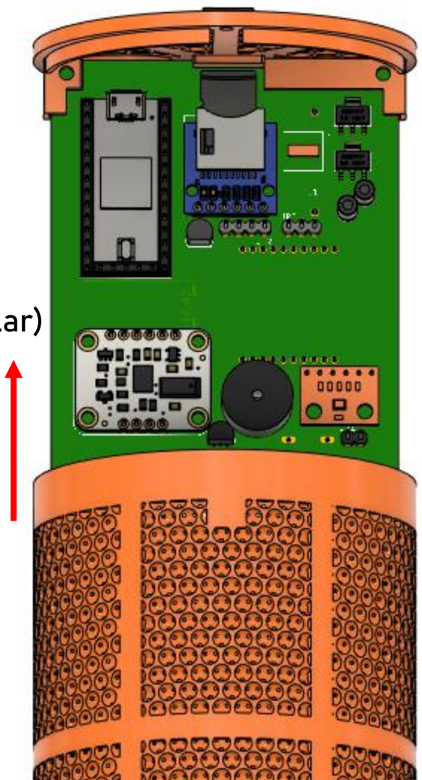
Configuration 2: Hexagonal Close Packed

- The payload is patterned with hexagonal close packed pattern to reduce weight
- Can be opened from the top
- Rectangular PCB bolted with the lid
- Camera gimbal protrudes from the payload

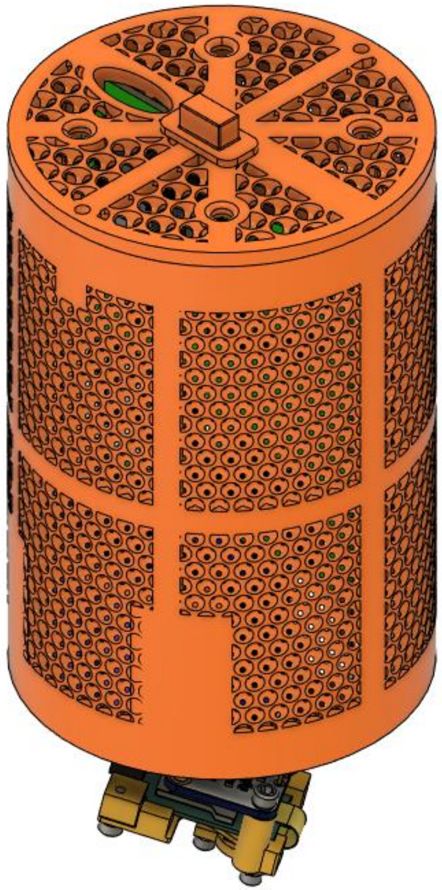








Payload Mechanical Layout of Components Trade & Selection (3/6)



Configuration	Advantages	Disadvantages
Configuration 1: One Solid Piece	• The payload protects the gimbal module • Provide more strength	• Bulky and heavy
Configuration 2: Hexagonal Close Packed	• Very light due to the pattern on the surface • Easier to assemble	• Harder to manufacture • More fragile

Selected Design	Rationales
Configuration 2: Hexagonal Close Packed	• Lightweight • Consume less space • Easier to access the inner components

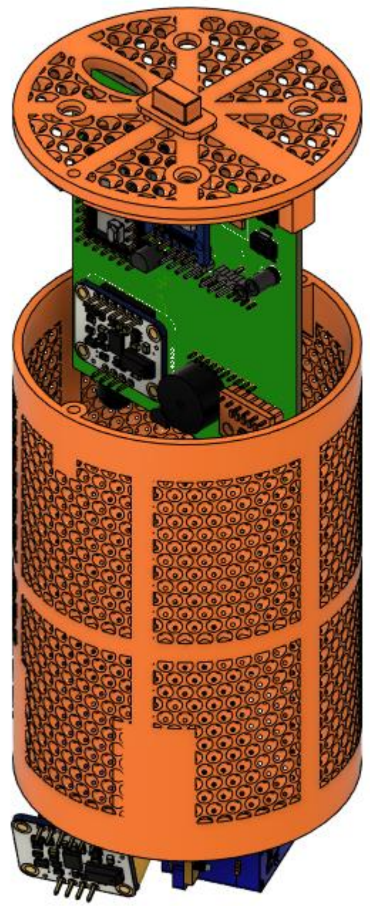
Payload Mechanical Layout of Components Trade & Selection (4/6)

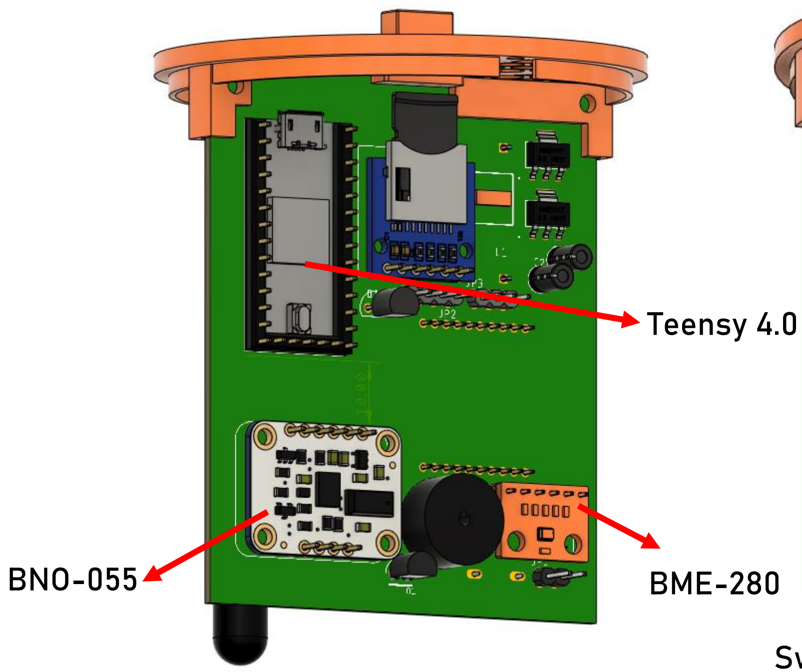
Payload Structural Material Trade & Selection

Usage	Material	Density (g/cm^3)	Impact Strength	Tensile Strength	Soften Temperature (°C)	Manufacturing process	Cost ($)
Payload Structure	PLA	1.24	Low	High	60	3D Printing	13.88
	PETG	1.27	Highest	Highest	85	3D Printing	21.40
	ABS	1.04	High	Low	105	3D Printing	35
	PP	0.89	Medium	Medium	65	3D Printing	40

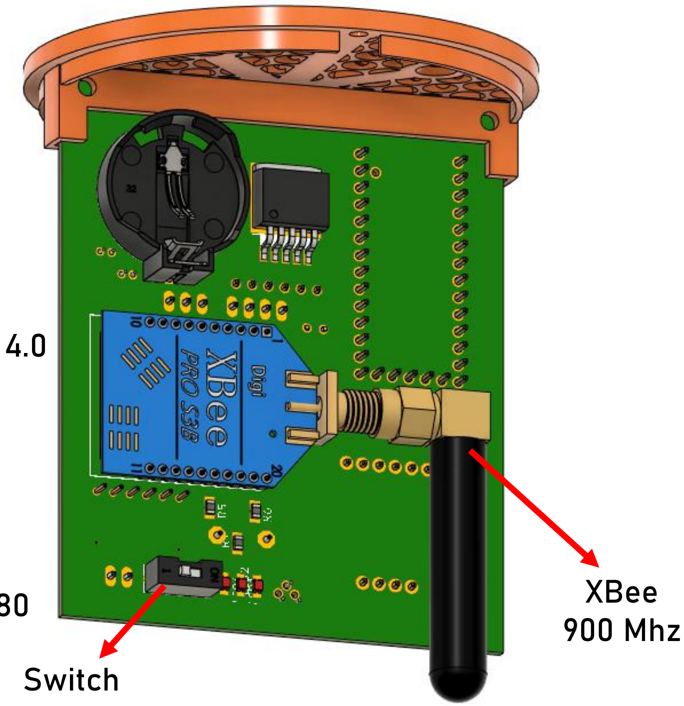
Selected Material	Rationales
PETG	• Due to the cheese grater-like surface structure, it is hard to print. Therefore, PETG which has a low chance of warping is chosen. Furthermore, PETG does have high impact and tensile strength.

Details on selected configuration: Location of electrical components





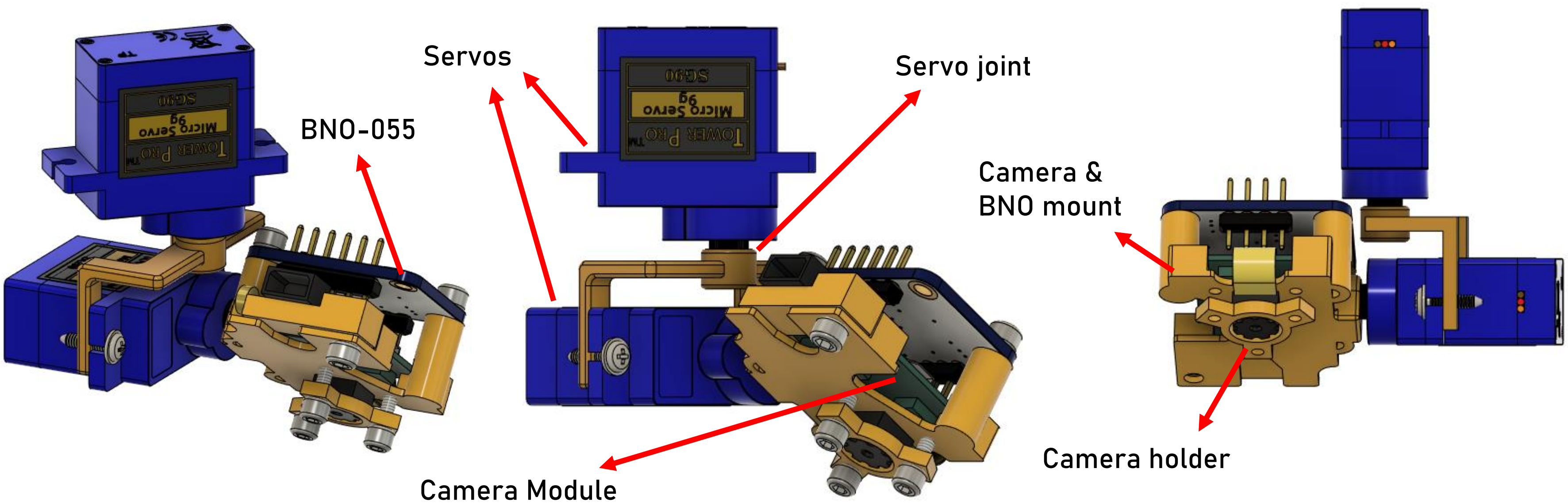
Front view



Back view

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

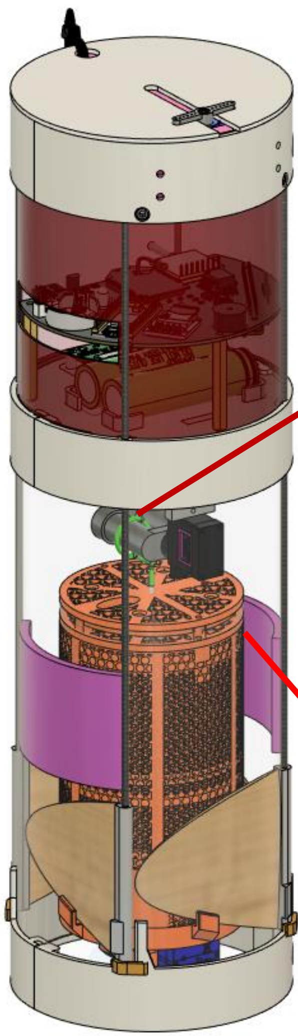
Details on selected configuration: Camera Gimbal

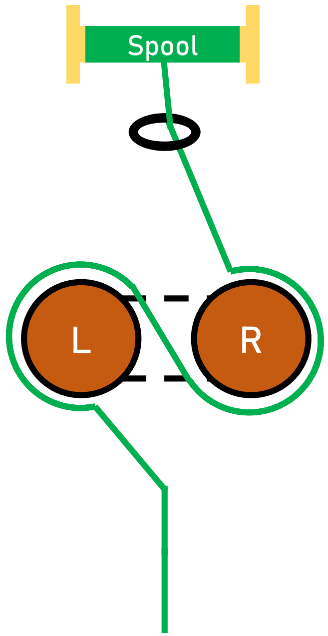


Front view

Side view

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



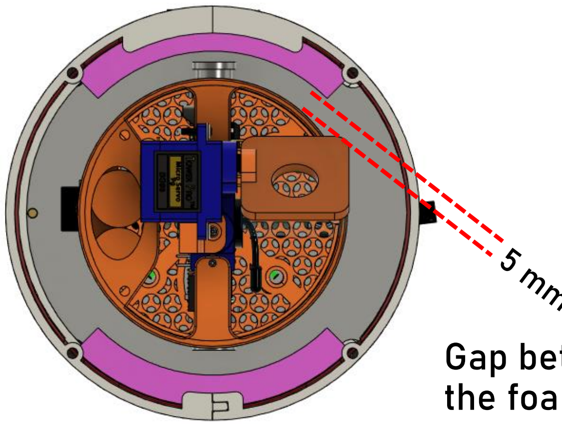


The brake fold the tether, prevent it from spooling down.

Depron foam

Configuration 1: Brake Mechanism with Depron foam

- The tether is wrapped around the cylinders.
- Depron foam is provided to secure the payload.
- Payload is placed in position but not tightly.
- Depron foam keeps the payload from swaying during launch.

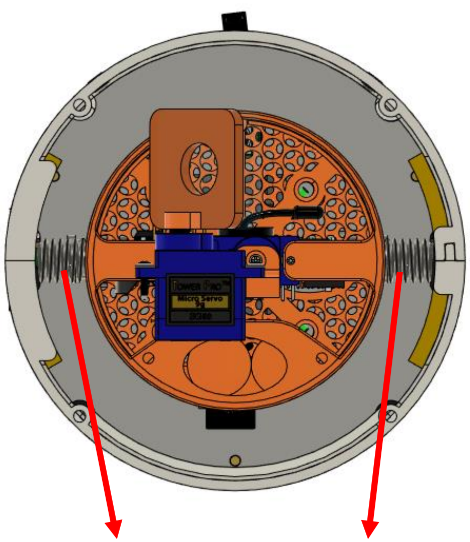


Gap between the foam & the payload

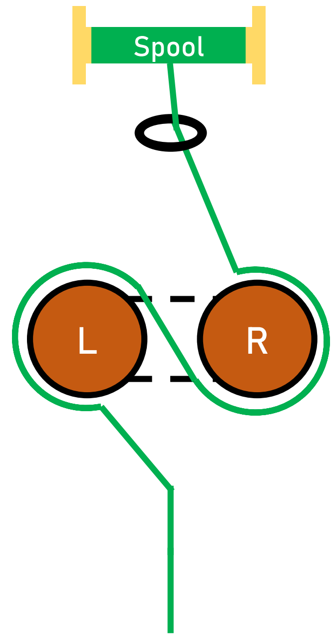
Payload Pre Deployment Configuration Trade & Selection (2/3)

Configuration 2: Brake Mechanism with Spring

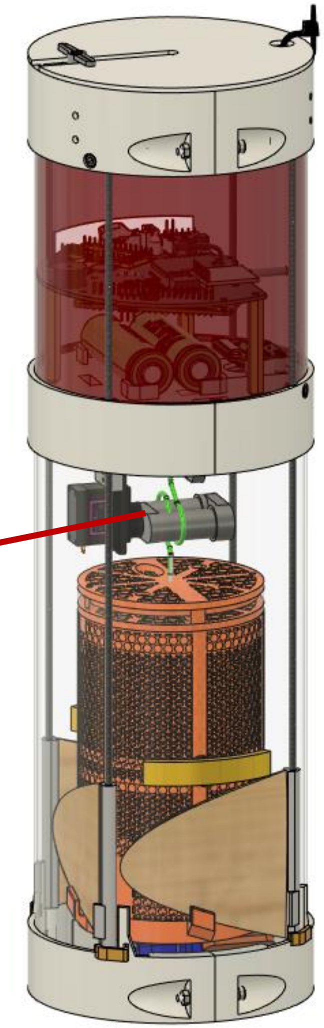
- The tether is wrapped around the cylinders
- The payload is placed in position between the springs
- The springs will help absorb shock force during launch



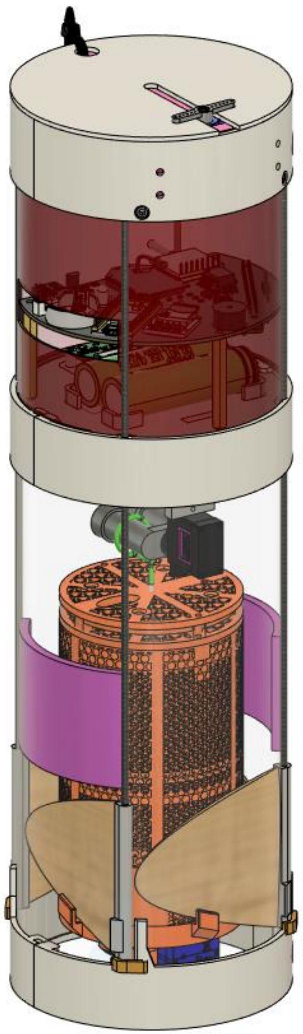
Springs holding the payload still



The brake fold the tether, preventing it from spooling down.



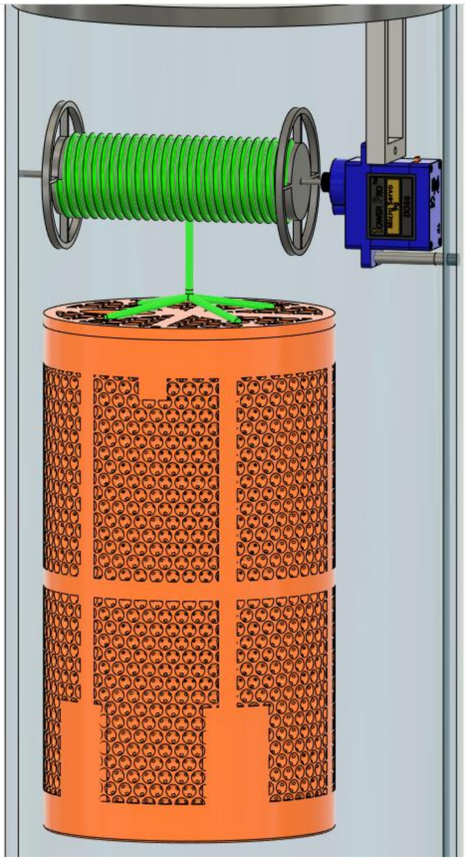
Payload Pre Deployment Configuration Trade & Selection (3/3)



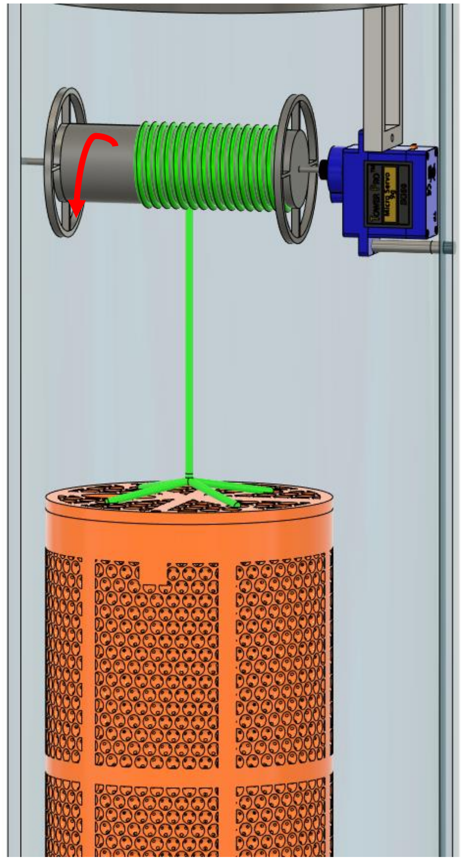
Configuration	Advantages	Disadvantages
Configuration 1: Brake Mechanism with Depron foam	• Lightweight • Easy to assemble • Higher vibration damping capability	• Slightly bulkier
Configuration 2: Brake Mechanism with Spring	• Consume less space	• Hard to assemble • The payload vibrates during ascent. • Heavier

Selected Design	Rationales
Configuration 1: Brake Mechanism with Depron foam	• Lightweight • Familiarity with depron foam

Payload Deployment Configuration Trade & Selection (1/4)



Stowed Configuration



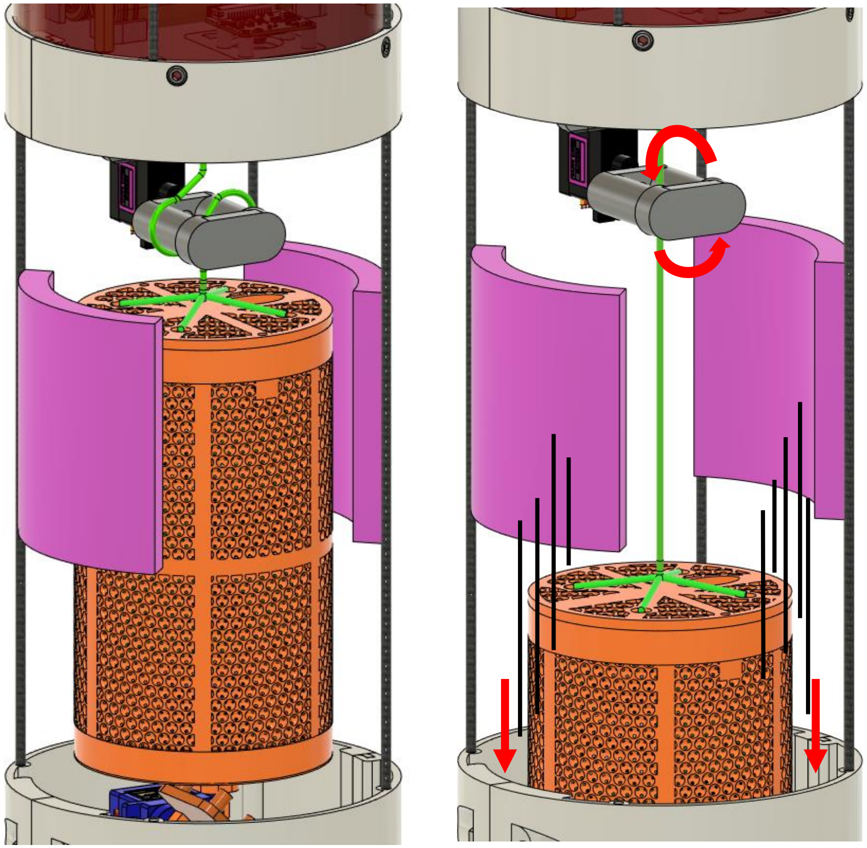
Deployed Configuration

Configuration 1: Reel system

- The spool is controlled by an actuator.
- The 10-meter tether is wound around the spool.
- Once the CanSat reaches 300 meters, an actuator will be triggered and start to deploy the payload.

