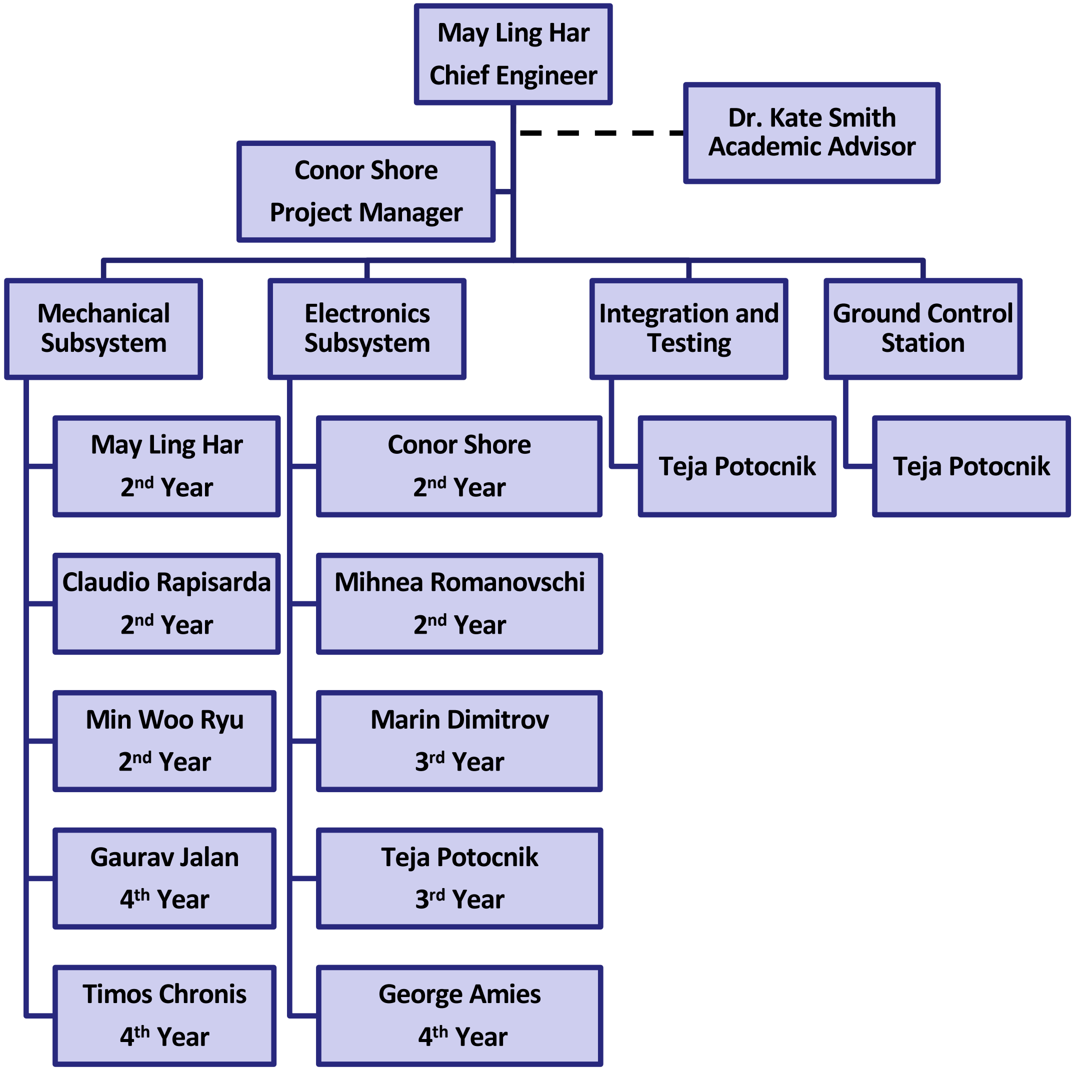
CanSat 2020
Critical Design Review (CDR)
Outline
Version 1.0

Team 4920

Manchester CanSat Project

Presentation Outline

Team Organization



Team Member	Responsibility
May Ling Har (MLH)	CE, ME
Conor Shore (CS)	PM, CDH, EPS
Teja Potocnik (TP)	I&T, GCS
Claudio Rapisarda (CR)	DC
Min Woo Ryu (MWR)	ME
Gaurav Jalan (GJ)	ME
Timos Chronis (TC)	DC
Mihnea Romanovschi (MR)	FSW
Marin Dimitrov (MD)	SE, CDH
George Amies (GA)	EPS, CDH

Acronyms

CDH	Communications and Data Handling
EPS	Electrical Power Sub-System
FSW	Flight Software
GCS	Ground Control Station
ME	Mechanical Sub-System
SE	Sensors Sub-System
DC	Descent Control Sub-System
CE	Chief Engineer
PM	Project Manager
I&T	Integration and Testing
CONOPS	Concept of Operations
A	Analysis
I	Inspection
T	Testing
D	Demonstration
TBC	To be confirmed
TBD	To be determined
RE#	Top Level Requirement
SL	System Level
SSL	Sub-system Level

GUI	Graphical User Interface
IDE	Integrated Development Environment
RTC	Real Time Clock
I2C	Inter-Integrated Circuit
SPI	Serial Peripheral Interface
ADC	Analog to Digital Converter
DAC	Digital to Analog Converter
EEPROM	Electrically Erasable Programmable Read-only memory
MCU	Microcontroller
ADU	Air Data Unit
IMU	Inertial Measurement Unit
CCU	Central Control Unit
CG	Centre of Gravity
NP	Neutral Point

System Overview

May Ling Har

Mission Summary

Objectives:

1. Build a CanSat with an atmospheric-sampling Science Payload, a delta-wing glider, that shall descend in a circular pattern and a Parachute, and a separate Container and Parachute.
2. The CanSat shall be launched in a sounding rocket to an altitude of 675-725 meters.
3. Once the CanSat is deployed from the rocket, the CanSat shall descend using a Parachute at a descent rate of 20 m/s.
4. The CanSat Container must protect the Science Payload from damage during the launch and deployment.
5. At 450 meters, the Container shall release the Science Payload. The Science Payload shall then descend in a circle for a minute and remain above 100 meters. After that, the Science Payload shall deploy a Parachute to descend at 10 m/s.
6. The Science Payload shall collect and transmit atmospheric data to a Ground Control Station in real-time, throughout its operation phase.
7. When the Science Payload lands, all telemetry transmission shall stop and a located audio beacon shall activate.
8. The Ground Control Station shall receive and display CanSat data.

Selectable Bonus and Rationale:

- Camera Bonus selected because of abundant team members experience.

External Objectives:

- Continue to deliver Manchester CanSat Project weekly, educational, space-related Workshops towards University of Manchester STEM Students.
- Continue to develop a UK University CanSat Competition for UK universities.
- Inspire other UK Universities and Academic Institutions to adopt the Manchester CanSat Project model to create a network of CanSat societies across the UK.

Summary of Changes Since PDR

The design of the CanSat has been altered since the PDR. Due to the COVID-19 pandemic, the University of Manchester has been on lockdown since March 18, 2020, and all prototyping and testing efforts ceased. It is expected that if the team had more time to continue prototyping and testing, more design changes and iterations would occur to improve the design.

System level changes are outlined below and will be discussed in more detail in their respective sections.

PDR	CDR	Rationale
Parachutes attached to their respective structures via strings and swivel pin.	Parachutes attached to their respective structures via strings, shock cord, and swivel pin.	The addition of a shock cord allows for the shock of the Parachute opening to be absorbed by the shock cord, decreasing the stress on the structure.
Epoxy and bolts used to secure Container plates.	Epoxy used to secure Container plates	The first prototype Container was assembled with only epoxy and was found to be stronger than necessary.
All 3D printed components made of ABS.	Payload X-frame arms, tail, parachute bay and frame attachment to be made of CPE+.	Compared to ABS, CPE+ offers higher toughness lowering risk of brittle fracture at arm joints, much lower warping which is beneficial for the stabilisers on tail and parachute bay where surface warping could lead to aerodynamic instability.
FPVDVR mounted with casing in front of CCU.	FPVDVR mounted under frame attachement without casing.	Due to larger footprint of the PCB v2 FPVDVR had to be relocated, the casing removed so that the view of the camera was not obstructed.
No power multiplexer in PCBs, size of PCBs at 48 mm x 30 mm.	Power multiplexer used in PCBs, size of PCBs at 57 mm x 35 mm.	The size of the PCB was increased to account for the addition of the power multiplexer.

System Requirement Summary

RE#	Requirement	Verification			
		A	I	T	D
1	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.		X		X
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.		X		X
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.	X	X		X
4	The container shall be a fluorescent color; pink, red or orange.	X	X		
5	The container shall be solid and fully enclose the science payload. Small holes to allow access to turn on the science payload is allowed. The end of the container where the payload deploys may be open.	X	X		
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	X			X
7	The rocket airframe shall not be used as part of the CanSat operations.	X			X
8	The container 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.	X	X	X	
9	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	X		X	
10	The container shall release the payload at 450 meters +/- 10 meters.	X		X	X
11	The science payload shall glide in a circular pattern with a 250 m radius for one minute and stay above 100 meters after release from the container.	X		X	X
12	The science payload shall be a delta wing glider.	X	X	X	
13	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10 meters/second, +/- 5 m/s	X		X	X
14	All descent control device attachment components shall survive 30 Gs of shock.	X		X	

System Requirement Summary

RE#	Requirement	Verification			
		A	I	T	D
15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.		X		
16	All structures shall be built to survive 15 Gs of launch acceleration.	X		X	
17	All structures shall be built to survive 30 Gs of shock.	X		X	
18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.		X		
19	All mechanisms shall be capable of maintaining their configuration or states under all forces.			X	
20	Mechanisms shall not use pyrotechnics or chemicals.	X			
21	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.	X		X	X
22	The science payload shall measure altitude using an air pressure sensor.	X	X	X	X
23	The science payload shall provide position using GPS.	X	X	X	X
24	The science payload shall measure its battery voltage.	X	X	X	X
25	The science payload shall measure outside temperature.	X	X	X	X
26	The science payload shall measure particulates in the air as it glides.	X	X	X	X
27	The science payload shall measure air speed.	X	X	X	X
28	The science payload shall transmit all sensor data in the telemetry.	X	X	X	X
29	Telemetry shall be updated once per second.	X		X	X
30	The Parachutes shall be fluorescent Pink or Orange .	X	X		
31	The ground system shall command the science vehicle to start transmitting telemetry prior to launch.	X		X	X

System Requirement Summary

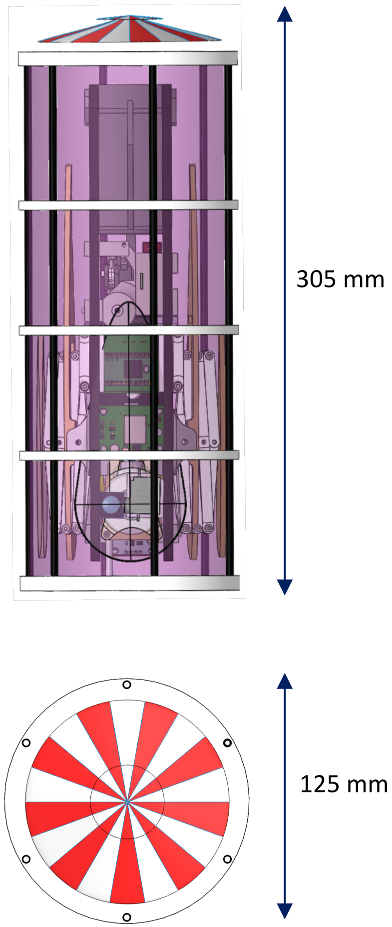
RE#	Requirement	Verification			
		A	I	T	D
32	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.			X	X
33	Telemetry shall include mission time with one second or better resolution. Mission time shall be maintained in the event of a processor reset during the launch and mission.	X		X	X
34	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	X		X	X
35	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.		X		
36	XBEE radios shall have their NETID/PANID set to their team number.		X	X	X
37	XBEE radios shall not use broadcast mode.	X	X		
38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	X	X		
39	Each team shall develop their own ground station.				X
40	All telemetry shall be displayed in real time during descent.			X	X
41	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		X		X
42	Teams shall plot each telemetry data field in real time during flight.			X	X
44	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		X		
45	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.		X		
46	Both the container and probe shall be labelled with team contact information including email address.				X
47	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.		X		X