Configuration 2: Brake mechanism

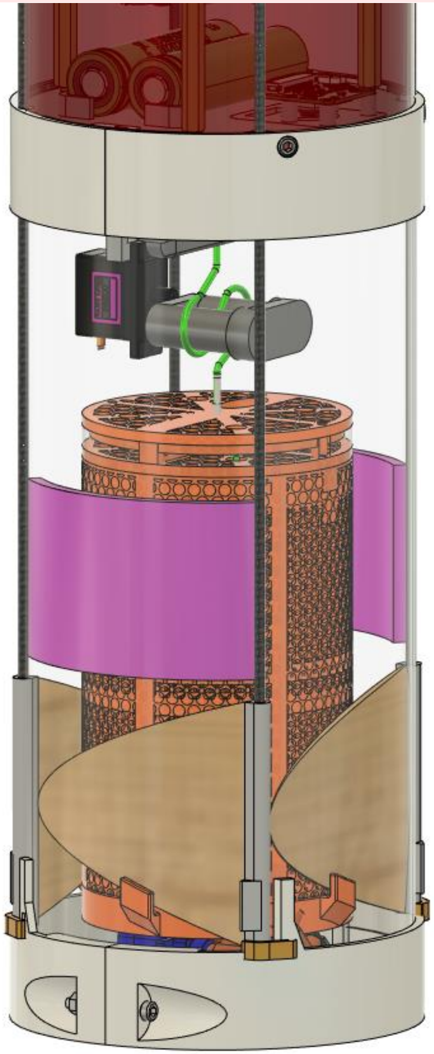
- This deploy system consists of two cylinders controlled by a servo
- This mechanism can control the spooling of the tether by creating the friction between the surface of cylinders and the tether.
- To stow the payload, the servo will rotate the cylinders 180 degrees and fold the tether.
- When the CanSat reaches 300 meters, the servo will be triggered, rotate the cylinders to unfold the tether, and deploy the payload.



Stowed Configuration   Deployed Configuration

The fins are hidden for better visibility

Payload Deployment Configuration Trade & Selection (3/4)

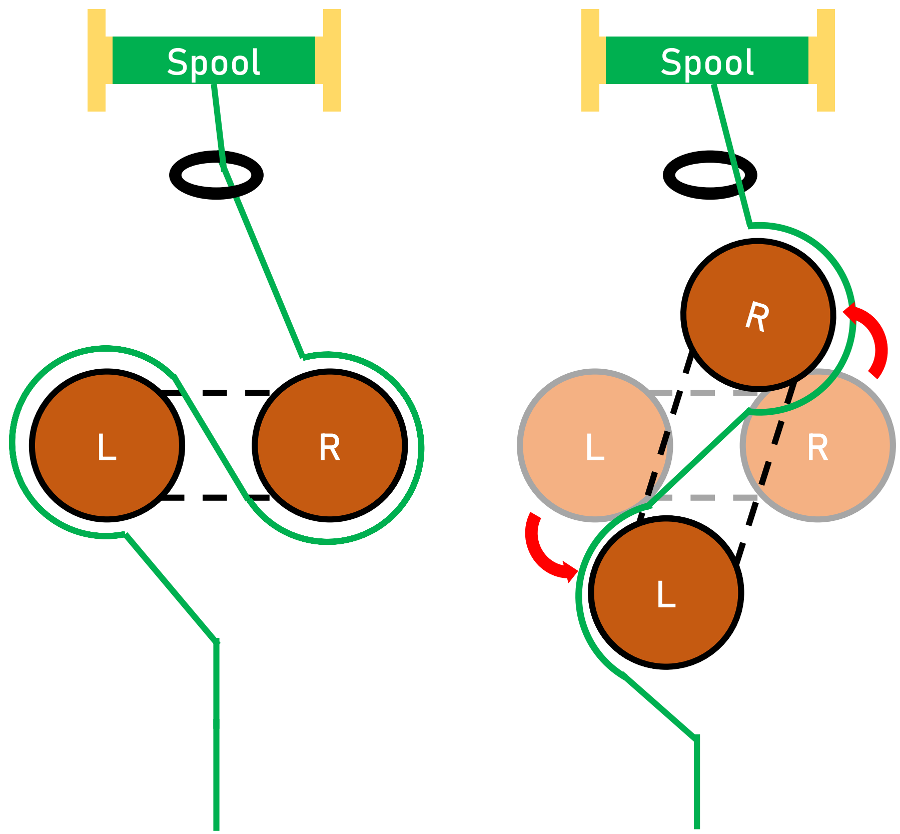


Configuration	Advantages	Disadvantages
Config. 1: Reel System	• Very simple mechanism • Easy to manufacture	• Bulkier and heavier
Config. 2: Brake System	• Consume less space • Lightweight	• Harder to assemble

Selected Configuration	Rationales
Config. 2: Brake System	• Lightweight and space-saving

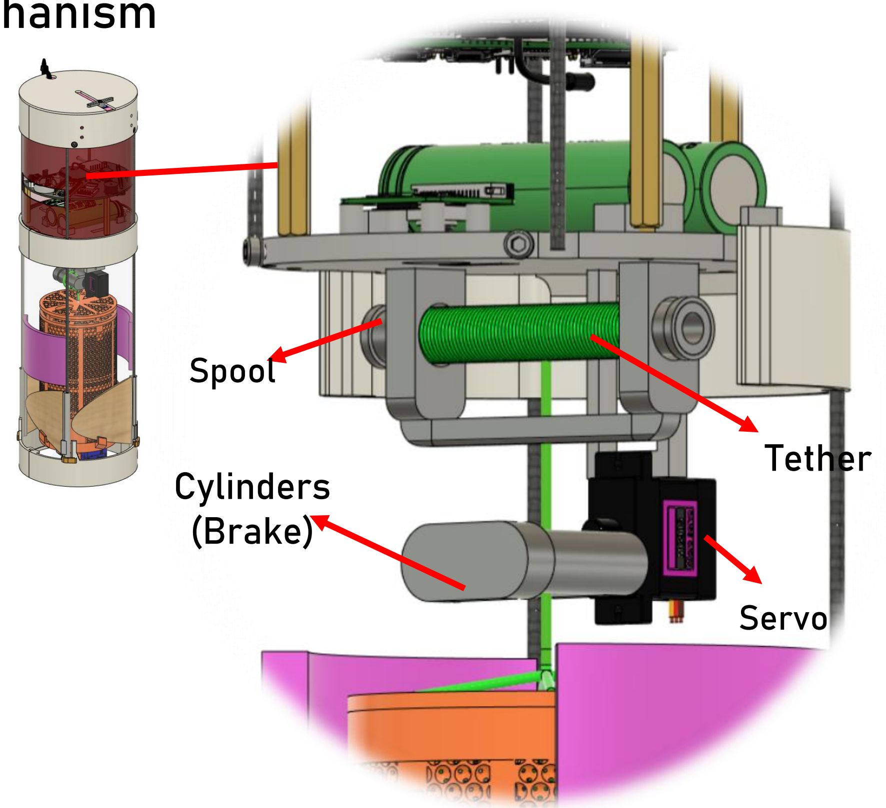
Payload Deployment Configuration Trade & Selection (4/4)

Detail on selected configuration: Brake mechanism



The cylinders restrict the tether from spooling down

Once the CanSat reaches 300 m, the servo will be triggered and tilts the break. The tether is unfolded.

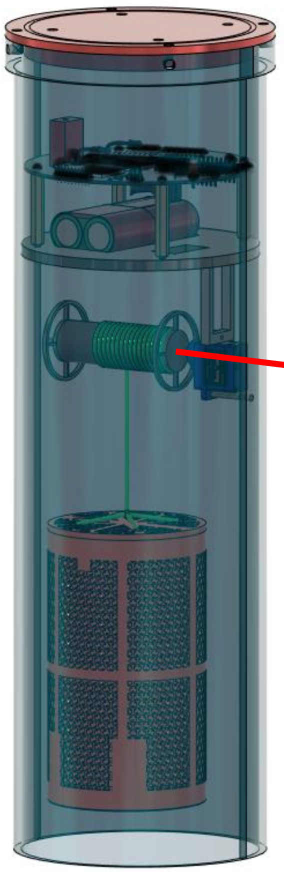


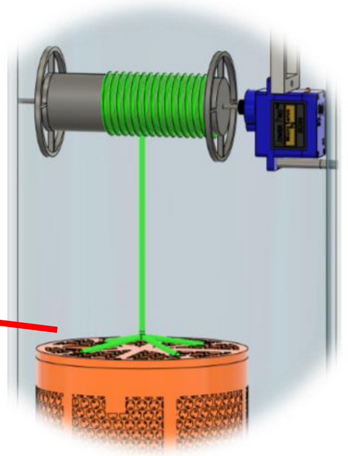
Developed from *STAR brake mechanism* : Lorenzo Olivieri, Francesco Sansone, Matteo Duzzi, and Alessandro Francesconi 2019, *TED Project: Conjugating Technology Development and Educational Activities*

Tether Design Trade & Selection (1/8)

Configuration 1: Reel system

- The spool connects to an actuator
- The unspooling rate is determined by how fast the actuator is rotating (RPM)
- Once the CanSat reaches 300 meters, an actuator will start to unspool the tether in 20 seconds



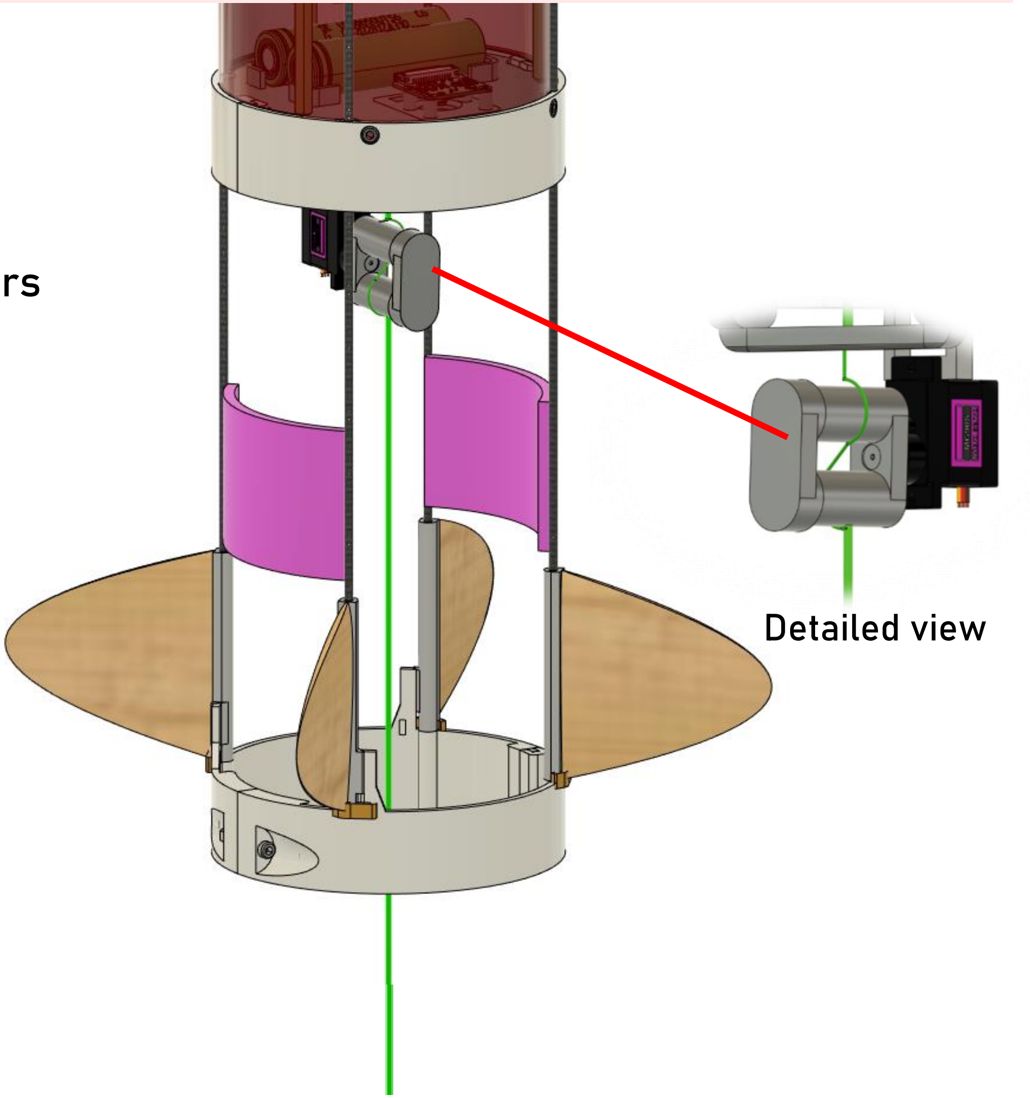


Detailed view

Tether Design Trade & Selection (2/8)

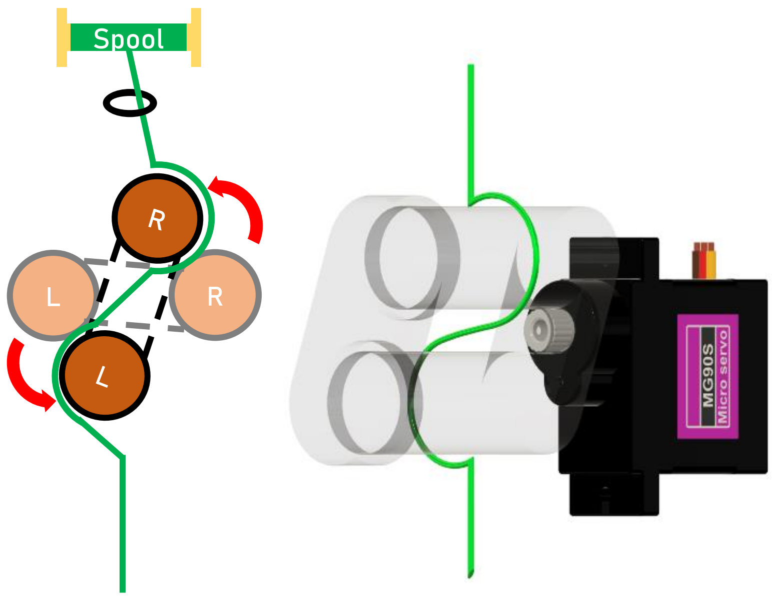
Configuration 2: Brake mechanism

- This mechanism can control the spooling of the tether by creating the friction between the surface of cylinders and the tether
- The brake doesn't fully let go of tether, but instead tilts itself to slightly block the way of the tether to control the unspooling rate
- The higher the length of the tether wrapped around the brake, the more friction will acts on it.

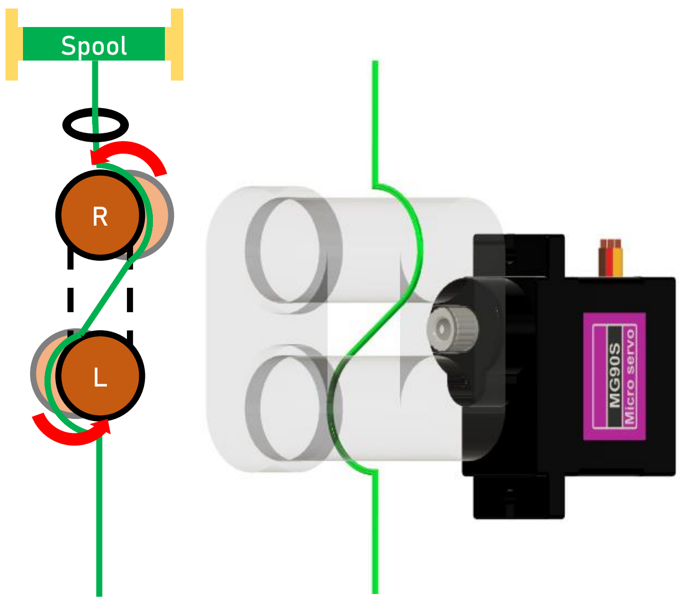


Configuration 2: Brake mechanism

- Deployment is split into 2 phases.
  Acceleration – *Constant velocity*

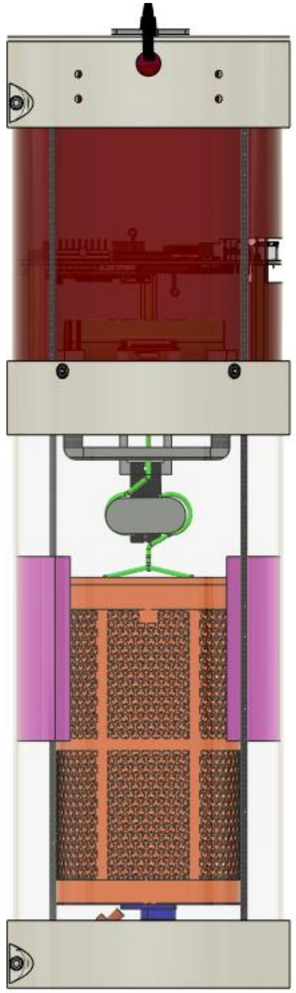


Acceleration – Once the payload transitions from a stowed configuration to deployed configuration, the brake will tilt and fully let go of the tether, causing the payload to accelerate for a short period of time.



Constant velocity – The brake will tilt back a little to restrict the tether to make the payload decelerate to a constant velocity.

Tether Design Trade & Selection (4/8)



Configuration	Advantages	Disadvantages
Config. 1: Reel System	• Simpler mechanism • Uncomplicated calculation	• To obtain the accurate spooling rate, high specs of the actuator are needed.
Config. 2: Brake System	• The spooling rate of the tether doesn't depend directly on the actuator. High specs servo is not needed.	• Complex calculation • Material with high coefficient of friction is needed

Selected Configuration	Rationales
Config. 2: Brake System	• Lightweight and space-saving. • Servo tend to be unreliable.

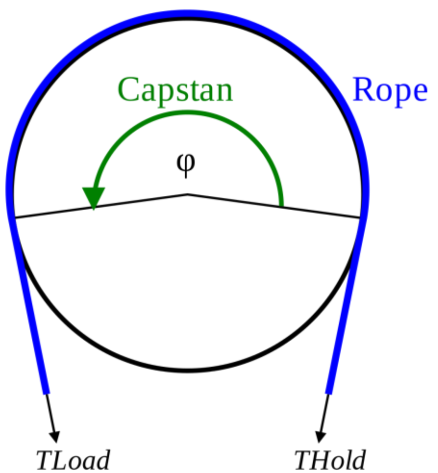
Tether Design Trade & Selection (5/8)

Detail on selected configuration: Capstan equation

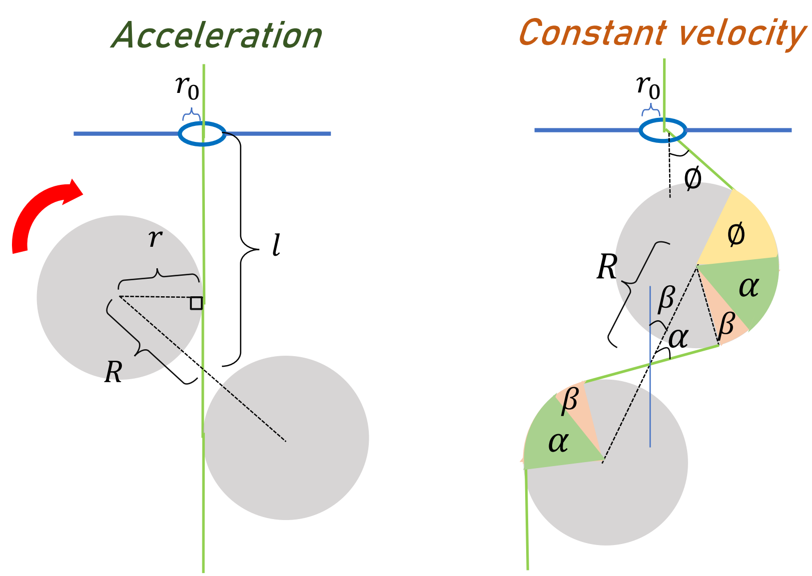
- The Capstan equation relates the hold-force to the load-force if a flexible line is wound around a cylinder.
- Used to find the exact angle to release the tether with the determined unspooling rate.

$$T_{load} = T_{hold} e^{\mu\theta}$$

$$\theta_{total} = 2(\alpha + \beta) + arctan\frac{Rsin\beta + r - r_0}{l - Rcos}$$



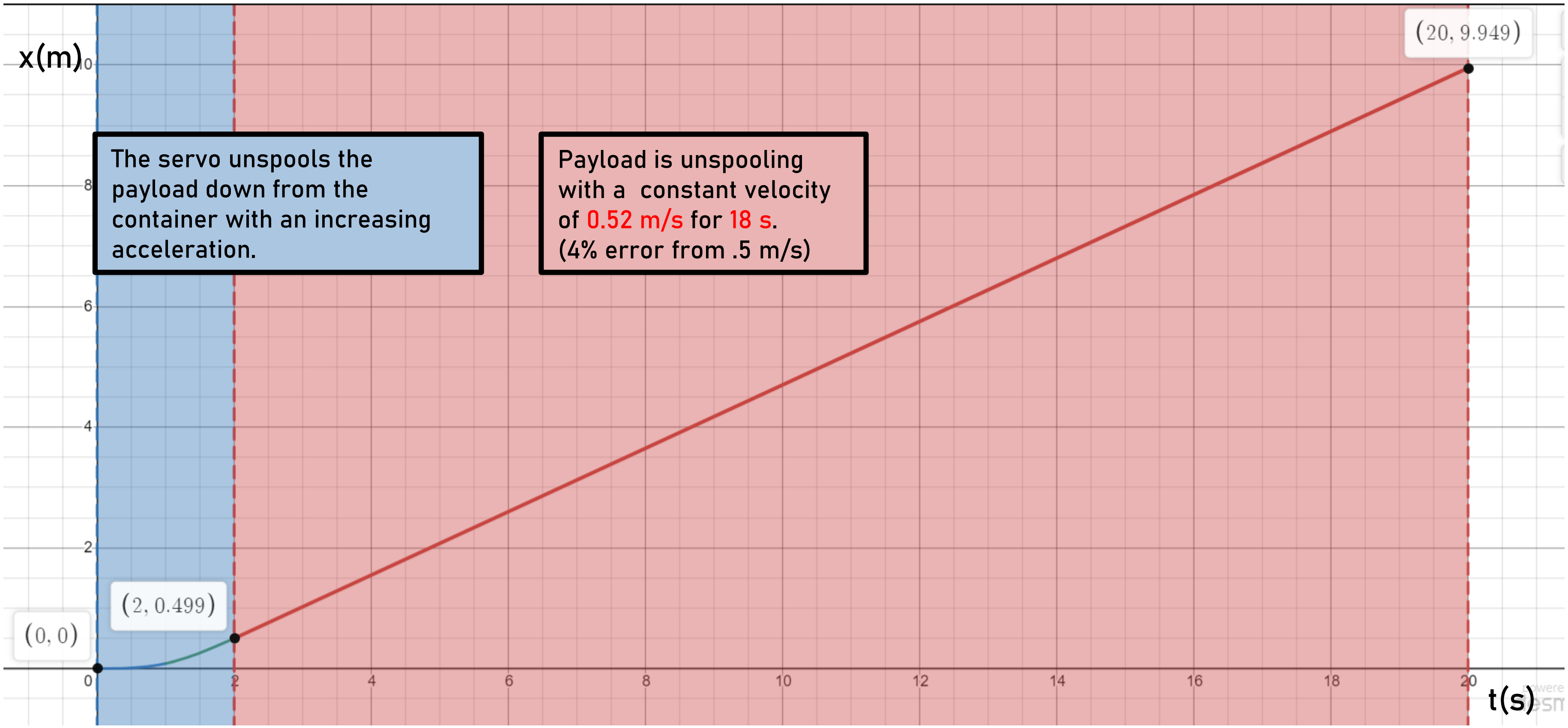
Reference : https://en.wikipedia.org/wiki/File:Capstan_equation_diagram.svg



α is used to increase the initial angle of the servo in the case that the servo doesn't rotate enough for the calculated angle.
β is the angle that servo rotates.