System Requirement Summary

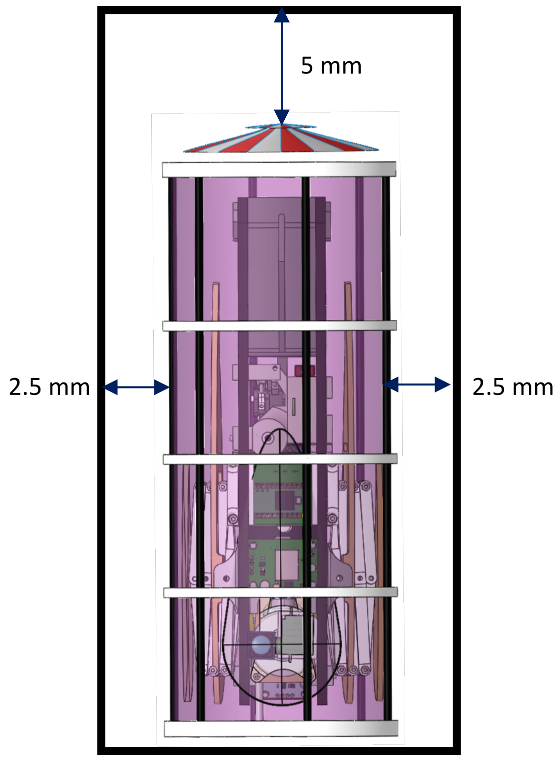
RE#	Requirement	Verification A	I	T	D
48	No lasers allowed.	X			X
49	The probe must include an easily accessible power switch that can be accessed without disassembling the CanSat and in the stowed configuration.	X	X		X
50	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the CanSat and in the stowed state.		X	X	X
51	An audio beacon is required for the probe. It may be powered after landing or operate continuously.		X	X	X
52	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.			X	X
53	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.		X	X	X
54	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.	X	X		X
55	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.		X		
56	The CANSAT must operate during the environmental tests laid out in Section 3.5.			X	X
57	Payload/Container shall operate for a minimum of two hours when integrated into rocket.		X		
B1	*Bonus: A video camera shall be integrated into the science payload and point toward the coordinates provided for the duration of the glide time. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the science payload is retrieved. Points will be awarded only if the camera can maintain pointing at the provided coordinates for 30 seconds uninterrupted.*	X		X	X