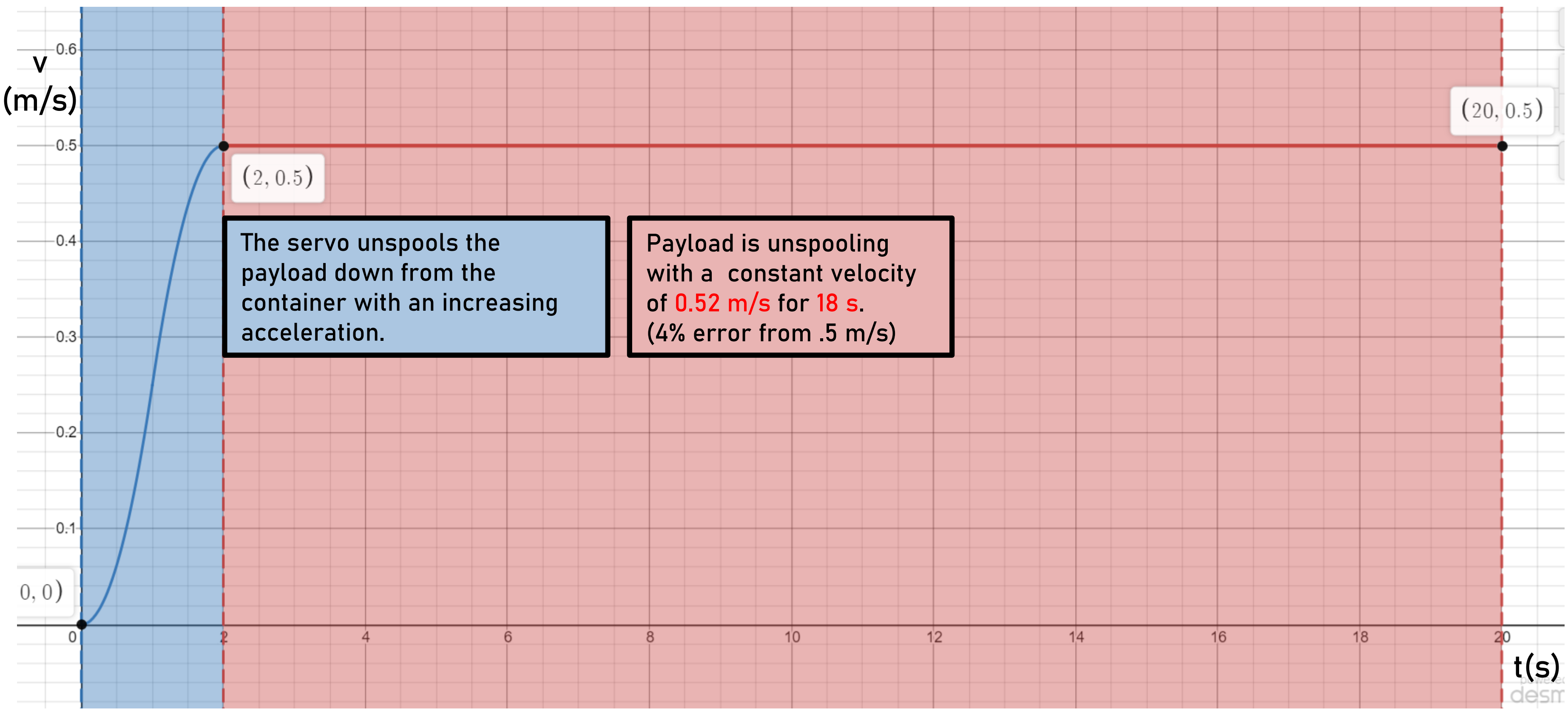
Tether Design Trade & Selection (6/8)

Detail on selected configuration: Distance-time graph of payload

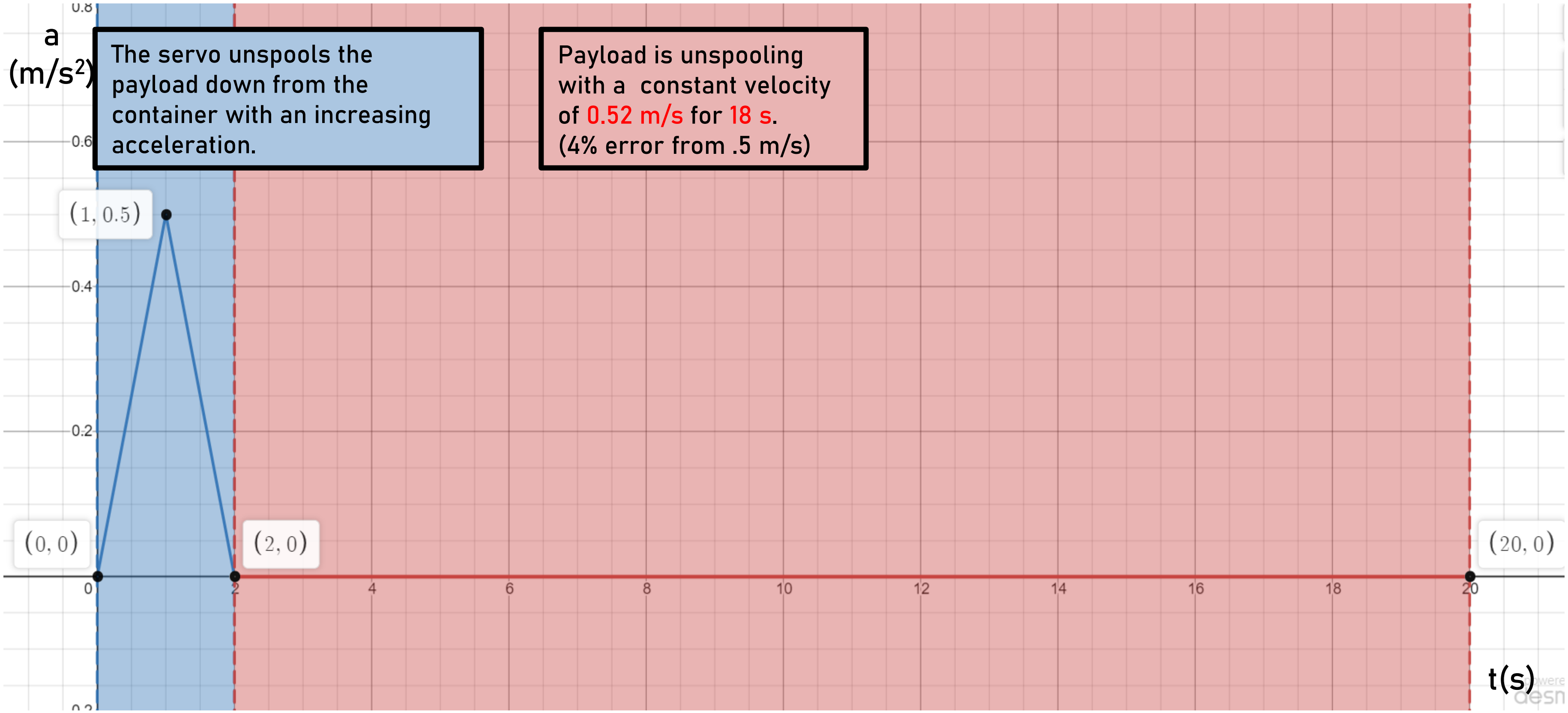


Tether Design Trade & Selection (7/8)

Detail on selected configuration: Velocity-time graph of payload



Detail on selected configuration: Acceleration-time graph of payload



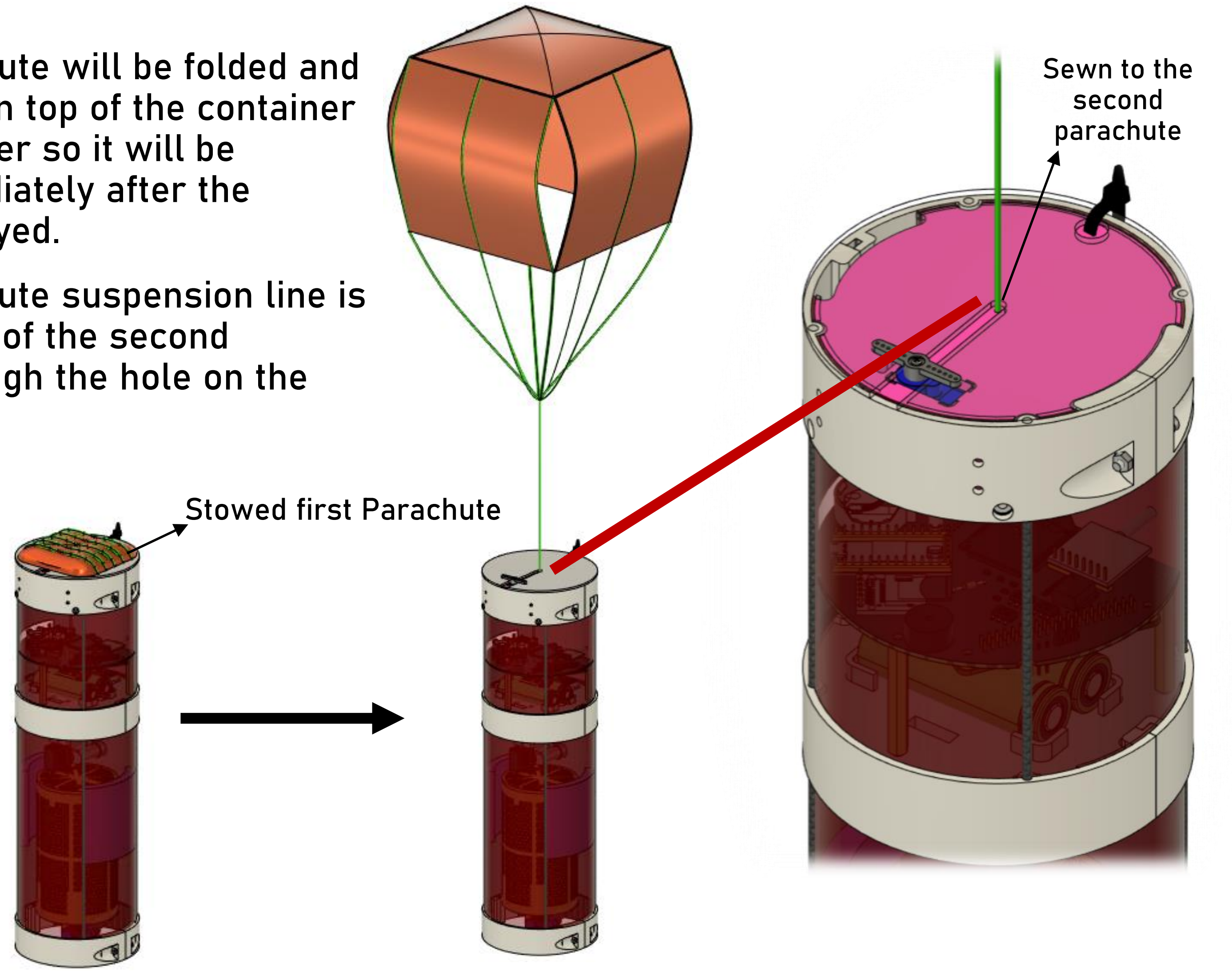
Tether Material Trade & Selection

Tether	Material	Diameter	Tensile Strength	Mass per 10 m	Cost ($)
Nano cord	Nylon/Polyester	0.75 mm	17 kg	4.1 g	$9.52
Micro cord	Nylon/Polyester	1.18 mm	46 kg	9.21 g	$8.60

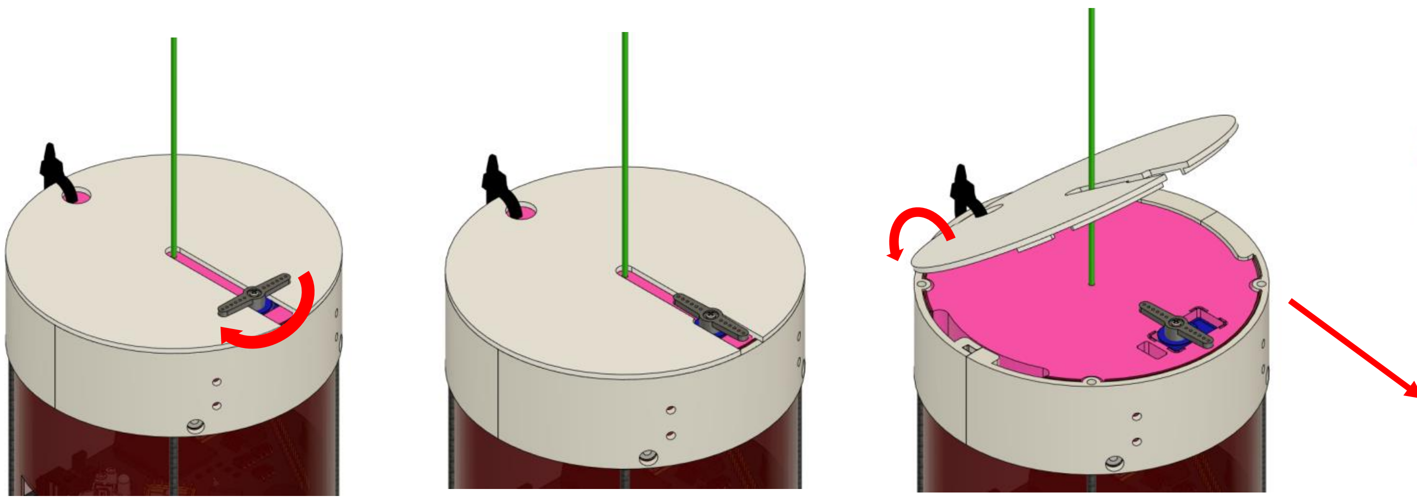
Selected Tether	Rationales
Nano cord	• Space-saving when spooled • Lighter • Provide enough strength to resist shock of the payload

Container First Parachute Deployment Mechanism

- 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 line is sewn to the top of the second parachute through the hole on the upper lid.



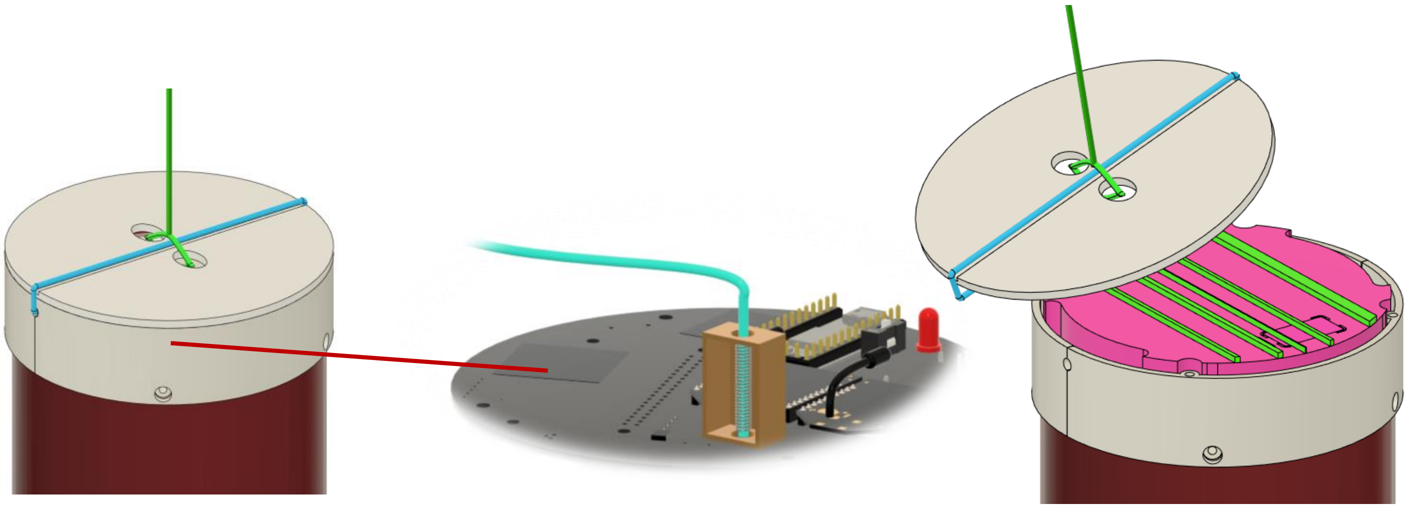
Configuration 1: Servo



Deployed Configuration

- 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 pushed by the folded parachute itself.
- The second parachute is deployed.

Configuration 2: Nichrome wire



- The first parachute is separated from the second parachute
- The first parachute is attached with the upper lid
- 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 fishing line.
- When the CanSat reaches 400 meters, the fishing line will be melted by heat generated by the nichrome wire.
- The second parachute is deployed. The first parachute is ejected with the upper lid.

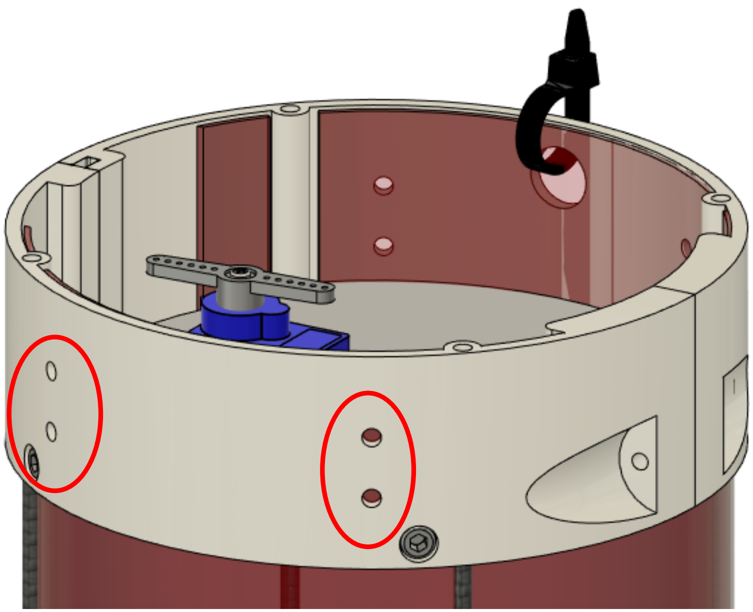
Deployed Configuration

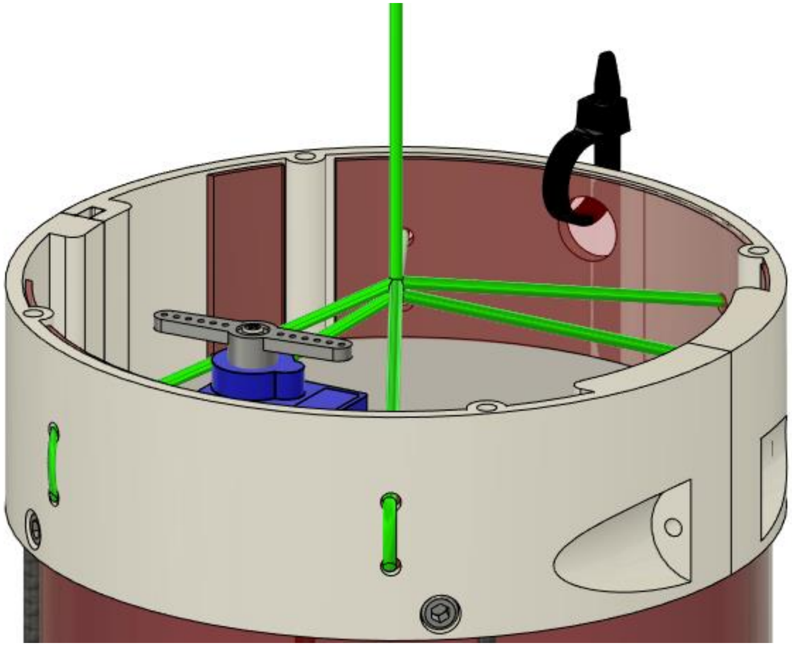
Container Second Parachute Deployment Mechanism Trade and Selection (3/4)

Configuration	Advantages	Disadvantages
Configuration 1: Servo	• More reliable • Could be tested many times	• Slightly bulkier
Configuration 2: Nichrome wire	• Consume less space	• Disposable • Hard to assemble and manufacture

Selected Design	Rationales
Configuration 1: Servo	• Could be tested many times • Familiarity with servo

Container Second Parachute Deployment Mechanism Trade and Selection (4/4)





Second Parachute attachment point

Electronics Structural Integrity

Mounting Methods

- Container PCB is bolted to a container floor using standoff screws.
- The battery is mounted to the 3D printed floor by flannel tape.
- The camera modules are bolted to the 3D printed structures.

Enclosures

- Container PCB will be covered with 3D printed parts and laminated paper.
- The standoff screws will be covered with electrical tape to prevent shorting.
- The main mission camera module will be covered by foam to absorb impact when landed.

Securing electrical connections

- All connectors of electronic components will be soldered to the PCB.

Descent Control attachment

- The first parachute suspension lines will be sewn on the top of the second parachute.
- The second parachute will be knotted to the container with nano cord.
- The spool will be mounted to the 3D printed structure.
- All servos will be bolted and glued to the securing slot.
- The fins will have slots for attaching to the carbon fiber rods.