Payload Physical Layout

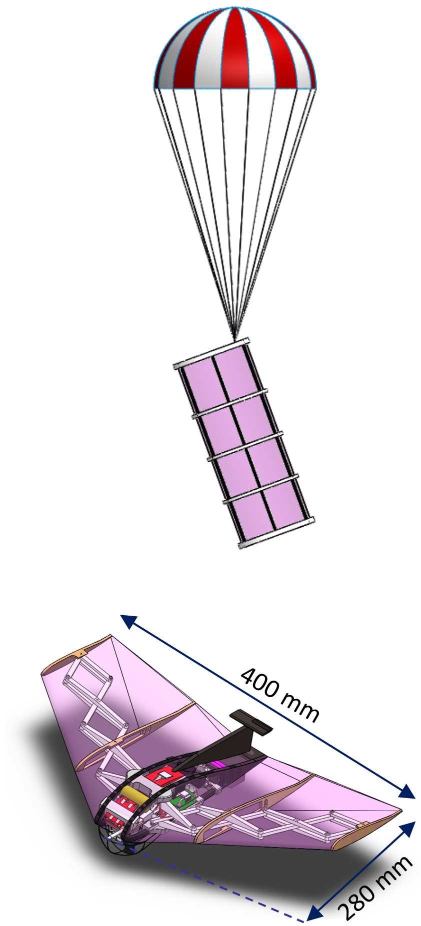
Stowed CanSat



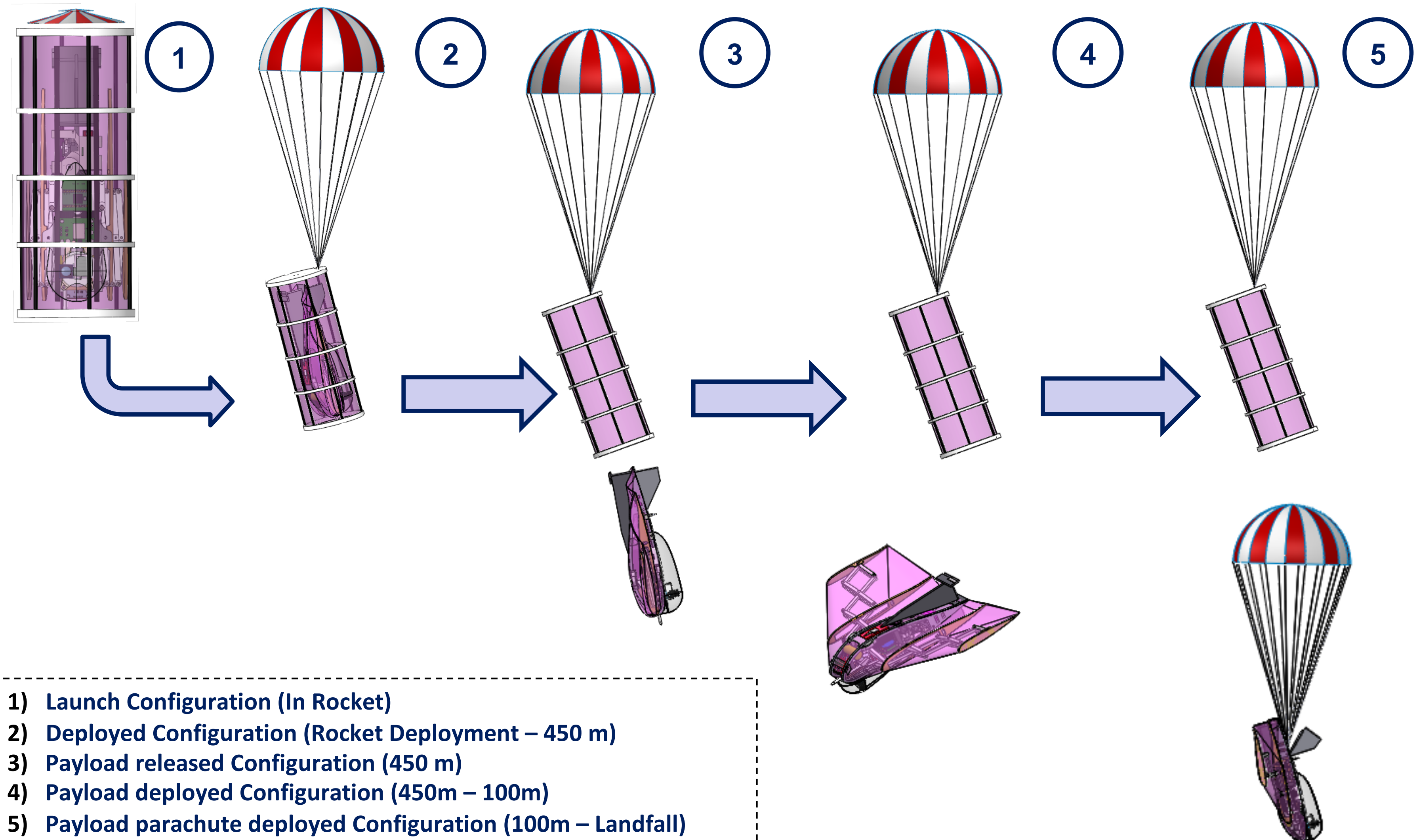
Stowed CanSat inside Rocket (launch configuration)



Deployed CanSat

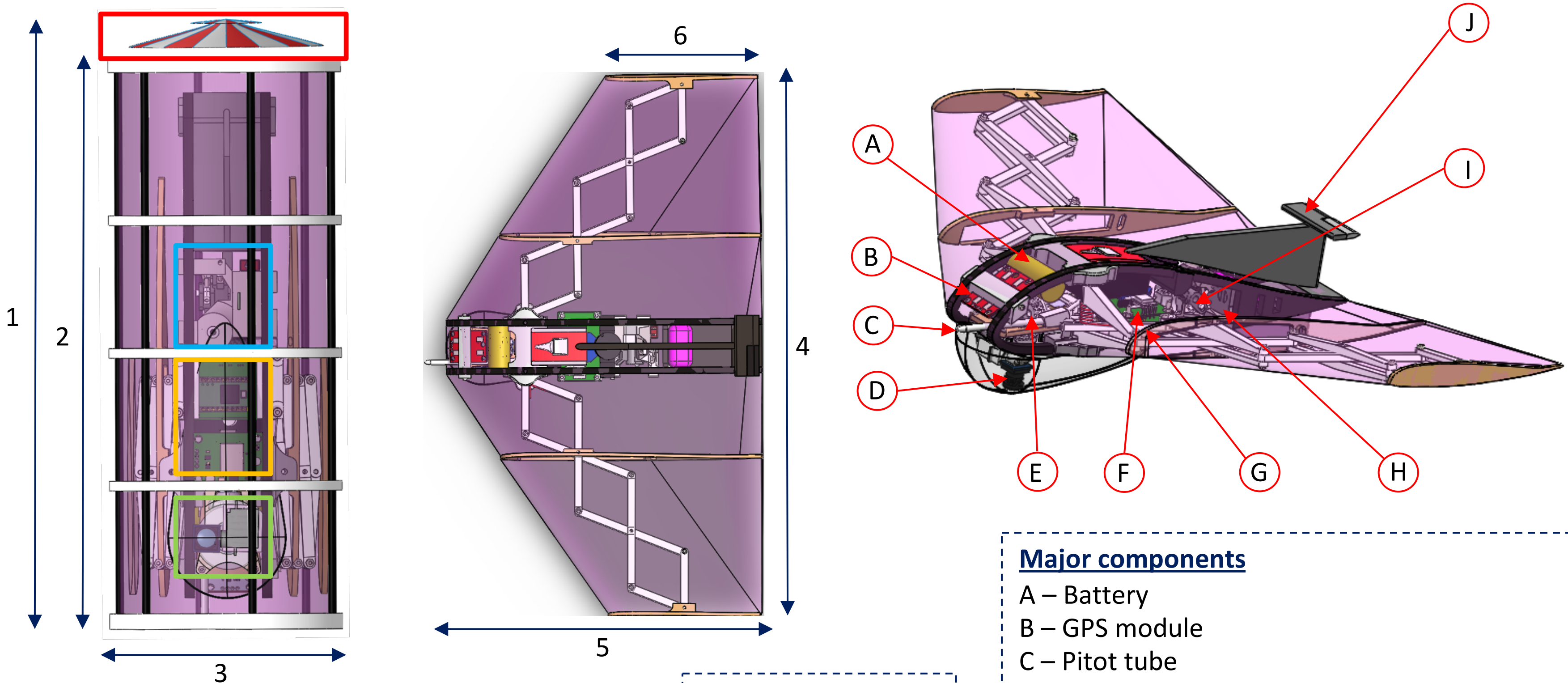


Payload Physical Layout



1) Launch Configuration (In Rocket)
2) Deployed Configuration (Rocket Deployment – 450 m)
3) Payload released Configuration (450 m)
4) Payload deployed Configuration (450m – 100m)
5) Payload parachute deployed Configuration (100m – Landfall)

Payload Physical Layout



Red – **Container Parachute Bay**
Blue – **Central Control Unit (CCU) subassembly**
Yellow – **PCB and Mounted Electronics**
Green – **Camera Mechanism subassembly**

Basic Dimensions

1 – 305 mm
2 – 290 mm
3 – 125 mm
4 – 400 mm
5 – 280 mm
6 – 120 mm

Major components

A – Battery
B – GPS module
C – Pitot tube
D – Camera
E – Camera pitch/yaw mechanism
F – PCB v2 + Teensy
G – PM sensor
H – Parachute bay
I – Central Control Unit (CCU)
J – Tail

System Concept of Operations

The following four slides outline the launch day activities from pre-launch to post-launch, including team member roles.

Roles and Responsibilities

Mission Control Officer: TC
Ground Station Crew: MLH, CS, TP, MR, GA, CR
Recovery Crew: GJ, MD, MWR
CanSat Crew: MLH, CS, TP, CR, MWR, GJ, MR, MD, GA

Additionally, MLH will be responsible for handing over telemetry data file to field judge for review.

Before CanSat Submission: Final Integration and Testing

- Between 08:00 and 12:00.
- Full team involved.
- Various CanSat I&T procedures are carried out prior to the competition to ensure that everything is in order. This is led by TP and performed by the *CanSat Crew*.
- Antenna and GCS set-up will be carried out by the *Ground Station Crew*. Simple plug-and-play philosophy stands behind the design of the GCS and Antenna systems.
- An I&T plan will be followed throughout this process to ensure that all procedures have been carried out sufficiently – see *Mission Operations Manual*.

System Concept of Operations

- 0. Pre-Launch
- 1. Launch
- 2. Container Parachute Deployment
- 3. CanSat Descent
- 4.1 Payload Release
- 4.2 Payload Wings Deployment
- 5.1 Container Descent
- 5.2 Payload Descent
- 6. Payload Parachute Deployment
- 7. Landfall
- 8. Recovery
- 9. Data Handover

System Concept of Operations

0. Pre - Launch

- CanSat switched on
- Telemetry transmitting start

1. Launch

- CanSat insertion in Rocket Payload Bay
- Rocket ignition and ascension
- Apogee reached

2. Parachute Deployment

- Rocket and nose cone separation
- CanSat deployed from rocket Payload Bay
- Container Parachute deploys
- Rocket and nose cone descend separately

3. CanSat Descent

- CanSat descent at 20 m/s with Parachute deployed

4. Payload Release

- 450 m altitude sensed by Payload
- Payload released from Container
- Payload wings deploy
- Camera begins recording

System Concept of Operations

5.1. Container Descent

- Container descends separately under deployed Parachute

5.2. Payload Descent (Glide)

- Payload descends by gliding in a circular motion of radius 250 m for a minute, remaining above 100 meters in altitude

5.3. Payload Descent (Parachute)

- Payload releases Parachute, and descends at 10 m/s

6. Landing

- Telemetry transmitting stop
- Audio beacon activation

7. Recovery

- Audio beacon operational
- All systems recovered by *Recovery Crew* (including Container)
- CanSat switched off

8. Data Handover

- Data formatted and saved to USB
- USB handed over to officials by MLH

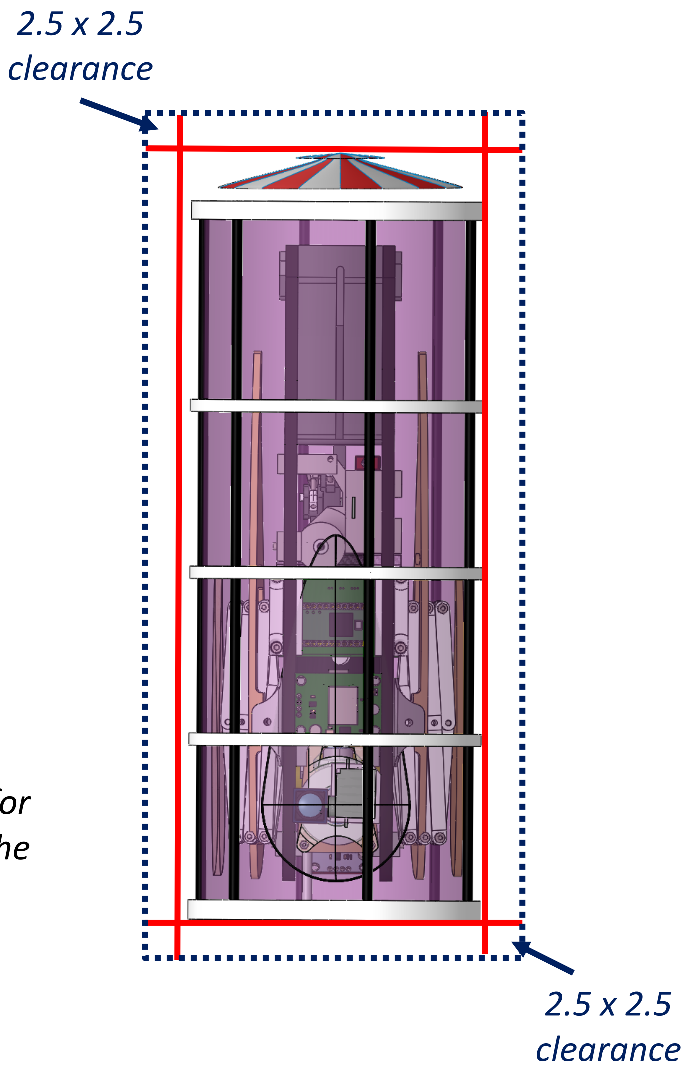
Launch Vehicle Compatibility

Dimensional constraints (as per Competition Requirements):
- Diameter - 125 mm
- Height - 310 mm

Dimensional constraints of current design:
- Diameter – **120 mm**
- Height – **305 mm**
- Diameter clearance – **2.5 mm each side**
- Height clearance – **2.5 mm each side**
- *No sharp protrusions*

Dimensions account for ease of fit and deployment.
The team will endeavor to increase the clearance size to 5 mm.