Mass Budget (1/5)

Container Mass Budget (Electronic Subsystem)

Components		Mass (g)	Error (g)	Reference
Electronics Components	Li-ion Battery 18650 (x2)	93.00	±0.00	Datasheet
	SG90 Servo	9.00	±0.00	Datasheet
	MG90S Servo	13.40	±0.00	Datasheet
	Teensy 4.0	2.8	±0.00	Datasheet
	BME-280	1.00	±0.00	Datasheet
	MAX-M8Q	8.50	±0.00	Datasheet
	Raspberry Pi Zero W	9.00	±0.00	Datasheet
	Raspberry Pi Camera v2.1	3.00	±1.00	Measurement
	cr2032	3.30	±0.00	Datasheet
	LM2596S	1.59	±0.00	Datasheet
	ams1117-3.3	1.00	±0.00	Datasheet
	XBee + Antenna 900 MHz (x2)	26.00	±0.00	Datasheet
	Buzzer	10.3	±2.00	Measurement
	cr2032 cell holder	1.70	±1.00	Measurement
	Raspberry Pi Camera v2.1	3.00	±0.00	Datasheet
	PCB	5.00	±5.00	Approximation
	Solder	10.00	±3.00	Approximation

TOTAL
201.59±12.00
grams

Mass Budget (2/5)

Container Mass Budget (Mechanical Subsystem)

Components			Mass (g)	Error (g)	Reference
Structure	3D Printed	3D printed rib (x3)	72.00	±5.00	Software Estimation
		Brake cylinders	8.67		
		PCB mount	20.70		
		Upper lid	16.02		
		Lower lid	16.52		
		Servo mount	1.58		
		Axle mount	6.14		
		Axle	3.00		
	Tether (10 m)		8.88	±2.00	Datasheet
	Depron foam		1.00	±1.00	Approximation
	M3x10 bolt (x4)		2.00	±1.00	Measurement
	M3x30 bolt (x2)		3.50	±1.00	Measurement
	M3 nut (x2)		0.64	±1.00	Measurement
	Standoffs (x6)		3.00	±1.00	Measurement
	Laminated Paper (x2)		5.00	±2.50	Approximation
	Carbon fiber rod (x6)		20.00	±2.00	Approximation
	Fins (x4)		30.00	±5.00	Approximation

TOTAL
218.65±21.50
grams

TOTAL CONTAINER MASS
419.24±33.50
grams

Mass Budget (3/5)

Payload Mass Budget (Electronic Subsystem)

Components		Mass (g)	Error (g)	Reference
Electronics Components	Li-ion Battery TR16340 (x2)	29.00	±1.00	Measurement
	SG90 Servo (x2)	18.00	±0.00	Datasheet
	Teensy 4.0	2.80	±0.00	Datasheet
	Adafruit 3202	2.80	±0.00	Datasheet
	BNO-055	3.00	±0.00	Datasheet
	MicroSD card reader	2.00	±1.00	Measurement
	BME-280	1.00	±0.00	Datasheet
	XBee + Antenna 900 MHz	13.00	±0.00	Datasheet
	Buzzer	10.3	±2.00	Measurement
	LM2596S	1.59	±0.00	Datasheet
	ams1117-3.3 (x2)	2.00	±0.00	Datasheet
	cr2032 cell holder	3.00	±0.00	Datasheet
	cr2032	3.30	±0.00	Datasheet
	Solder	10.00	±3.00	Approximation

TOTAL
101.79±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
181.14±10.00
grams

Mass Budget (5/5)

Total CanSat Mass

Total Container mass 419.24±33.50 grams		Total CanSat mass 600.38±43.50 grams
Total Payload mass 181.14±10.00 grams		

Total Mass Margin = |600.00 – 600.38| = 0.38 grams

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

- The wall thickness and infill will be reduced.
- The material will be changed to fiberglass.
- The container's battery will be changed from 18650 (93 g) to 16650 (72 g) in trade of shorter operation time.

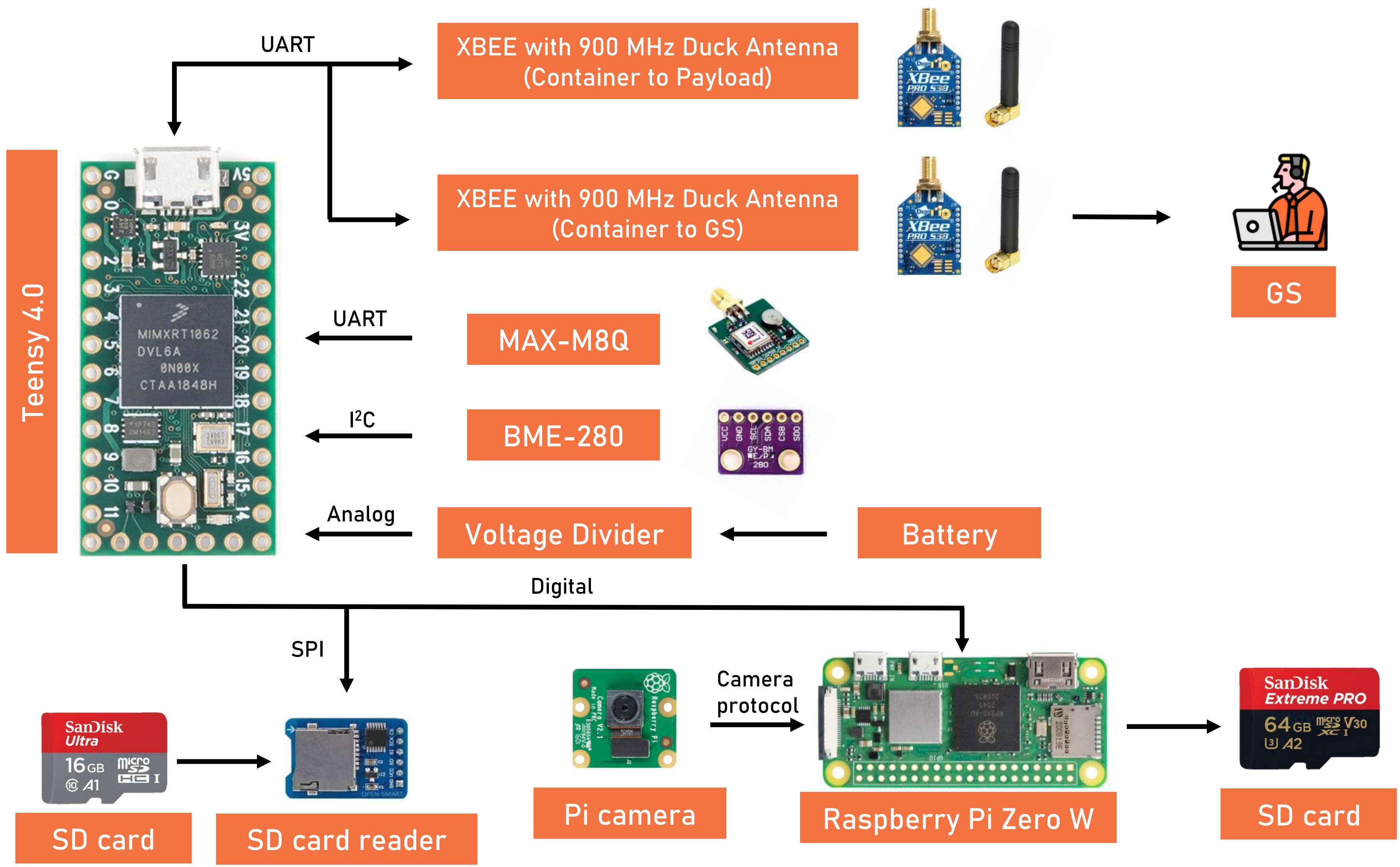
Communication and Data Handling (CDH) Subsystem Design

Krissada Singhakachain,
Krin Kaweewongsonthorn

Container CDH Overview (1/2)

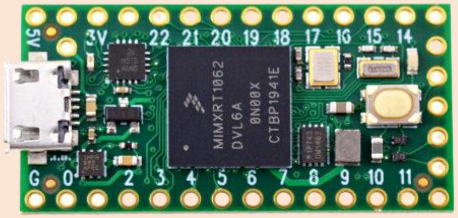
MCU - Teensy 4.0	• Control all other components
XBee radio – XBee Pro 900MHz	• Communication between the container, the ground station and the payload
Antenna – 900MHz Duck Antenna	• An external antenna used to increase the gain of the XBee radio
Data storage – Sandisk Ultra	• Store telemetry data
Sensors	• GPS, Air pressure sensor and Voltage divider
Other	• Camera is used for bonus mission (Camera has a dedicated SD card module). • Buzzer 92 dB loud audio beacon • Teensy's power real time clock is supplied by a CR2032 cell (to maintain track of time even when the switch is switched off).

Container CDH Overview (2/2)



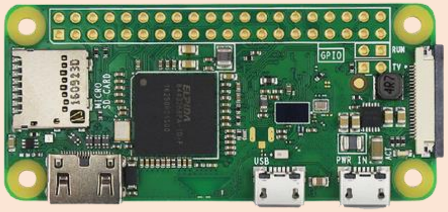
Container Processor & Memory Trade & Selection (1/5)

Container Processor	Clock Speed (MHz)	Supply Voltage (V)	GPIO Pins	Interfaces	Memory (kB)	RAM (kB)	EEPROM (kB)	Boot time (s)	Cost ($)
ATMEGA 328P	16	5.0	23	UART 1 SPI 2 I^2C 1	32	2	1	1.7	2.28
Teensy 4.0	600	3.3, 5.0	40	UART 7 SPI 3 I^2C 2 USB 2	2048	1024	64	1.4	19.95

Selected Container Processor		Rationale
Teensy 4.0		• Fast boot time • Enough interfaces for mission • Fast Clock Speed • Enough Memory storage • Sufficient GPIO pins for application • Higher Memory, RAM and EEPROM

Container Processor & Memory Trade & Selection (2/5)

Container Processor	Clock Speed (MHz)	Supply Voltage (V)	GPIO Pins	Interfaces	Memory (kB)	RAM (kB)	EEPROM (kB)	Boot time (s)	Cost ($)
Raspberry Pi Zero W	1000	5.0	40	UART 1 SPI 1 I^2C 1 SCB 1	USER SD CARD	512	-	14.4	28.3
Teensy 4.0	600	3.3, 5.0	40	UART 7 SPI 3 I^2C 2 USB 2	2048	1024	64	1.4	19.9

Selected Container Processor (For bonus mission)	Rationale
Raspberry Pi Zero W 	• Very high clock speed • Suitable for camera interface • High processing abilities High spec camera that is suitable for requirement

Container Processor & Memory Trade & Selection (3/5)

Memory Reader/Write Module	Supply voltage	Interface	Size (mm)	Cost ($)
MINI microSD Card Reader	4.5 ~ 5.5	SPI	18 x 25 x 3	1.3
Catalex microSD card Reader	4.5 ~ 5.5	SPI	24 x 42 x 4	1.5

Selected Container Memory Reader/Write module	Rationale
Mini microSD card Reader Module 	• Affordable cost • Small-size

Container Processor & Memory Trade & Selection (4/5)

Selected Container Memory	Memory Storage (GB)	Interface	Speed (Mb/s)		Cost ($)
			Read	Write	
SanDisk Ultra	16	SPI and SD	100	60	3.88
SanDisk Extreme Pro	32	SPI and SD	170	90	13.00
Kingston	8	SPI and SD	60	50	5.64

Selected Container Memory	Rationale
SanDisk Ultra 	• Cheaper, Faster Read/Write speed than Kingston • Sufficient storage for the mission

Container Processor & Memory Trade & Selection (5/5)

Raspberry pi Memory	Memory Storage (GB)	Interface	Speed (Mb/s)		Cost ($)
			Read	Write	
SanDisk Ultra	8	SPI and SD	80	20	3.5
SanDisk Extreme Pro	64	SPI and SD	170	90	12.00
SanDisk Extreme	32	SPI and SD	100	60	7.39

Selected Raspberry pi Memory (For bonus mission)	Rationale
SanDisk Extreme pro 	• Sufficient memory storage • Fast Read/Write speed for camera interface

Container Real-Time Clock

Container RTC	Size (mm)				Supply Voltage (V)	Status	Reset tolerance	Cost ($)
	L	W	H	Weight (g)				
DS3231	25.5	16.4	12.5	4.2	3.3	Hardware	External Supply Battery	1.67
Teensy Built-in RTC	Included in the microcontroller				3.3	Hardware	External Supply battery	0

Selected Container RTC	Rationale
Teensy built-in RTC 	• No extra cost • Use no extra space and weight • With hardware module time value will be precise • High accuracy

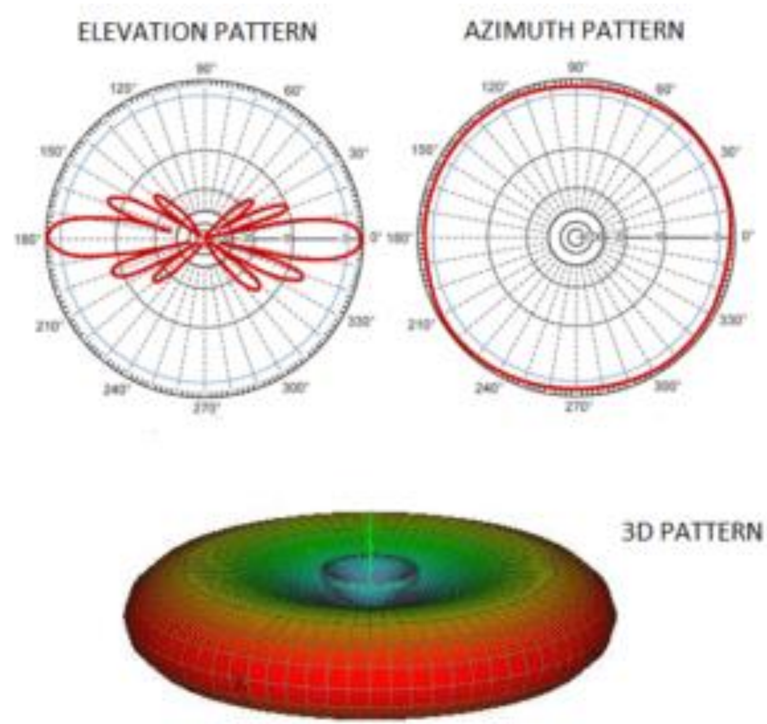
Container Antenna Trade & Selection (1/4)

Container to Payload Antenna Model	Connection Type	Frequency (MHz)	Type	Gain (dBi)	Cost
 GSM 900MHz Patch Soft Antenna	IPEX Female	880~915	Directional	4	$0.51
 900 MHz Quad-Band Cellular Duck Antenna	RP-SMA Male	900~1800	Omnidirectional	3	$3.00
 Antenna GSM/DCS (900-1800MHz)	FME Male	900~1800	Omnidirectional	2.14	$20.86

Container Antenna Trade & Selection (2/4)

Selected Container-to-Payload links Antenna: 900 MHz Quad-Band Cellular Duck Antenna

- Omnidirectional antenna design for receiving signal in all direction
- IPEX or FME to RP-SMA header(Male) for connection to XBee not required



The range of transmission has not been tested yet

Reference : https://www.mpantenna.com/omnidirectional-antenna-radiation-patterns/

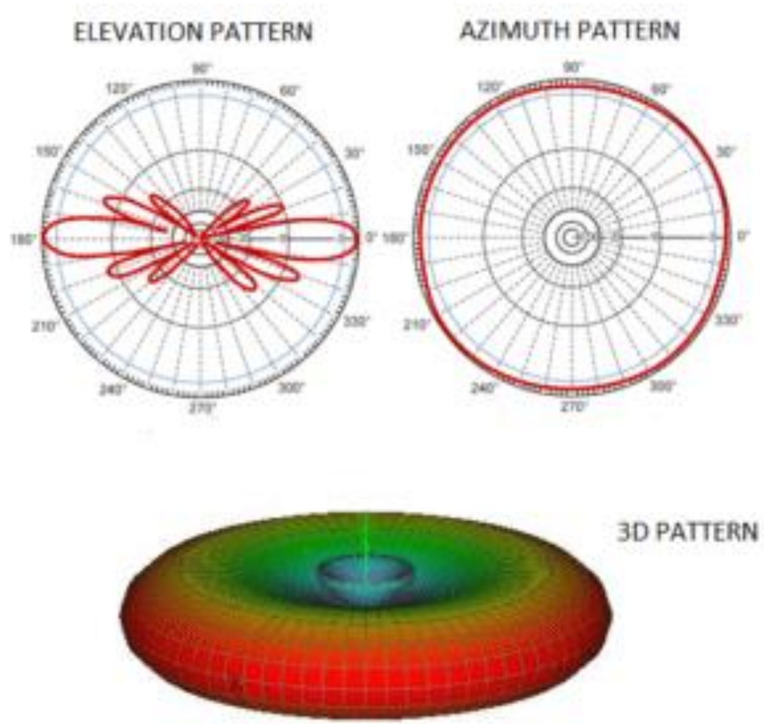
Container Antenna Trade & Selection (3/4)

Container to GS Antenna Model	Connection Type	Frequency (MHz)	Type	Gain (dBi)	Cost
 GSM 900MHz Patch Soft Antenna	IPEX Female	880~915	Directional	4	$0.51
 900 MHz Quad-Band Cellular Duck Antenna	RP-SMA Male	900~1800	Omnidirectional	3	$3.00
 Antenna GSM/DCS (900-1800MHz)	FME Male	900~1800	Omnidirectional	2.14	$20.86

Container Antenna Trade & Selection (4/4)

Selected Container-to-GS link Antenna: 900 MHz Quad-Band Cellular Duck Antenna

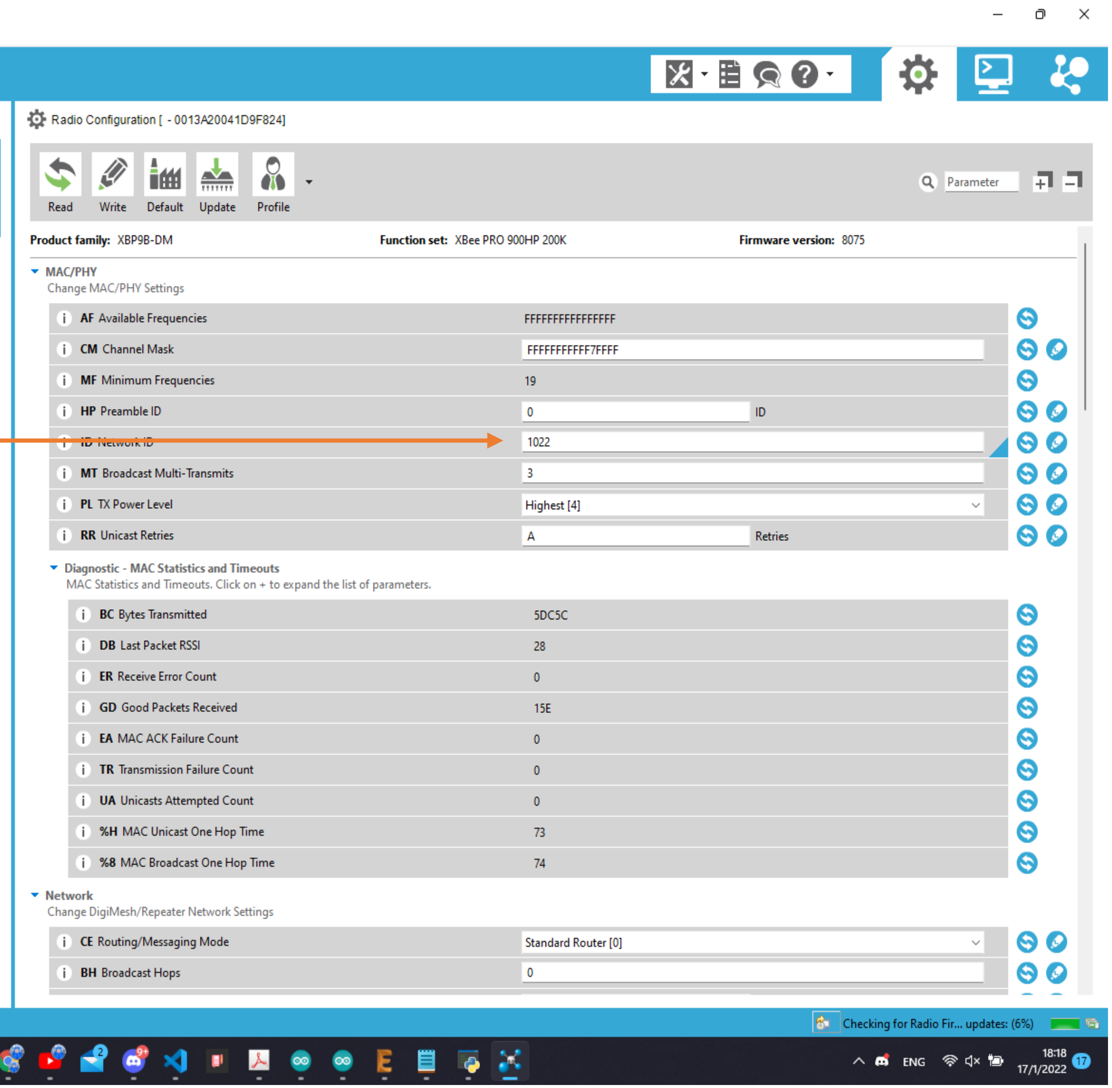
- Omnidirectional antenna design for receiving the signal in all directions
- IPEX or FME to RP-SMA header(Male) for connection to XBee not required



The range of transmission has not been tested yet

Reference : https://www.mpantenna.com/omnidirectional-antenna-radiation-patterns/

Container Radio Configuration



Container NETID is set to team number

Selected XBee radio: 900 MHz

Container Telemetry Format (1/2)

FIELD	EXPLANATION
TEAM_ID	The assigned team identification.
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)
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
PACKET_TYPE	The ASCII character 'C' for Container telemetry, character 'T' for Tethered Payload relay telemetry, and character 'X' for optional custom packets
MODE	'F' for flight (the default mode upon system start) and 'S' for simulation
TP_RELEASED	'N' for not released and 'R' for released
ALTITUDE	Altitude in units of meters and must be relative to ground level. The resolution must be 0.1 meters
TEMP	Temperature in degrees Celsius with a resolution of 0.1 degrees C
VOLTAGE	Voltage of the CanSat power bus. The resolution must be 0.01 volts
GPS_TIME	Time generated by the GPS receiver. The time must be reported in UTC and have a resolution of a second
GPS_LATITUDE	The latitude generated by the GPS receiver in decimal degrees with a resolution of 0.0001 degrees North
GPS_LONGITUDE	The longitude generated by the GPS receiver in decimal degrees with a resolution of 0.0001 degrees West

Container Telemetry Format (2/2)

FIELD	EXPLANATION
GPS_ALTITUDE	The altitude generated by the GPS receiver in meters above mean sea level with a resolution of 0.1 meters
GPS_SATS	The number of GPS satellites being tracked by the GPS receiver. This must be an integer number
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
CMD_ECHO	Fixed text command id and argument of the last received command with no commas. For example, CXON or SIMENABLE.

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

Packet Data Example: 1022,03:04:19.54,982,C,F,N,0.67,32.37,7.51,03:04:19,14.9943,103.1039,0.6,3,PRELAUNCH,CXON

- 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

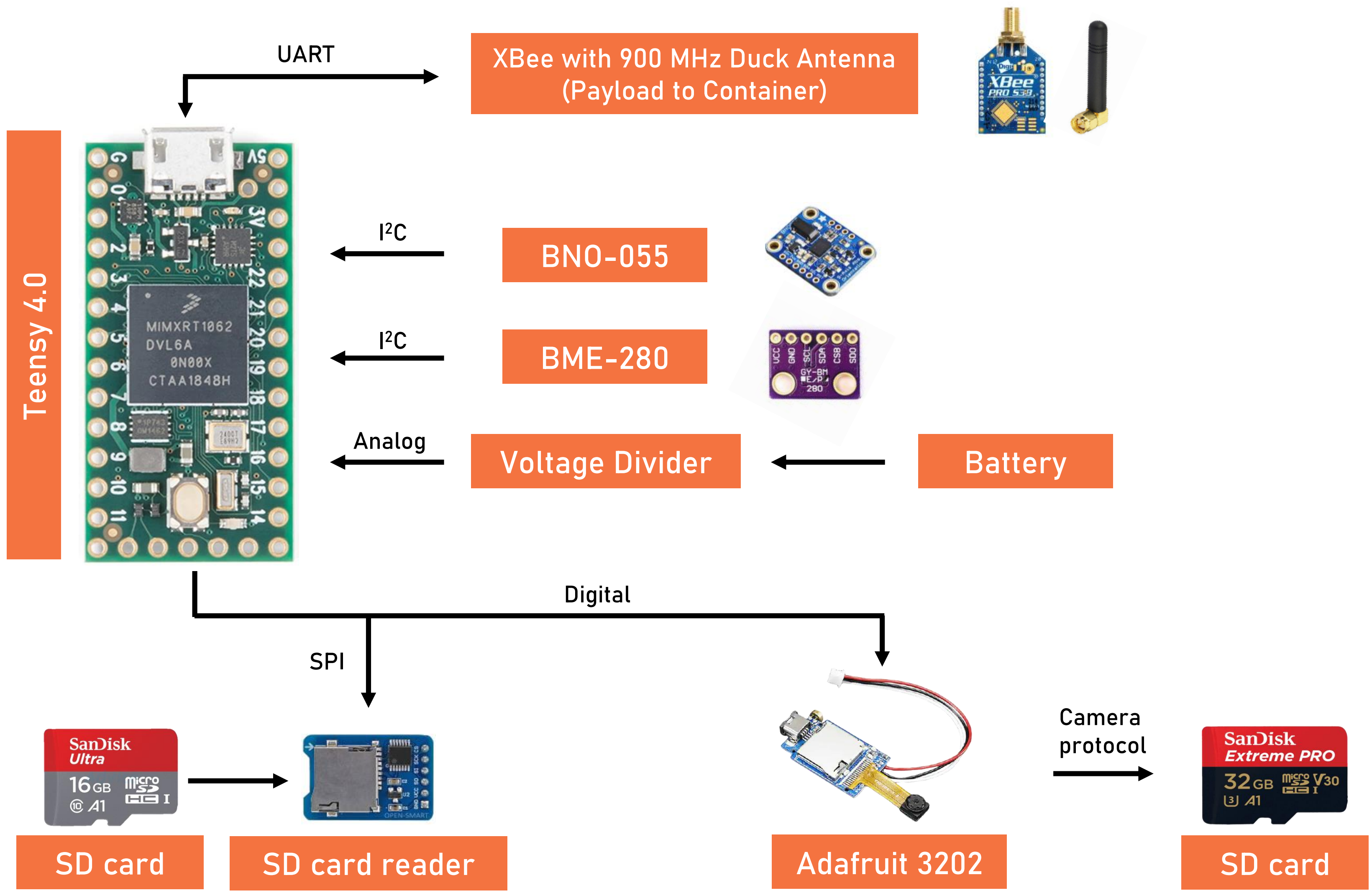
COMMAND	FORMAT	EXAMPLE
CX Container Telemetry On/Off	CMD,<TEAM_ID>,CX,<ON_OFF>	CMD,1022,CX,ON
ST Set Time	CMD,<TEAM_ID>,ST,<UTC_TIME>	CMD,1022,ST,13:35:59
SIM Simulation Mode Control	CMD,<TEAM_ID>,SIM,<MODE>	CMD,1022,SIM,DISABLE
SIMP Simulated Pressure Data	CMD,<TEAM_ID>,SIMP,<PRESSURE>	CMD,1022,SIMP,101325

FIELD	MEANING
<ON_OFF>	On or Off : CX->Container telemetry transmissions : PX->Science Payload transmission
<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 CDH Overview (1/2)

MCU: Teensy 4.0	• This is the microcontroller that is used to control all other components.
XBee radio – XBee Pro 900 MHz	• XBee radio is used for communication between the payload and the container.
Antenna – 900MHz Duck Antenna	• An external antenna is used to increase the gain of the XBee Radio.
Data storage – Sandisk	• Store telemetry data
Sensors	• GPS, Air pressure sensor, Air temperature sensor and Voltage divider
Other	• Camera has an internal SD card module. • Buzzer 92 dB loud audio beacon. • Teensy's power real time clock is supplied by a CR2032 cell (to maintain track of time even when the switch is switched off).

Payload CDH Overview (2/2)



Payload Processor & Memory Trade & Selection (1/4)

Payload Processor	Clock Speed (MHz)	Supply Voltage (V)	GPIO Pins	Interfaces	Memory (kB)	RAM (kB)	EEPROM (kB)	Boot time (s)	Cost ($)
ATMEGA 328P	16	5.0	23	UART 1 SPI 2 I^2C 1	32	2	1	1.7	2.28
Teensy 4.0	600	3.3, 5.0	40	UART 7 SPI 3 I^2C 2 USB 2	2048	1024	64	1.4	19.95

Selected Payload Processor	Rationale
Teensy 4.0 	• Fast Boot time • Enough interfaces for mission • Fast Clock Speed • Sufficient GPIO pins for our usages • Higher Memory, RAM, and EEPROM

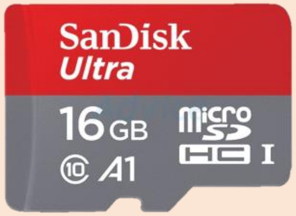
Payload Processor & Memory Trade & Selection (2/4)

Memory Reader/Write Module	Supply voltage	Interface	Size (mm)	Cost ($)
MINI microSD Card Reader	4.5 ~ 5.5	SPI	18 x 25 x 3	1.3
Catalex microSD card Reader	4.5 ~ 5.5	SPI	24 x 42 x 4	1.5

Selected Payload Memory Reader/Write module	Rationale
Mini microSD card Reader Module 	• Affordable cost • Small-size

Payload Processor & Memory Trade & Selection (3/4)

Selected Payload Memory	Memory Storage (GB)	Interface	Speed (Mb/s)		Cost ($)
			Read	Write	
SanDisk Ultra	16	SPI and SD	100	60	3.88
SanDisk Extreme Pro	32	SPI and SD	170	90	12.00
Kingston	8	SPI and SD	60	50	5.64

Selected Payload Memory	Rationale
SanDisk Ultra 	• Cheaper • Faster Write speed than Kingston • Sufficient storage for the mission

Payload Processor & Memory Trade & Selection (4/4)

Adafruit 3202 Memory	Memory Storage (GB)	Interface	Speed (Mb/s)		Cost ($)
			Read	Write	
SanDisk Extreme Pro	32	SPI and SD	100	90	13.00
SanDisk Extreme Pro	64	SPI and SD	170	90	13.00
SanDisk Extreme	32	SPI and SD	100	60	7.39

Selected Adafruit 3202 Memory	Rationale
SanDisk Extreme pro 	• Sufficient memory storage • Fast Read/Write speed for camera interface and operating Adafruit 3202

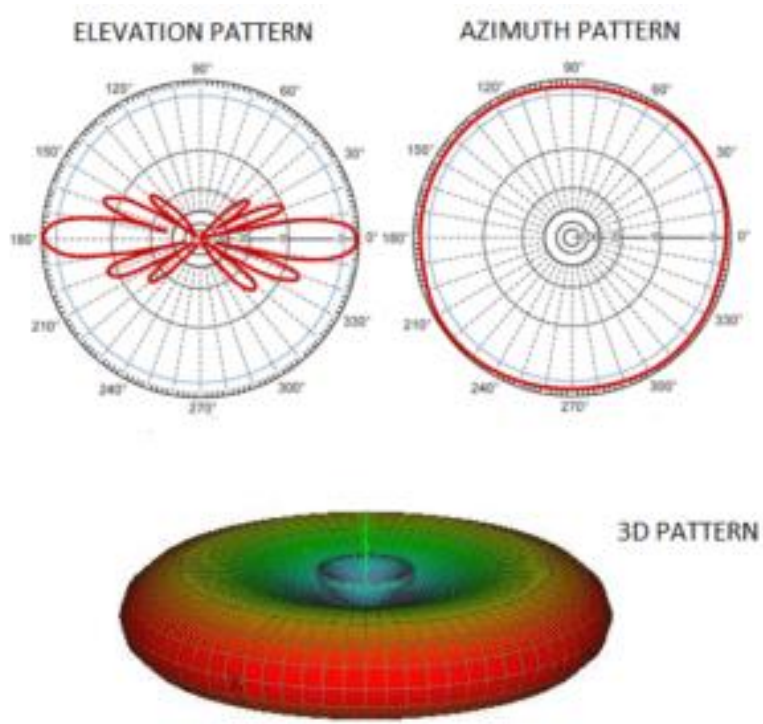
Payload Antenna Trade & Selection (1/2)

Payload to Container Antenna Model	Connection Type	Frequency (MHz)	Type	Gain (dBi)	Cost
 105262 Molex Flexible Antenna	IPEX Female	902~928	Directional	2	$0.51
 900 MHz Quad-Band Cellular Duck Antenna	RP-SMA Male	900~1800	Omnidirectional	3	$3.00
 VAS Universal Vee Antenna	SMA Male	800~6000	Omnidirectional	1.9	$12.95

Payload Antenna Trade & Selection (2/2)

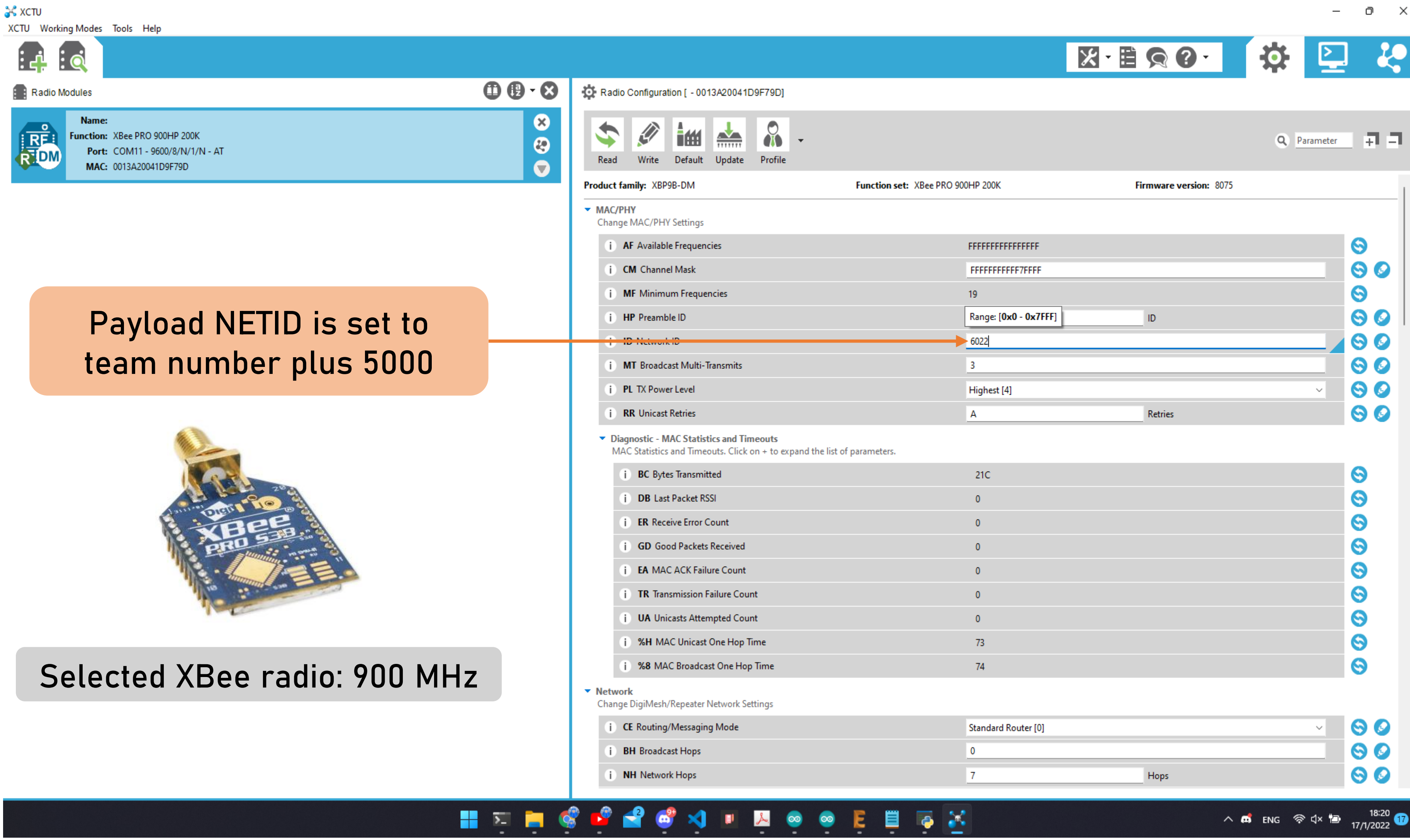
Selected Payload-to-Container links Antenna: 900 MHz Quad-Band Cellular Duck Antenna

- Omnidirectional antenna design for receiving signals in all directions
- Smallest size of all
- IPEX or SMA(Male) to RP-SMA header(Male) for connection to XBee not required



The range of transmission has not been tested yet

Reference : https://www.mpantenna.com/omnidirectional-antenna-radiation-patterns/



Payload NETID is set to team number plus 5000

Selected XBee radio: 900 MHz

Payload Telemetry Format (1/2)

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 (2/2)

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

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

Packet Data Example:

1022,03:04:19.54,1,P,45.1,26.5,7.25,-0.31,-0.19,0.12,-0.47,1.39,9.58,-0.78,0.29,9.69,5,RELEASED

- 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

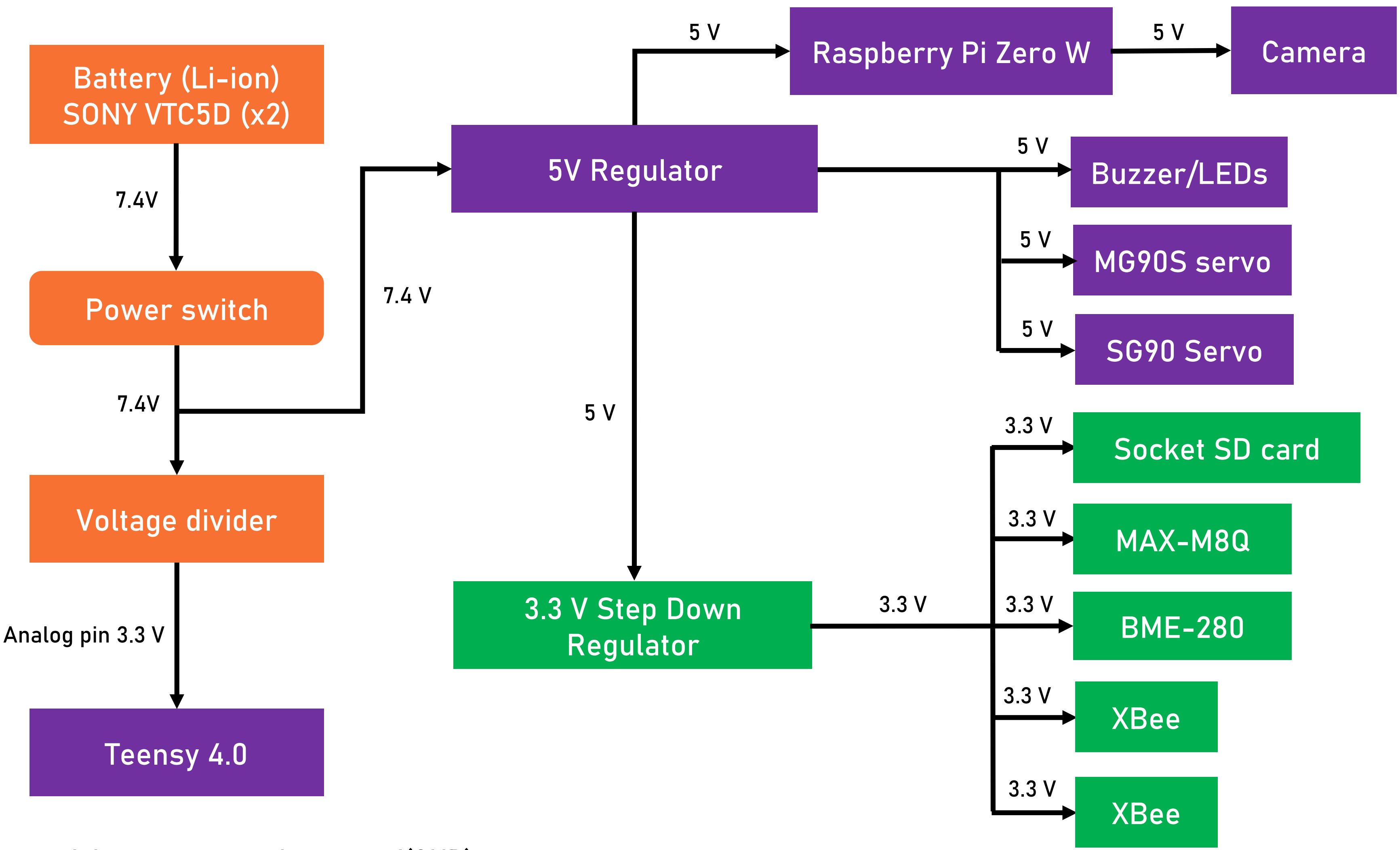
Electrical Power Subsystem (EPS) Design

Pitiphoom Achapramote

EPS Overview

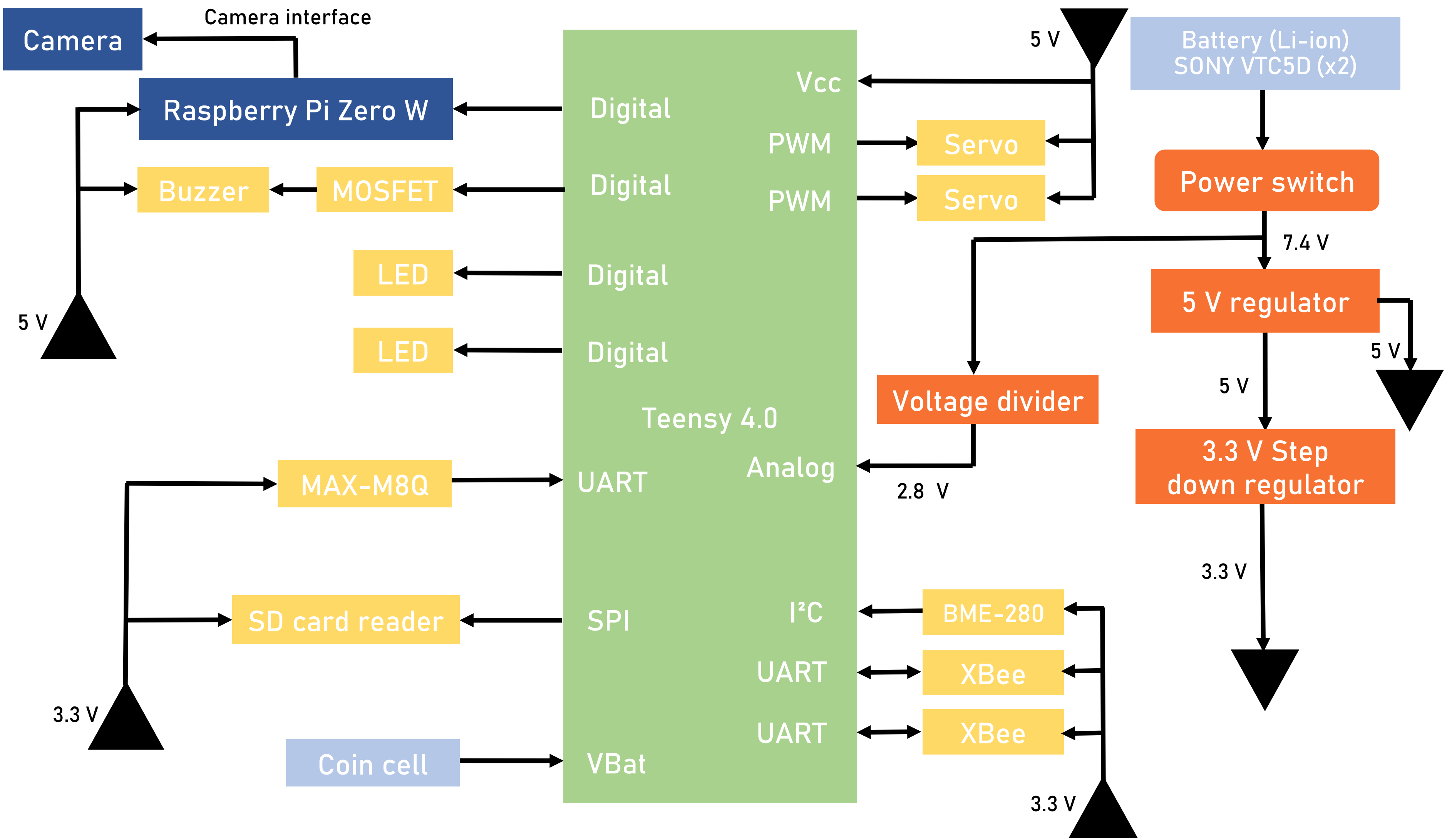
Component	Purpose(s)
Battery	Supplies voltage to the circuit
Power Switch	Allows power on/off state of the board
Voltage Step-down Regulator	Lowers the voltage from above 3.3 V to 3.3 V
Voltage Regulator	Steps down voltage for sensors and components
Voltage Divider	Provides voltage feedback and measurement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

Container Electrical Block Diagram (1/2)



*Every module are connected to ground(GND)

Container Electrical Block Diagram (2/2)