Multiple test launches and integration with the launch vehicle used for our test launches will be performed for every assembled prototype at the University of Manchester to verify Launch Vehicle Compatibility.



Sensor Subsystem Design

May Ling Har

MANCHESTER CANSAT PROJECT

Sensor Subsystem Overview

Selected Component	Function
ICM-20948 9-axis IMU	Measures angular velocity, angular acceleration, and magnetic heading. All measurements contain readings in 3-axis.
BMP 388 Barometric Pressure Sensor	Measures the air pressure to provide temperature compensated altitude information. Also provides temperature information.
u-blox NEO-M8N GPS Module	Tracks the position of the Payload. Also provides ground speed readings.
MS4525DO Differential Pressure Sensor	Measures differential pressure to provide airspeed readings.
GP2Y1010AU0F Particulate Sensor	Measures the concentration of particulates in the air.
RunCam Nano 2 CMOS Camera	Used for camera bonus objective to record position of target location.
HMDVR Digital Video Recorder	Used to record video from the camera.
Voltage divider	Used for battery voltage measurement.
Motor encoder	Used for measuring the motor's rotational speed.

Sensor Changes Since PDR

No changes to the Sensor Subsystem have been made since the PDR.

Sensor Subsystem Requirements

RE #	Requirement	Verification A	Verification I	Verification T	Verification D
1	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.		X		X
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.		X		X
9	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	X		X	
10	The container shall release the payload at 450 meters +/- 10 meters.	X		X	X
11	The science payload shall glide in a circular pattern with a 250 m radius for one minute and stay above 100 meters after release from the container.	X		X	X
13	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10meters/second, +/- 5 m/s	X		X	X
14	All descent control device attachment components shall survive 30 Gs of shock.	X		X	
15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.		X		
16	All structures shall be built to survive 15 Gs of launch acceleration.	X		X	
17	All structures shall be built to survive 30 Gs of shock.	X		X	

Sensor Subsystem Requirements

RE#	Requirement	Verification			
		A	I	T	D
18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performanceadhesives.		X		
22	The science payload shall measure altitude using an air pressure sensor.	X	X	X	X
23	The science payload shall provide position using GPS.	X	X	X	X
24	The science payload shall measure its battery voltage.	X	X	X	X
25	The science payload shall measure outside temperature.	X	X	X	X
26	The science payload shall measure particulates in the air as it glides.	X	X	X	X
27	The science payload shall measure air speed.	X	X	X	X
28	The science payload shall transmit all sensor data in the telemetry.	X	X	X	X
29	Telemetry shall be updated once per second.	X		X	X
41	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		X		X
56	The CANSAT must operate during the environmental tests laid out in Section 3.5.			X	X
57	Payload/Container shall operate for a minimum of two hours when integrated into rocket.		X		
B1	Bonus: A video camera shall be integrated into the science payload and point toward the coordinates provided for the duration of the glide time. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the science payload is retrieved. Points will be awarded only if the camera can maintain pointing at the provided coordinates for 30 seconds uninterrupted.	X		X	X

Payload Air Pressure Sensor Summary

Component	Interface	Resolution (Pa)	Accuracy (hPa) / Error (m)*	Size (mm) L x W x H	Mass (g)	Cost(£)
BMP388	I^2C / SPI	0.016	+/- 0.4 +/- 0.03	2.0 x 2.0 x 0.75	0.06	2.62

Air pressure data is sensed with the BMP388 sensor. There is an Arduino library for it which is of importance to the sensor's successful integration into the system. The pressure **data** is 24 bit format. To calculate the altitude, the hypsometric equation, shown below, will be used. Using the provided library the air pressure is directly taken and put into the equation.

The operation **range** of the sensor is between 300 and 1250 hPa. The supply **voltage** is 3.3 V and the typical **current** consumption is 3.4 µA.

Hypsometric formula

$$h = \frac{\left(\left(\frac{P_0}{P}\right)^{\frac{1}{5.257}} - 1\right) \times (T + 273.15)}{0.0065}$$

$P_0 = Pressure\ At\ Ground\ Level$

$P = Current\ Pressure$

$T = Current\ Temperature$

Payload Air Temperature Sensor Summary

Component	Interface	Resolution (°C)	Accuracy (°C)	Size (mm) L x W x H	Mass (g)	Cost (£)
BMP388	I^2C / SPI	0.005	± 0.3	2.0 x 2.0 x0.75	0.06	2.62

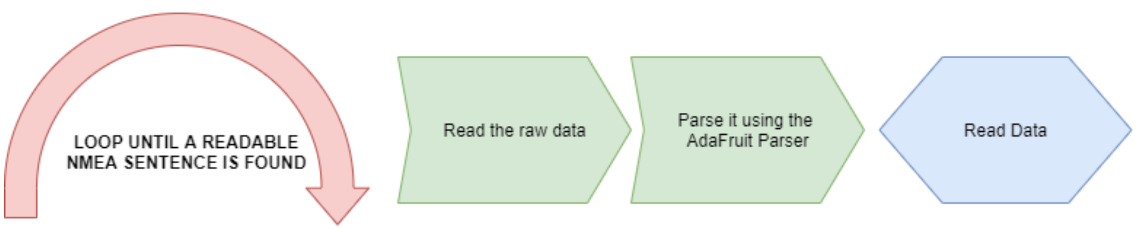
Temperature data will also be taken from the BMP388 sensor. The Arduino BMP library provides easy interface to the sensor. The temperature **data format** is 24 bits. The temperature is also important for altitude calculation, as it can be seen from the equation, shown on the previous slide. Using the provided library the temperature is directly obtained and put into the hypsometric equation in the previous slide.

The temperature operating **range** is from –20 degrees Celsius to +65 degrees Celsius. The supply **voltage** is 3.3 V and the typical **current** consumption is 3.4 µA as mentioned in the previous slide.