Container Power Trade & Selection

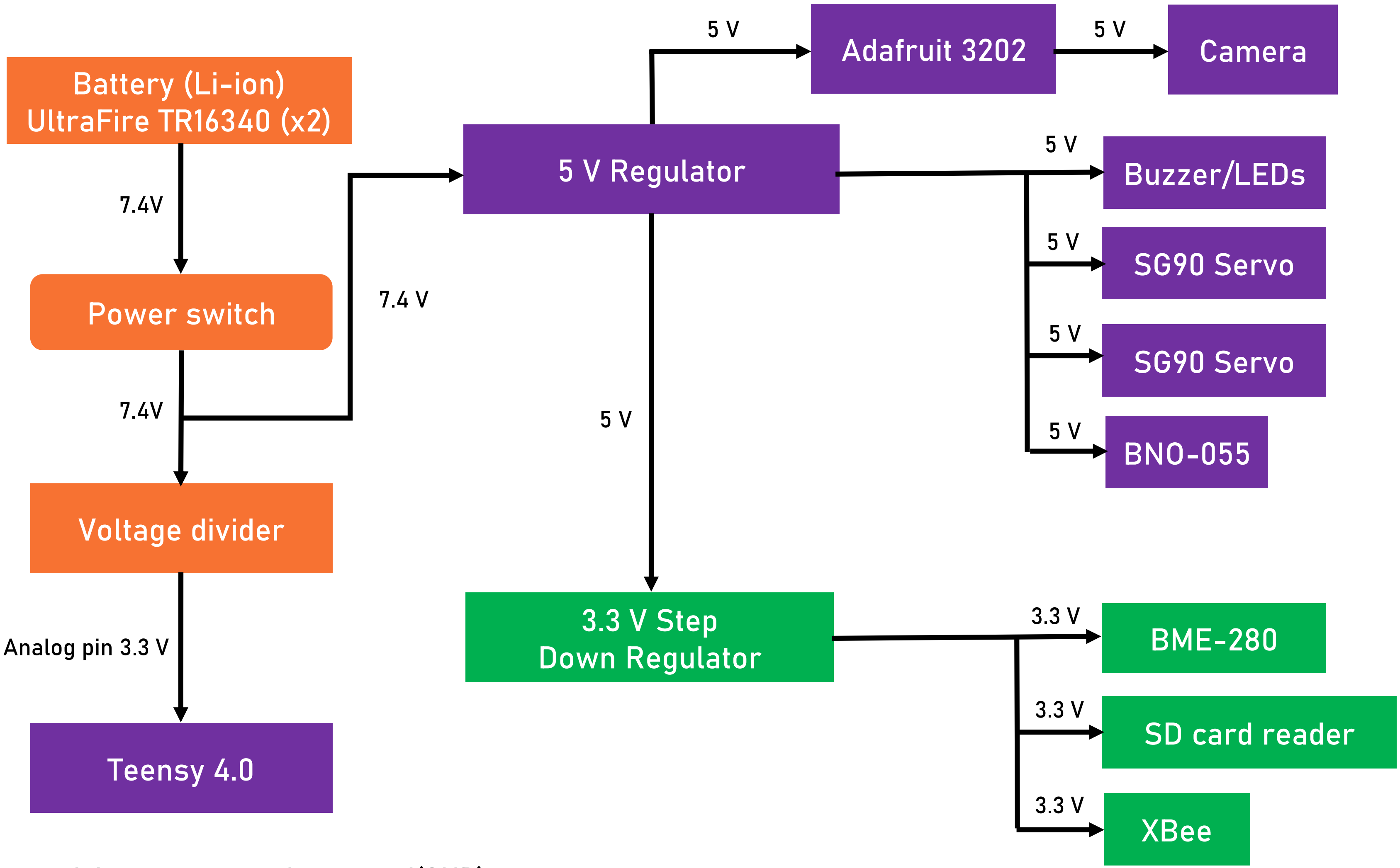
Battery model	Battery type	Quantity	Configuration	Size (mm)	Mass (g)	Supply voltage	Charge (mA·h)	Maximum Continuous Discharge Current	Cost ($)
Vapcell Original INR 16650	Li-ion	2	Series	65 x 16 x 32	76	7.4	2000	8A	10.99
SONY VTC5D	Li-ion	2	Series	65 x 18 x 32	93	7.4	2800	30A	12

Selected Container Power Supply	Rationales
SONY VTC5D 	• Highest continuous discharge current • Higher capacity • Provide enough electricity for the container to operate for 2 hours

Container Power Budget

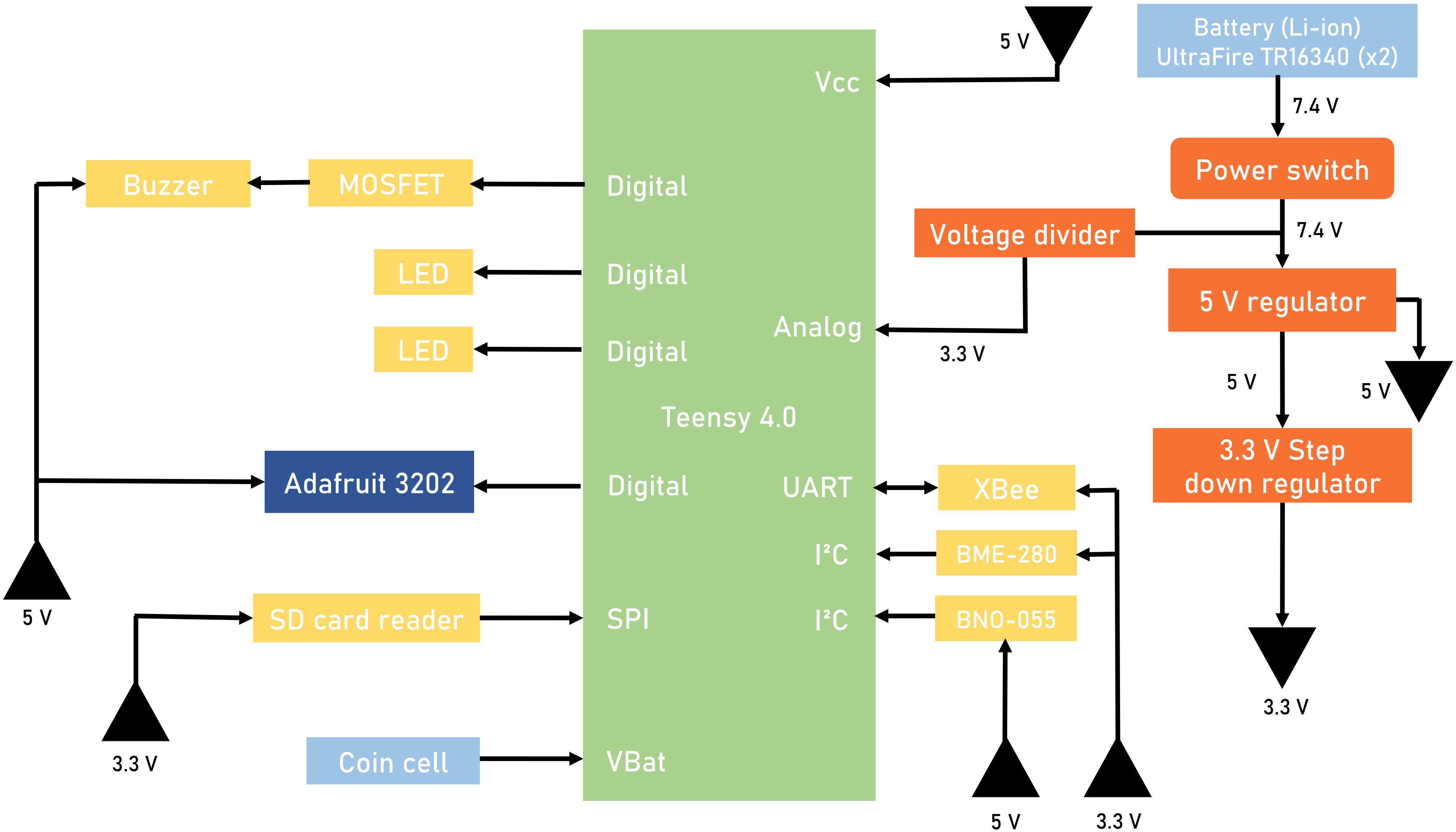
Component	Supply voltage(V)	Current (Peak)	Power	Power Consumption (W·h)	Duty cycle	Data reference
Teensy 4.0	3.3	100.0 mA	0.330 W	0.330	100%	Datasheet
Raspberry Pi Zero W	3.3	370.0 mA	1.221 W	1.221	100%	Datasheet
MAX-M8Q	3.3	26.0 mA	0.0858 W	8.58×10^{-2}	100%	Datasheet
SD card reader	3.3	200.0 mA	0.66 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 mA	0.974 W	0.974	100%	Datasheet
XBEE	3.3	295 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 mA	0.016 W	0.016	100%	Measurement*
LED	3.3	5 mA	0.016 W	0.0016	10%	Measurement*
LED	3.3	5 mA	0.016 W	0.0016	10%	Measurement*
MG90S Servo	5.0	400 mA	2 W	0.1	5%	Measurement*
SG90 Servo	5.0	360 mA	1.8 W	0.09	5%	Measurement*
TOTAL			8.318 W	4.48 W·h		
Battery	7.4	2800mAh	-	20.72 W·h	Margin	*16.24 W·h*
*The measurement of current is approximated, but no uncertainly is given.					Time	*4 hours 37 minutes*

Payload Electrical Block Diagram (1/2)



*Every module are connected to ground(GND)

Payload Electrical Block Diagram (2/2)



Payload Power Trade & Selection

Battery model	Battery type	Quantity	Configuration	Size (mm)	Mass (g)	Supply voltage	Charge (mA·h)	Maximum Continuous Discharge Current	Cost ($)
UltraFire TR16340	Li-ion	2	Series	35 x 16 x 32	30	7.4	2600	8A	3.93
INR18650-26E	Li-ion	2	Series	36 x 18 x 65	46	7.4	2600	8A	5.31

Selected Payload Power Supply	Rationales
UltraFire TR16340 	• Provide enough electricity for payload to operate for 2 hours • Small size • Less weight

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	110.0 mA	0.550 W	0.550	100%	Datasheet
BNO-055	5	12.28 mA	0.0614 W	0.0614	100%	Datasheet
SD card reader	3.3	200.0 mA	0.66 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 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 mA	0.016 W	0.016	100%	Measurement*
LED	3.3	5 mA	0.016 W	0.0016	10%	Measurement*
LED	3.3	5 mA	0.016 W	0.0016	10%	Measurement*
SG90 Servo	5.0	360 mA	1.8 W	0.09	5%	Measurement*
SG90 Servo	5.0	360 mA	1.8 W	0.09	5%	Measurement*
TOTAL			6.44 W	2.79 W·h		
Battery	7.4	2600mAh	-	19.24 W·h	Margin	*16.45 W·h*
*The measurement of current is approximated, but no uncertainly is given.					Time	*6 hours 53 minutes*

Flight Software (FSW) Design

Krissada Singhakachain, Arkkhanirut Pandej

FSW Overview (1/2)

Overview of the CanSat FSW Design

- The CanSat container will gather sensor data then save to SD card and send to ground station via XBee.
- The CanSat payload sensor data will be polled 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 on the container to record the deployment of the payload.

Programming Language

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

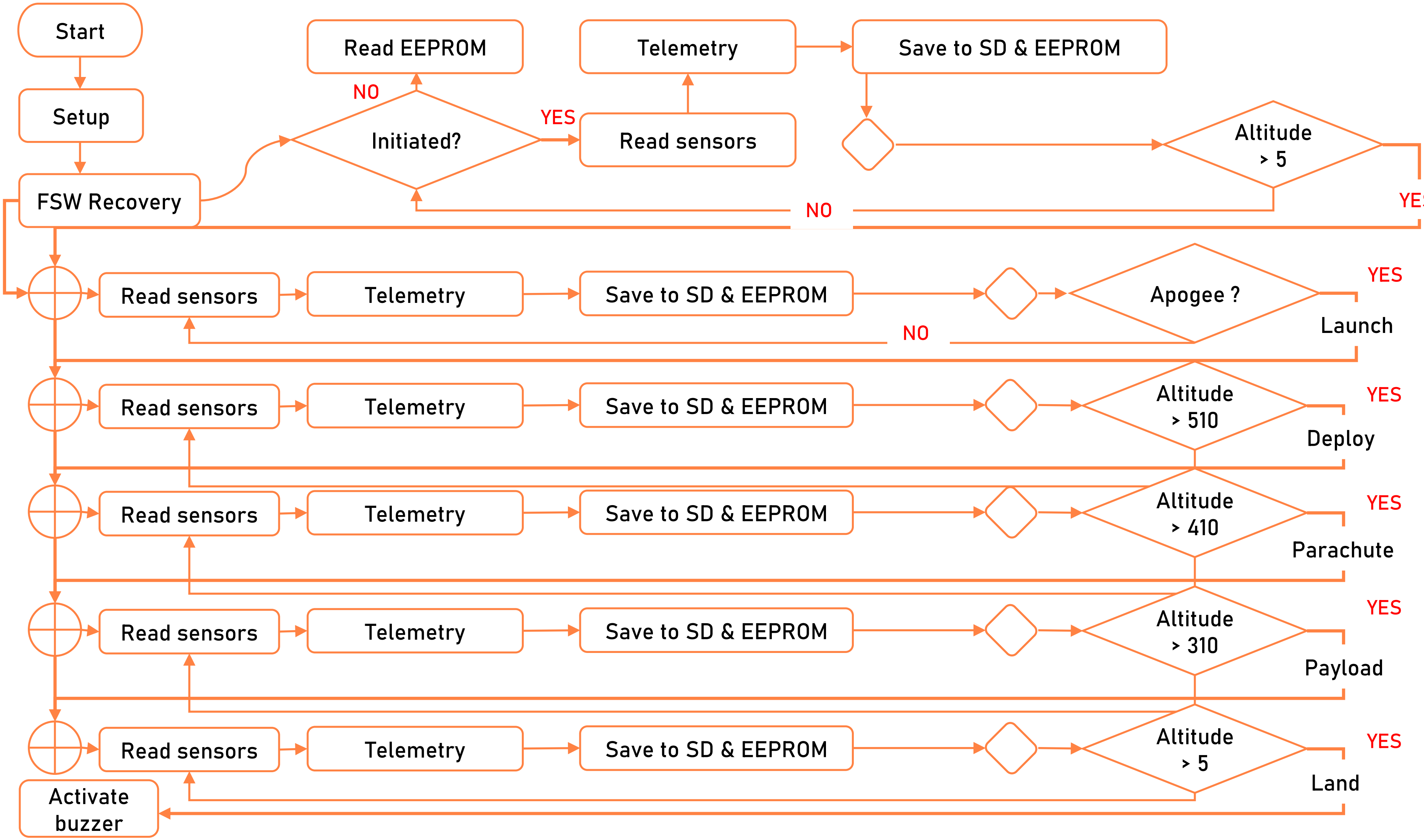
Development Environment

- Arduino IDE
- Visual Studio Code
- Qt Designer

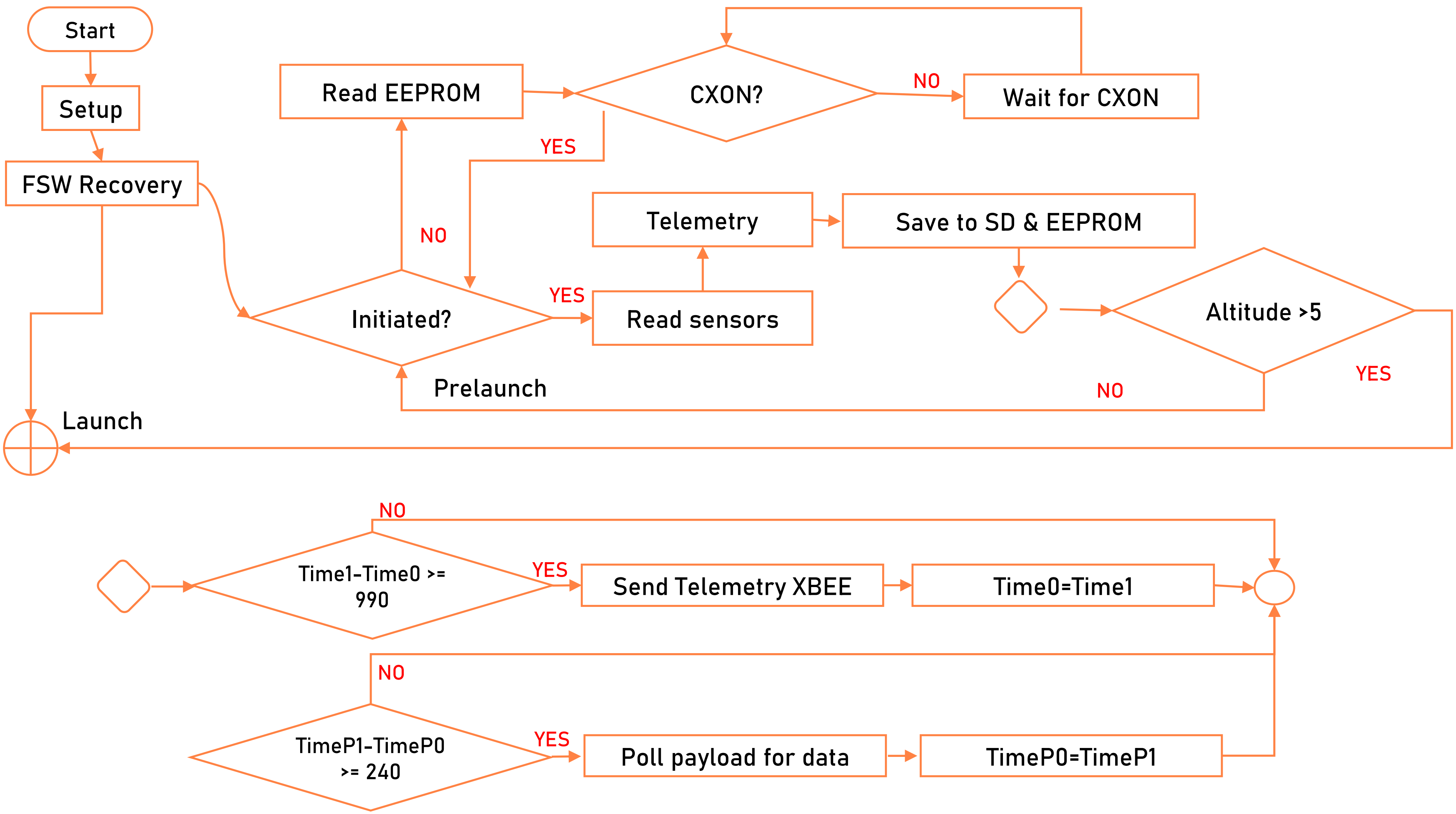
FSW Overview (2/2)

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.

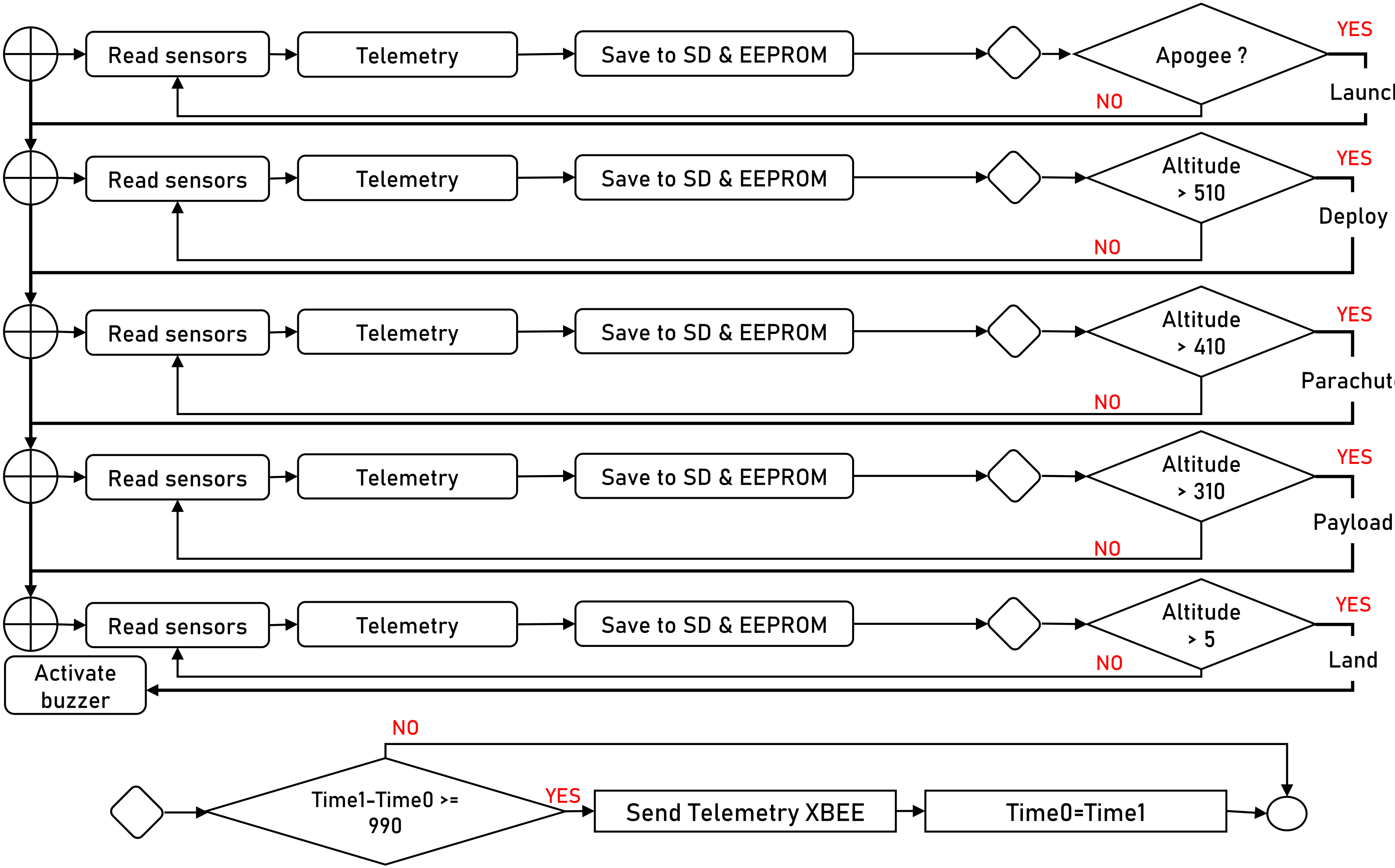
Container FSW State Diagram (1/4)



Container FSW State Diagram (2/4)



Container FSW State Diagram (3/4)



Container FSW State Diagram (4/4)

Data Recovery

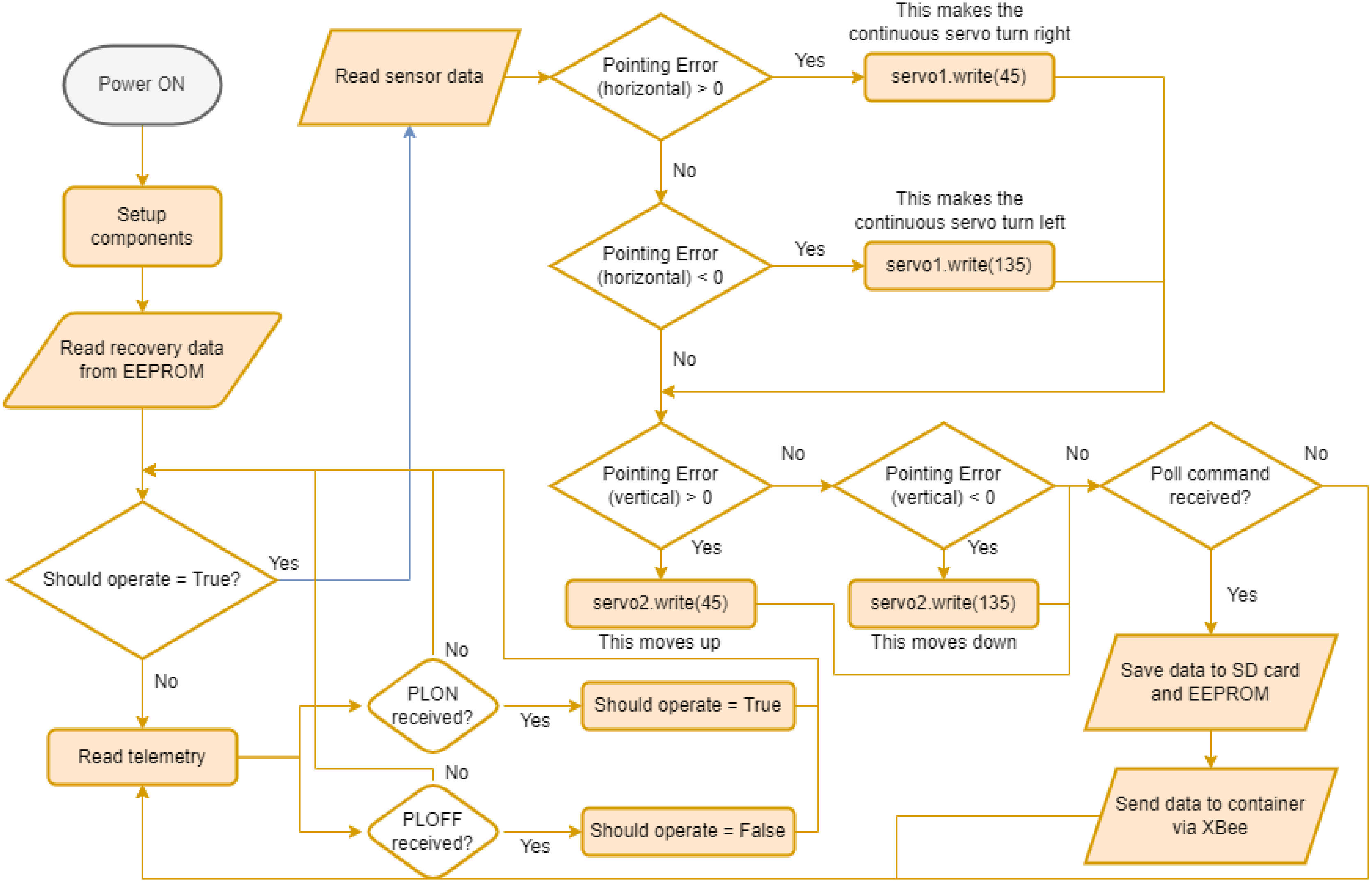
Reasons for reset

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

Data to recover

- State, packet count, and reference altitude is written 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 FSW State Diagram (1/2)



Payload 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 cause may differ from our analyzed predictions.

Data to recover

- State, packet count, and reference altitude is written into the processor EEPROM and to be read on recovery.
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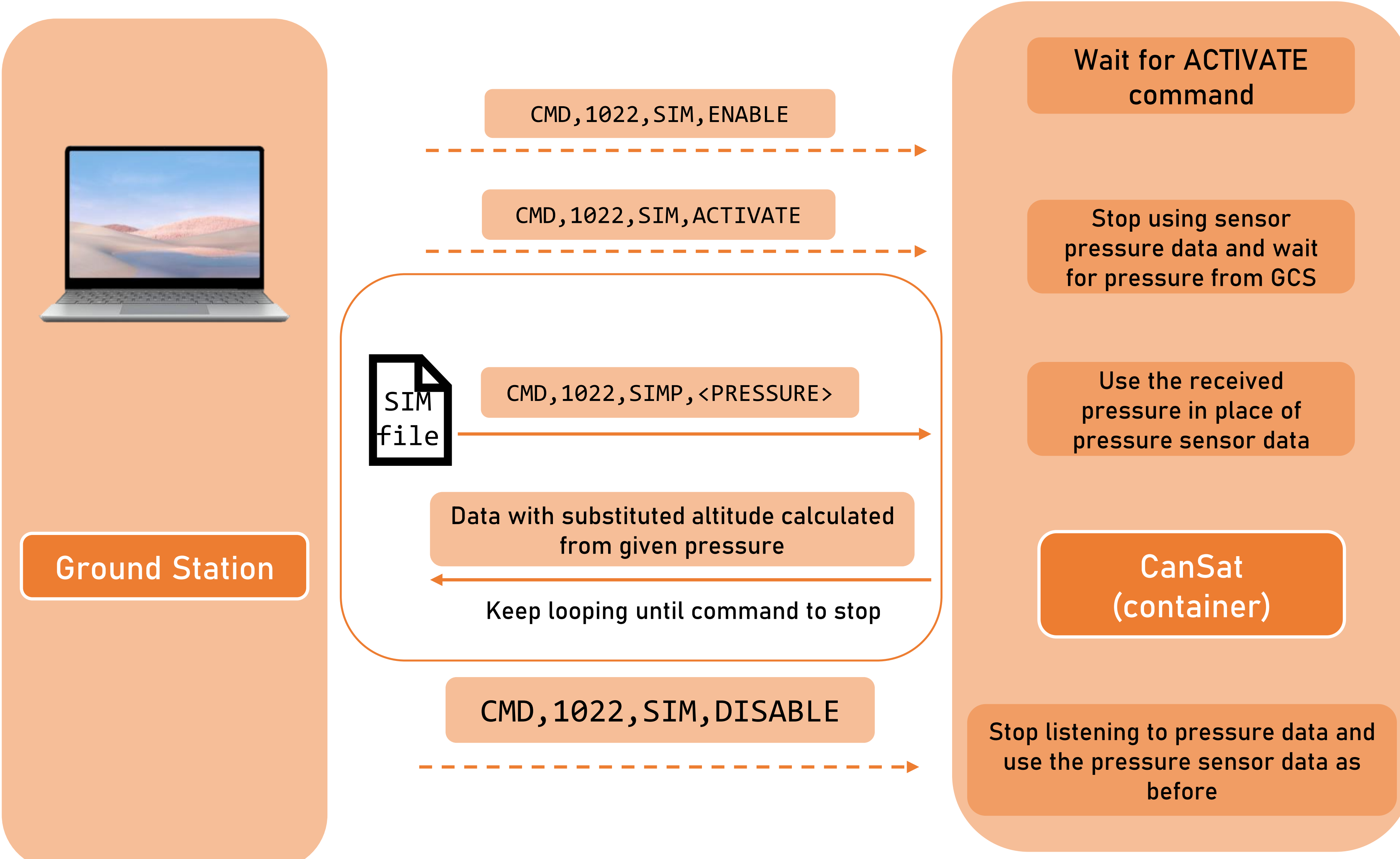
Simulation Mode Software



Software Development Plan (1/2)

Prototyping and prototyping environment

- Sensors are tested separately.
- Prototype box with all the component have 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 parts are merged and debugged to form a full system

- Tests are done as soon as respective components arrive to avoid late development.
- Software logic is written roughly beforehand and needs little changes when adapted with sensors.
- Codebase is maintained mainly on GitHub for easy 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 with the actual model successfully.
- All sensors and electrical components are tested separately before being integrated with the CanSat prototype to prove the functionality of the software.
- FSW is evaluated to be compatible with the mission requirements.

Development Team

Krissada Singhakachain →	Responsible for combining all system and developing GCS software
Arkkhanirut Pandej →	Responsible for subsystem testing and developing CanSat software

Ground Control System (GCS) Design

Krissada Singhakachain

GCS Overview

GCS Design

Yagi Antenna 900MHz

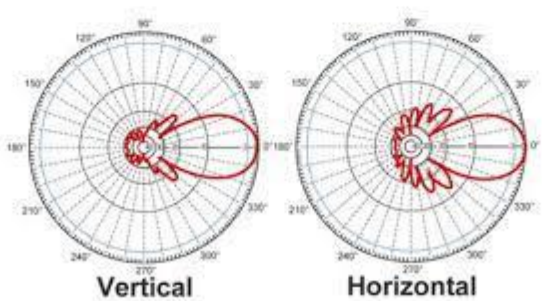
Digi XBee PRO 900 MHz
(ground station's)

Laptop

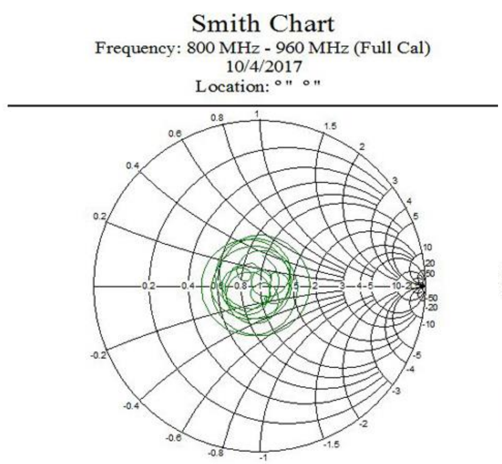
- The laptop can operate for more than 2 hours on battery
- Windows auto-update feature will be disabled.
- An umbrella is equipped to prevent laptop from overheating.

GCS Antenna Trade & Selection (1/2)

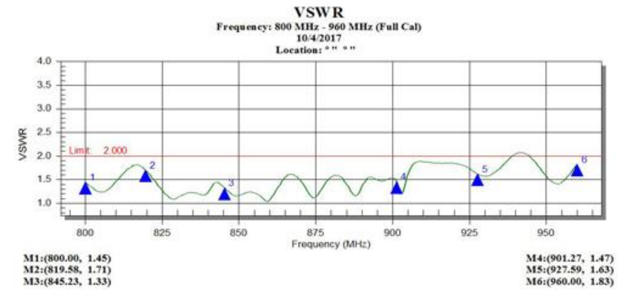
Antenna Model	Connection Type	Frequency (GHz)	Type	Gain (dBi)	Cost
Monopole Dipole External GSM	N-Female	860 - 960	Omnidirectional	11	$82.13
YAGI UDA ANTENNA 10E	SMA-Male	800 - 960	Directional	13.9	$32.00



Radiation Pattern



Impedance



Voltage Standing Wave Ratio

Reference: http://emaxit.co.th/index.php/emaxit-shop/yagi-antenna/yagi-uda-antenna-800-960-mhz-10e-sma-m-detail

GCS Antenna Trade & Selection (2/2)

Handheld Antenna

Tabletop Antenna

Selected antenna mounting: Handheld Antenna

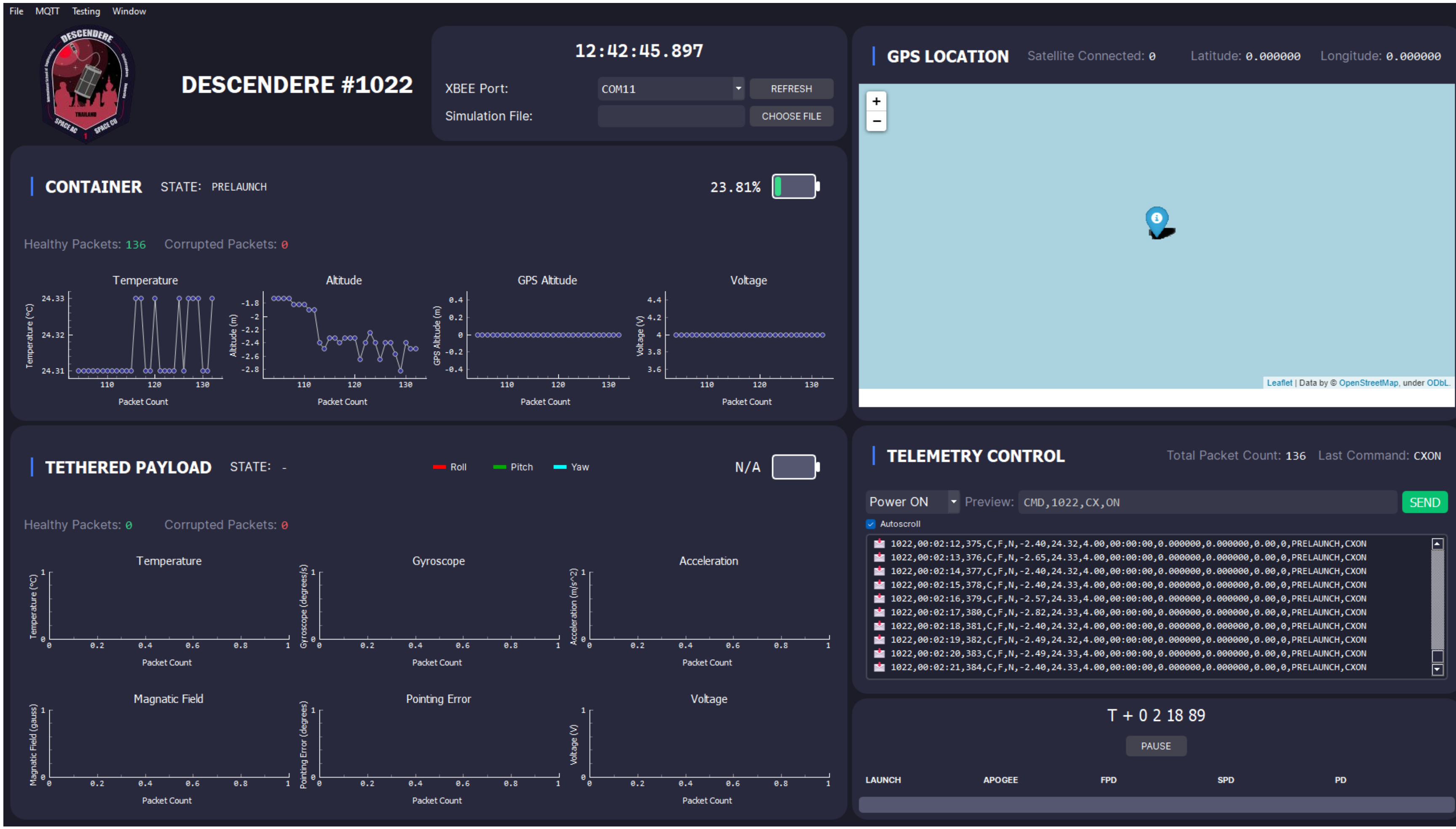
Reasons for selection:

- Handheld antenna can be focused in certain direction effectively.
- This method has been proven to be successful in from past experience.

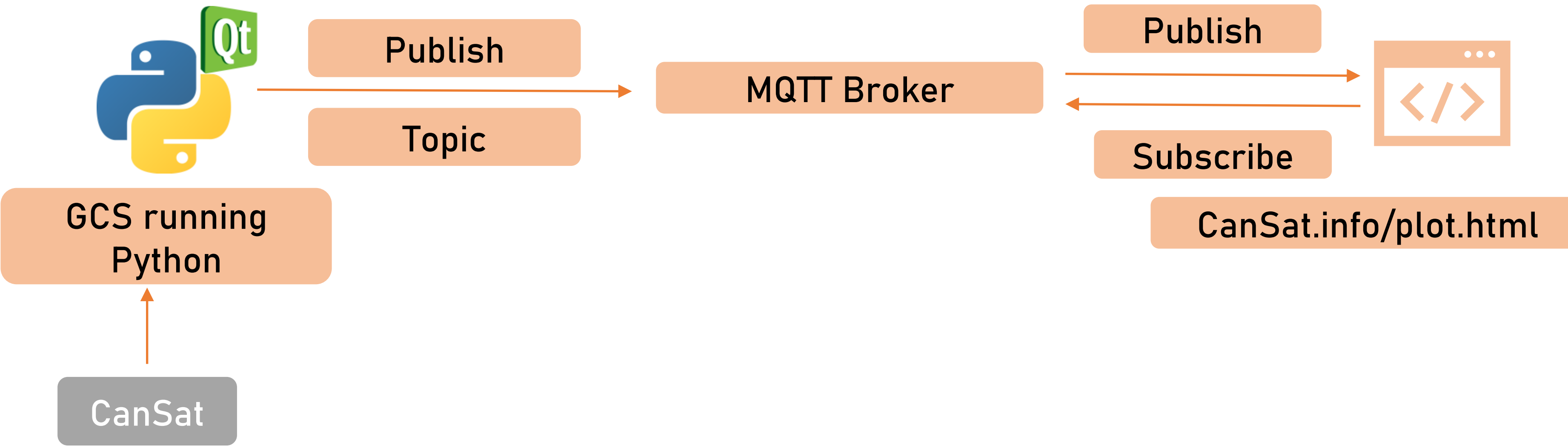
GCS Software (1/2)

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.

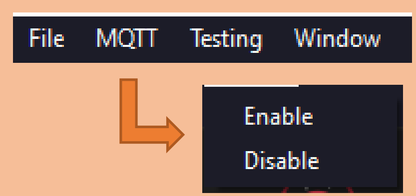
GCS Software (2/2)



MQTT Integration (1/2)



MQTT feature can be toggled in the UI context menu



Selected language: Python

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

MQTT Integration (2/2)

Container and payload telemetry is received.

↓

Telemetry data saved to .csv file

↓

Received telemetry data is also published to MQTT broker immediately

↓

Destination is at `cansat.info`

MQTT broker
`cansat.info`

Port
`1883`

Topic
`Team/1022`

Test Plan

Research libraries (the recommended library is selected) → Implement MQTT to the UI code → Create sample data → Test the MQTT connection (using sample code provided in the guide)

CanSat Integration and Test

Thasvarit Krueklai

CanSat Integration and Test Overview

- Test Overview
  - Subsystem Level Testing
    - Sensors
    - CDH
    - EPS
    - Radio Communication
    - FSW
    - Mechanical
    - Descent Control
  - Environmental Testing
    - Drop Test
    - Thermal Test
    - Vibration Test
    - Fit Test
    - Vacuum Test
  - Simulation Test Plan
    - Flight Mode
    - Simulation Mode
  - Integrated Level Function Testing
    - Descent Testing
    - Communications
    - Mechanisms
    - Deployment

Subsystem Level Testing Plan

Sensors	• Sensors Calibration and Reliability test
CDH	• Timing test • SD card storage test
EPS	• Power Sufficiency Test • Current Leakage and Inefficiency Test
Radio Communication	• 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
Mechanical	• Container & TP mass control • Parachute ejection test • Payload release mechanism • Camera stabilization
Descent Control	• Descent velocity test • Container parachute drop test • Separation test

CanSat Integration and Test Overview (2/3)

Integrated Level Function Testing

Descent Tests	• Container parachute test
Communication	• XBEE communication test • Communication between components on the PCB will be tested
Mechanism	• Container opening mechanism
Deployment	• Release TP from 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

Simulation Test Plan

Flight mode	• Container operates using actual sensor data
Simulation mode	• Container receives simulated barometric pressure values from GCS and substitute those value with actual pressure sensor reading for calculation

Subsystem Level Testing Plan (1/2)

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 (2/2)

Sensors	
Air Pressure	Measuring altitude at location where altitude is known
Air Temperature	Compare measured 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

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.

Descent Test

- 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).
- The overall descent of CanSat will be tested with drone to make sure that system functions at corresponding altitude levels.
- The CG point and CP point will be determined and measured with rope tightened to the bottom of payload and swing-test to find the exact CP point.

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 the tethered payload 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 • To test whether the fins can be deployed when the payload starts to spool down.

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 the university laboratory to see the effect and tolerance in extreme temperature of both electronic and mechanical components.
- The payload will be held in the machine for 60°C 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 casually 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.

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
Pitiphoom
Suvijak
Sitthitat

→

Assembly Crew
Kittipon
Nuchit
Sornpakarn

→

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:
Sitthitat

→

CanSat Crew Damage Inspection:
Thasvarit
Shinakrit

Mission Operations Manual Development Plan (1/2)

GCS Operations	CanSat Operations
• Install sun umbrella & setup laptop GCS. • Setup GCS software and external connections including laptop, XBee and handheld antenna • Test the communication between CanSat and GCS • Check GCS software connectivity • Final check on communication after installation into the rocket	• Inspect all electronics components, connections & mounting • Check whether all integrated subsystems are functional • Fold the parachute, install TP into Container & assemble CanSat • Make a full system and processor reset & perform a final check with GCS whether the system is working properly or not • Fit check & weight measurement • CanSat Delivery at check-in point

Mission Operations Manual Development Plan (2/2)

GCS Operations

- The assigned team members will have to prepare and stock required equipment, setup the ground station (Umbrella, GCS Software, Connections), and test the communication of Container & TP to GCS.

CanSat Operations

Preparations

- The assigned team members will make the last inspections, conduct all mandatory tests & final checks incl.fit check, weight measurement, deploy mechanism check, power check, DC test, etc., and be ready to make any corrections if required.The team will deliver CanSat to the check-in point which is the point it stays until our launch queue.

Recovery & Post-launch Sequences

- The assigned recovery team will be tracing the CanSat during descent.
- The audio beacon and GPS coordinates will be used to help locate CanSat position after touchdown.

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 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.
- The first parachute is fluorescent orange; the second is fluorescent pink.
- Our team must not walk out the field until it is safe.