GPS Sensor Summary

Component	Interface	Horizontal Position Accuracy (m)	Velocity Accuracy (m/s)	Time-To-First-Fix (s)		Size (mm) L x W x H	Mass (g)	Cost (£)
				Cold	Hot			
uBlox NEOM8N	I^2C/ SPI/UART	2.5	0.05	29	1	16 x 12 x2.2	3.00	6.78

The **data format** of the chosen GPS is NMEA-0183. The operating **voltage** is 5 V and the typical **current** consumption is 0.023 A. The signal received by this module is L1C/A at 1575.42 MHz making its **range** dependent on the broadcasted signal.



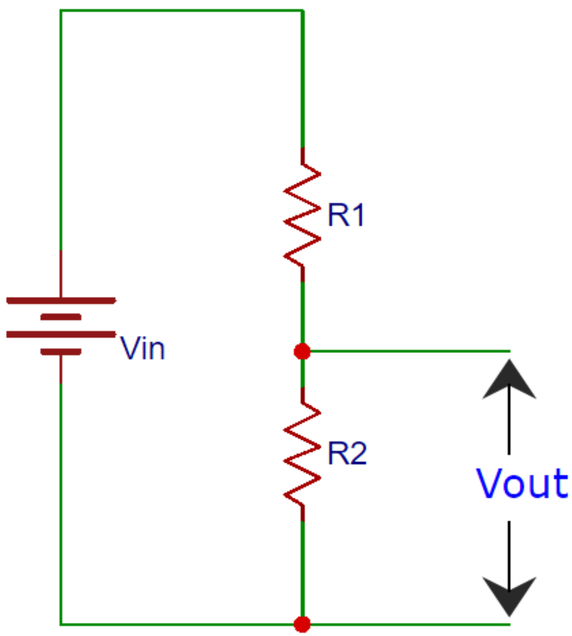
Pseudo code in the form of diagram

Payload Voltage Sensor Summary

Component	Interface	Resolution (mV)	Size (mm) L x W x H	Mass (g)	Cost (£)
Onboard ADC + Voltage Divider	Analog	1.6	Included in the MCU	Included in the MCU	Included in the MCU

The voltage divider is needed as the inbuilt Teensy ADC measures voltage values up to 3.3 V. The **data format** is 10 bit. The resistor values are known and will be added into the code as constants. The analog read will be taken from the pin and put into the equation to calculate the desired voltage. The **range** is 0 to 3.3 V. The **current** consumption would be around 0.35 mA as there is a constant current flow through the two voltage divider resistors. For operating **voltage**, the input voltage to the MCU can be considered which is 5 V, because the analogRead is done using the Teensy. The sensitivity is 0.0016 V.

$$V_{in} = analogRead(analogPin) * \frac{3.3}{4095} * \frac{R_1 + R_2}{R_2}$$



Air Speed Sensor Summary

Component	Interface	Pressure Range (kPa)	Accuracy (% span)	Size (mm) L x W x H	Mass (g)	Cost (£)
MS4525DO	I^2C / SPI	± 6.89	± 0.25	12.4 x 17.4 x 7.2	3.0	31.57

The presented sensor together with a pitot tube will be used for air speed measuring. It has a 14-bit **data format**. The equation shown below will be used for estimating the air flow. The measured values for the stagnation pressure and the static pressure are obtained by the presented sensor and will be substituted into the equation to calculate the air speed. The operating **voltage** of the sensor is 3.3 V, while the typical **current** consumption is 0.003 A. The pressure data will be read by the MCU analog pins and fit into the equation to calculate the air speed.

$$u = \sqrt{\frac{2(P_t - P_s)}{\rho}}$$

u is the air speed
P_t is the stagnation pressure
P_s is the static pressure
ρ is the fluid density

Particulate/Dust Sensor Summary

Component	Interface	Resolution (µm/m³)	Size (mm) L x W x H	Mass (g)	Cost (£)
GP2Y1010AU0F	Analog	1.6	46 x 34 x 17.6	15	7.43

The operating **voltage** of the sensor is 5 V, while the typical **current** consumption is 0.02 A. The **sensitivity** of the sensor is 0.5 V/0.1mg/m³. The temperature operating **range** of the sensor is from –40 degrees Celcius to 85 degrees Celcius. After measuring the output voltage of the sensor, the dust density will be calculated using the shown equation. The typical output voltage when there is zero dust and the typical sensitivity are initially set to 0.6 and 0.5, but can be calibrated depending on the sensor's performance. The measurement **range** is from 0 to 500µg/m³. The operating temperature is between –10 degrees Celcius to +65 degrees Celcius.

$$dust\ density = \frac{V_o - V_{oc}}{K * 100}$$

V_o is the sensor's output voltage
V_c is the typical output voltage when there is zero dust.
K is typical sensitivity in units of V per 100 µg/m3

Bonus Objective Camera Summary

Component	Interface	Resolution	Field of View (deg)	Size (mm) L x W x H	Mass (g)	Cost (£)
RunCam Nano 2	Serial	976 x 582	155	14 x 14 x 16	3.2	12.58

The resolution of the selected camera meets the requirement of 640x480 pixels in colour. The operating **voltage** of the camera is 5 V and the typical **current** consumption is 0.11 A. The horizontal resolution of the camera is 700 TVL, the SNR is bigger than 50 dB. The lens is 2.1 mm (M8) FOV 155 degrees.

The video data will be stored in a HM Digital Video Recorder which is controlled by the MCU.

Container Air Pressure Sensor Summary

There is no air pressure sensor in the Container.

The air pressure sensor in the Payload is enough to determine the altitude and the circuit is simpler.

Descent Control Design

May Ling Har

Descent Control Overview

Stage 1: apogee → 450 m

Container is released from the rocket at apogee. The Container parachute is deployed with the payload stowed inside the container.