CanSat Label

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Phachara@spaceac.net
kittipon_am@outlook.co.th

Requirements Compliance

Kittipon Amornprasertkij

Requirements 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	114-118	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	37	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	29-31	Completed
4	The container shall be a fluorescent color; pink, red or orange.	Comply	29-31	Completed
5	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	37	Completed
6	The rocket airframe shall not be used as part of the CanSat operations.	Comply	37	Completed
7	The rocket airframe shall not be used as part of the CanSat operations.	Comply	37	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	74-75	Completed

Requirements Compliance (2/7)

Rqmt Num	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	76-78	Completed
12	0 altitude reference shall be at the launch pad.	Comply	37	Completed
13	All structures shall be built to survive 15 Gs of launch acceleration.	Partial	186-187	Theoretically com plies, awaiting test
14	All structures shall be built to survive 30 Gs of shock.	Partial	186-187	Theoretically complies, awaiting test
15	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	95	Completed
16	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Partial	186-187	Theoretically complies, awaiting test
17	Mechanisms shall not use pyrotechnics or chemicals.	Comply	81-98	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	30	Completed
19	Both the container and payload shall be labeled with team contact information including email address.	Comply	195	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	209	Completed

Requirements 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	120, 136	Completed
22	XBEE radios shall have their NETID/PANID set to their team number.	Comply	132, 144	Completed
23	XBEE radios shall not use broadcast mode.	Comply	144	Completed
24	The container shall include electronics to receive sensor payload telemetry.	Comply	120-121	Completed
25	The container shall include electronics and mechanisms to release the science payload on a tether.	Comply	98	Completed
26	The container shall include a GPS sensor to track its position.	Comply	41	Completed
27	The container shall include a pressure sensor to measure altitude.	Comply	40	Completed
28	The container shall measure its battery voltage.	Comply	42	Completed
29	The container shall transmit its telemetry once per second (1 Hz) in the formats described in the Telemetry Requirements section.	Comply	133-135	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	133-135	Completed
31	The container shall stop polling and transmitting telemetry when it lands.	Comply	159	Completed

Requirements 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	85, 90	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	149-150, 153-154	Completed
34	An audio beacon is required for the container. It shall be powered after landing.	Comply	158-160, 195	Completed
35	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.	Partial	120, 136	Theoretically complies, awaiting test
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	151, 155	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	85, 90	Completed
38	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	Comply	149-150, 153-154	Completed
39	The CanSat must operate during the environmental tests laid out in Section 3.5.	Partial	187-188	Theoretically complies, awaiting test

Requirements 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	152,155	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	144	Completed
42	The science payload shall transmit sensor telemetry to the container when polled.	Comply	145-146	Completed
44	The science payload shall include a pressure sensor, temperature sensor and rotation sensor.	Comply	136	Completed
45	The science payload shall include a video camera pointing 45 degrees up from the payload NADIR direction.	Comply	33	Completed
46	The science payload shall maintain orientation so the camera always faces south within +/- 20 degrees.	Comply	33	Completed
47	The payload shall be connected to the container with a 10 meter tether	Comply	98	Completed
48	At 300 meters, the payload shall be released from the container at a rate of .5 meters per second.	Comply	101, 103, 105	Completed
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	158-165	Completed
50	The container shall maintain mission time throughout the whole mission even with processor resets or momentary power loss.	Comply	161-162	Completed

Requirements 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	133-135, 145-146	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	166	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	166	Completed
54	The container flight software shall only enter simulation mode after it receives the SIMULATION ENABLE and SIMULATION ACTIVATE commands.	Comply	135	Completed
55	The ground station shall command the CanSat to start transmitting telemetry prior to launch.	Comply	159, 174	Completed
56	The ground station shall generate csv files of all sensor data as specified in the Telemetry Requirements section.	Comply	133, 143	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	131-133, 142-143	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	134, 146	Completed
59	Each team shall develop their own ground station.	Comply	170, 175	Completed

Requirements 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	174-175	Completed
61	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	174-175	Completed
62	Teams shall plot each telemetry data field in real time during flight.	Comply	174-175	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	170-173	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	170-173	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	135	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	134	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	164-165	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	47-48	Completed

Management

Kittipon Amornprasertkij

CanSat Budget – Hardware (1/2)

- Electronics Hardware

Components	Quantity	Price	Price (Total)	Justification
Teensy 4.0	1	$19.95	$19.95	Actual
Raspberry Pi Zero	1	$10	$10	Estimate
BNO-055	1	$10	$10	Estimate
BME-280	1	$9	$9	Estimate
XBee-Pro s3b	2	$50	$50	Estimate
Buzzer 12 mm	1	$6.78	$6.78	Actual
mosfet – VN2222LL-G	1	$0.49	$0.49	Actual
LED	1	$4	$4	Estimate
RP-SMA male Omnidirectional Antenna	1	$40	$40	Actual
SanDisk Ultra	1	$4	$4	Actual
SanDisk Extreme Pro	1	$15	$15	Actual
Ams1117-3.3	3	$2.64	$7.92	Actual
Raspberry Pi Camera	1	$40.88	$40.88	Estimate

CanSat Budget – Hardware (2/2)

- Electronics Hardware

Components	Quantity	Price	Price (Total)	Justification
cr032 cell holder	1	$1	$1	Actual
Monopole Dipole External GSM	1	$28	$28	Estimate
LM2596S	1	$7.15	$7.15	Actual
SD card reader	1	$1	$1	Actual
switch	1	$0.4	$0.4	Actual
Header	5	$0.1	$0.5	Actual
Micro LED	2	$1	$2	Estimate
resistor	2	$1	$2	Estimate
capacitor	3	$1	$3	Estimate
Zenior diode	2	$1	$2	Estimate
SG90 Servo	1	$2.95	$2.95	Actual
MG90S Servo	1	$3.92	$3.92	Actual
Adafruit 3202	1	$12.5	$12.5	Estimate

CanSat Budget – Mechanics

- Mechanics Hardware

Components	Quantity	Price	Price (Total)	Justification
PETG	2	$21.54	$43.08	Actual
ABS	2	$15	$30	Actual
Balsa	1	$3.07	$3.07	Estimate
Carbon fiber Rod	4	$1	$4	Actual
Orange & Pink Nylon	5	$0.4	$2	Estimate
M3*25mm	2	$1	$2	Estimate
M3*10mm	4	$1	$4	Estimate
Nano Cord	1	$2	$2	Estimate
Depron Foam	1	$2	$2	Estimate
Zip Cable Tie	1	$0.2	$0.2	Estimate
Laminated Paper	1	$1	$1	Estimate

CanSat Budget – Other Costs

- Other Costs

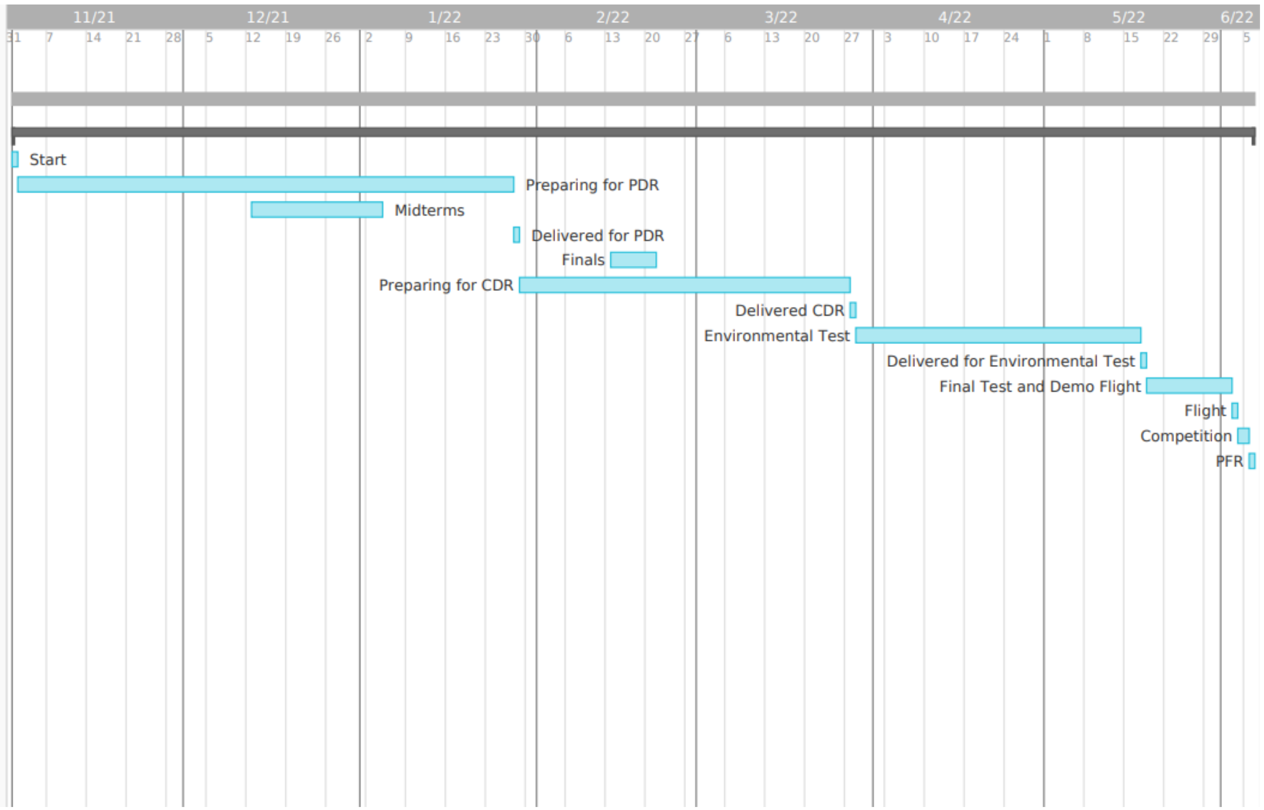
Components	Quantity	Price	Price (Total)	Justification
Test Facilities	-	-	-	Provided
Experimental Tools	-	-	-	Provided
Antenna Holder	-	-	-	Provided
Airline Ticket	10	$1700	$17000	Estimate
Travel Costs in USA	10	$170	$1700	Estimate
Prototyping	2	$150	$300	Estimate
Registration Fee	1	$200	$200	Actual
Rental Fee	5	$800	$4000	Estimate
Insurance Fee	10	$34	$3400	Estimate
Visa Fee	10	$160	$1600	Actual
Internet in USA	2	$120	$240	Actual

CanSat Budget – Total

Components	Price
Electronics Hardware	$274.58
Mechanics	$142.35
Exact Total	$416.93
Travel Costs in USA	$28440

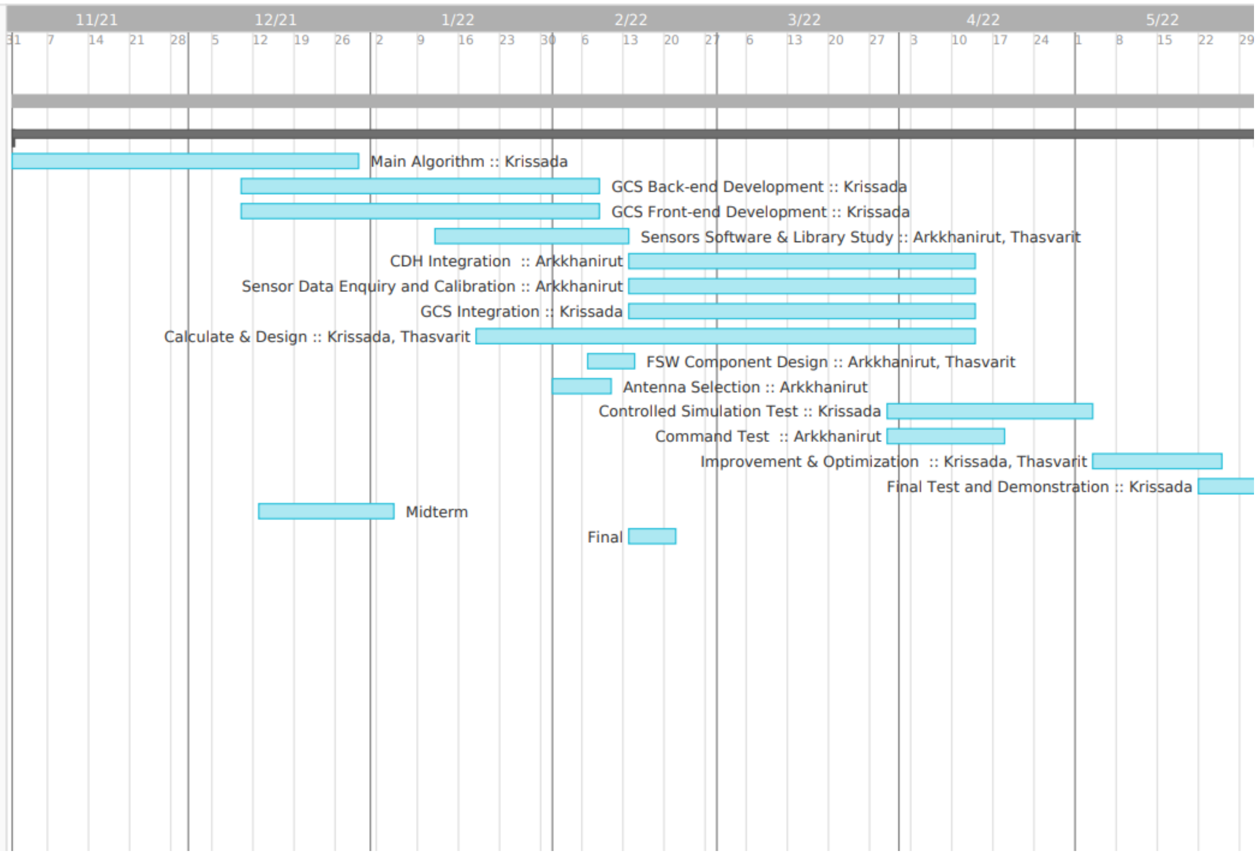
Program Schedule Overview

DESCENDERE	start	end
	11/01/21	**06/06/22**
Start	11/01	11/01
Preparing for PDR	11/02	01/27
Midterms	12/13	01/04
Delivered for PDR	01/28	01/28
Finals	02/14	02/21
Preparing for CDR	01/29	03/27
Delivered CDR	03/28	03/28
Environmental Test	03/29	05/17
Delivered for Environmental Test	05/18	05/18
Final Test and Demo Flight	05/19	06/02
Flight	06/03	06/03
Competition	06/04	06/05
PFR	06/06	06/06



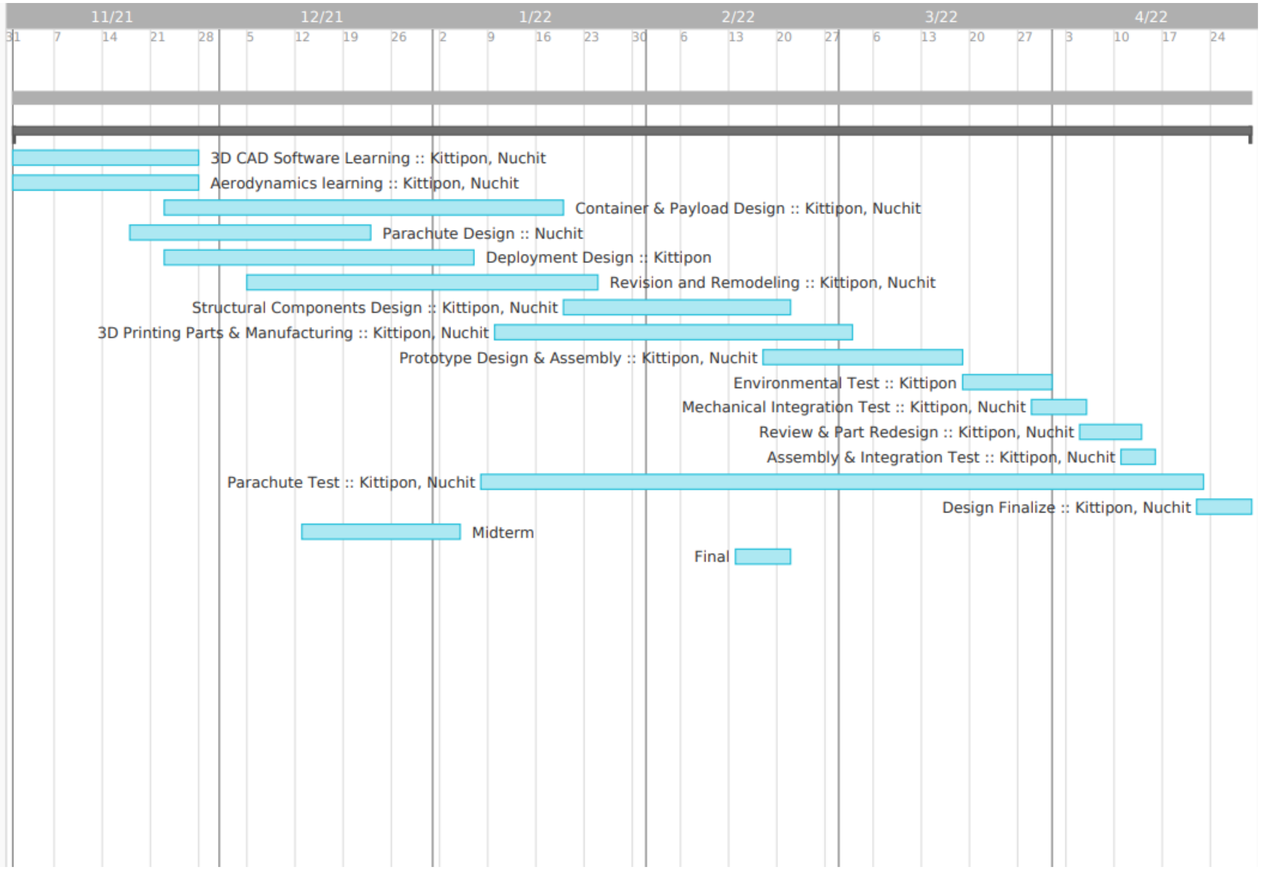
Detailed Program Schedule (1/3) Software: CDH, FSW & GCS

CDH FSW DC GCS	start	end
	11/01/21	05/31/22
Main Algorithm	11/01	12/29
GCS Back-end Development	12/10	02/08
GCS Front-end Development	12/10	02/08
Sensors Software & Library Study	01/12	02/13
CDH Integration	02/14	04/13
Sensor Data Enquiry and Calibration	02/14	04/13
GCS Integration	02/14	04/13
Calculate & Design	01/19	04/13
FSW Component Design	02/07	02/14
Antenna Selection	02/01	02/10
Controlled Simulation Test	03/30	05/03
Command Test	03/30	04/18
Improvement & Optimization	05/04	05/25
Final Test and Demonstration	05/22	05/31
Midterm	12/13	01/04
Final	02/14	02/21



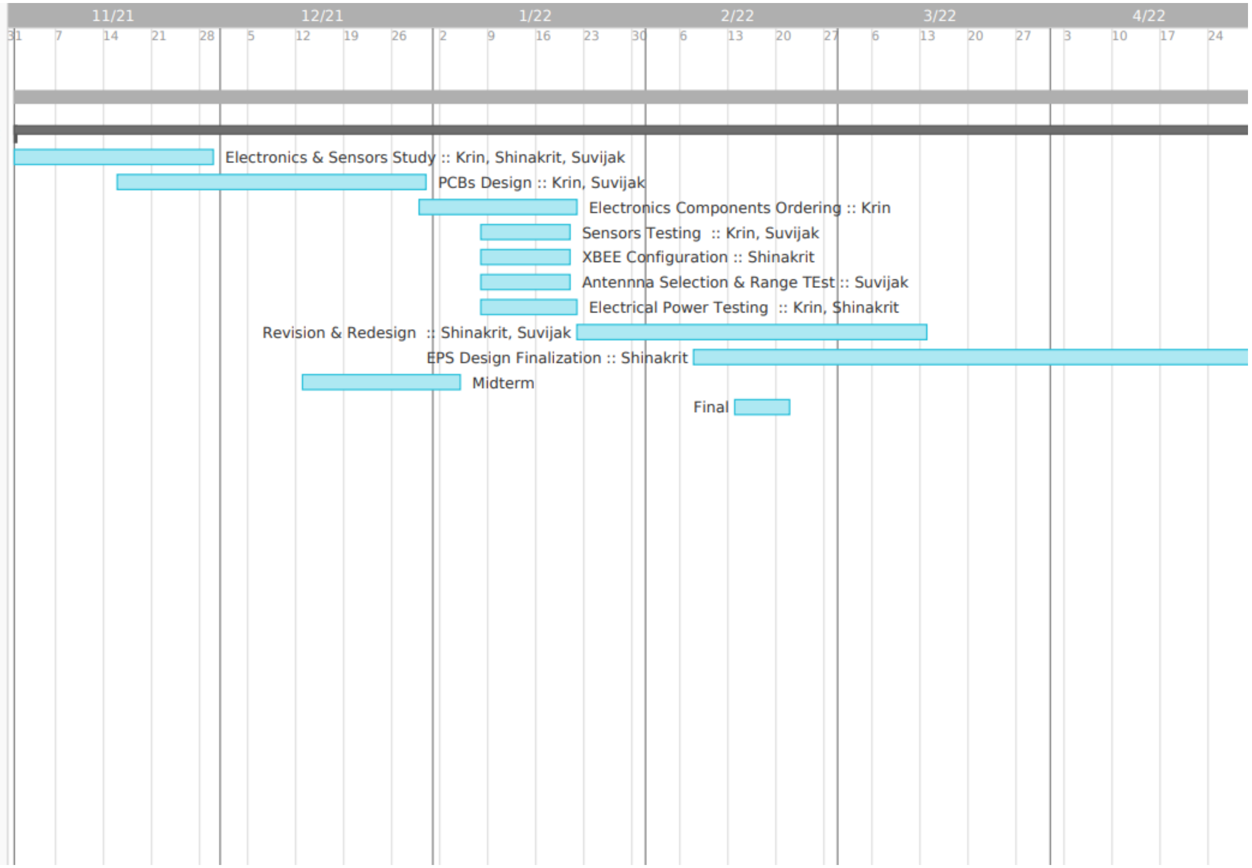
Detailed Program Schedule (2/3)
Mechanical & Descent Control Subsystem

Mechanical&Descent Control	start	end
	11/01/21	04/29/22
3D CAD Software Learning	11/01	11/27
Aerodynamics learning	11/01	11/27
Container & Payload Design	11/23	01/19
Parachute Design	11/18	12/22
Deployment Design	11/23	01/06
Revision and Remodeling	12/05	01/24
Structural Components Design	01/20	02/21
3D Printing Parts & Manufacturing	01/10	03/02
Prototype Design & Assembly	02/18	03/18
Environmental Test	03/19	03/31
Mechanical Integration Test	03/29	04/05
Review & Part Redesign	04/05	04/13
Assembly & Integration Test	04/11	04/15
Parachute Test	01/08	04/22
Design Finalize	04/22	04/29
Midterm	12/13	01/04
Final	02/14	02/21



Detailed Program Schedule (3/3)
EPS & Sensor Subsystem

EPS&Sensor	start	end
	11/01/21	**04/30/22**
Electronics & Sensors Study	11/01	11/29
PCBs Design	11/16	12/30
Electronics Components Ordering	12/30	01/21
Sensors Testing	01/08	01/20
XBEE Configuration	01/08	01/20
Antennna Selection & Range TEst	01/08	01/20
Electrical Power Testing	01/08	01/21
Revision & Redesign	01/22	03/13
EPS Design Finalization	02/08	04/30
Midterm	12/13	01/04
Final	02/14	02/21



Conclusions

Administration & Finance

Major Accomplishments
- Schedules & Plans are created.
- Financial management is secure.
- PDR was completed.

Major Unfinished Work
- Airline tickets sponsors have not been found yet.
- Members Visa have not been applied.

MS, EPS, Sensor Subsystem

Major Accomplishments
- All electronic components are chosen.
- Container & TP were discussed for the best available choice.

Major Unfinished Work
- The fully integrated electronic & mechanical subsystem needs to be tested.

CDH, FSW, DC & GCS

Major Accomplishments
- FSW design is done.
- CDH is managed.

Major Unfinished Work
- The full communication range needs to be tested.

Why are we ready to proceed to next state to development?

Our team is prepared for CDR since we have designs that are almost ready to be tested and developed, and the timetable and deadline have been met. We are ready!