Stage 2A: 450 m → ≥100 m

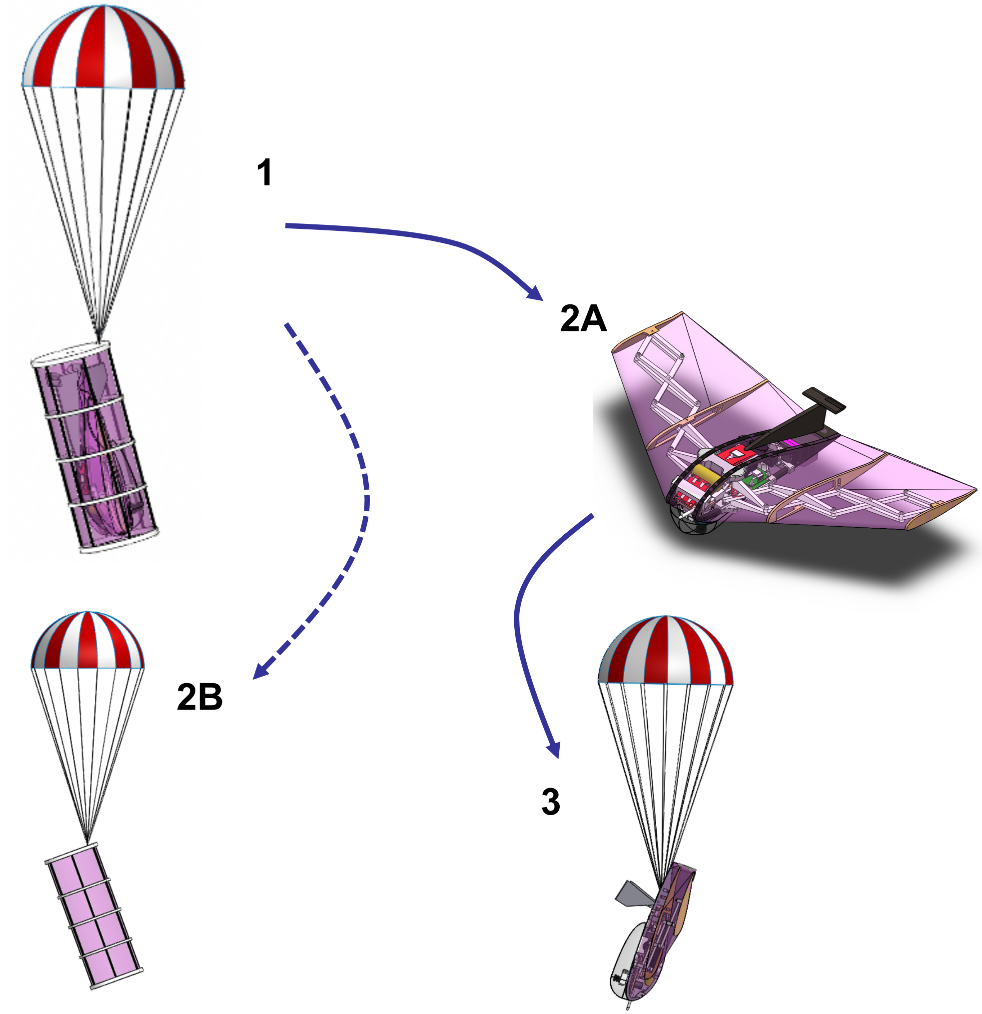
The payload is released from the container and glides in a circular pattern for 60 seconds while data acquisition takes place and the camera tracks its target.

Stage 2B: 450 m → landfall

After the payload is released, the container continues to descend under its parachute.

Stage 3: ≥100 m → landfall

The payload parachute is deployed.



Container and container parachute *will be* ***fluorescent pink***
Payload parachute *will be* ***fluorescent pink***

Descent Control Changes Since PDR

PDR	CDR	Rationale	Prototype Testing
Container parachute attached to the container with strings and a swivel pin	A shock cord are added to the end of the container parachute strings and attached to the swivel pin	The shock cord will help absorb the shock of the separating parts coming to a halt at the ends of the cord. Hence, less stress will be exerted on the container's structure.	N/A due to COVID-19 lockdown
Payload parachute attached to the glider with strings and a swivel pin	A shock cords are added to the end of the payload parachute strings and attached to the swivel pin	The shock cords will help absorb the shock of the separating parts coming to a halt at the ends of the cord. Hence, less stress will be exerted on the glider's structure.	N/A due to COVID-19 lockdown

No further changes have been made since the PDR because of the COVID-19 lockdown that affected the University. We intended to run wind tunnel tests, flight simulator validations and test launches. However, no access was provided to university facilities, hence we were unable to proceed with our planned activities to test descent control components.

Descent Control Requirements

RE#	Requirement	Verification			
		A	I	T	D
1	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.		X		X
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.		X		X
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.	X	X		X
4	The container shall be a fluorescent color; pink, red or orange.	X	X		
5	The container shall be solid and fully enclose the science payload. Small holes to allow access to turn on the science payload is allowed. The end of the container where the payload deploys may be open.	X	X		
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	X			X
7	The rocket airframe shall not be used as part of the CanSat operations.	X			X
8	The container 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.	X	X	X	
9	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.	X		X	
10	The container shall release the payload at 450 meters +/- 10 meters.	X		X	X
11	The science payload shall glide in a circular pattern with a 250 m radius for one minute and stay above 100 meters after release from the container.	X		X	X
12	The science payload shall be a delta wing glider.	X	X	X	
13	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10 meters/second, +/- 5 m/s	X		X	X
14	All descent control device attachment components shall survive 30 Gs of shock.	X		X	

Descent Control Requirements

RE#	Requirement	Verification			
		A	I	T	D
16	All structures shall be built to survive 15 Gs of launch acceleration.	X		X	
17	All structures shall be built to survive 30 Gs of shock.	X		X	
18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.		X		
19	All mechanisms shall be capable of maintaining their configuration or states under all forces.			X	
30	The Parachutes shall be fluorescent Pink or Orange	X	X		
38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	X	X		
48	No lasers allowed.	X			X
B1	*Bonus: A video camera shall be integrated into the science payload and point toward the coordinates provided for the duration of the glide time. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the science payload is retrieved. Points will be awarded only if the camera can maintain pointing at the provided coordinates for 30 seconds uninterrupted.*	X		X	X

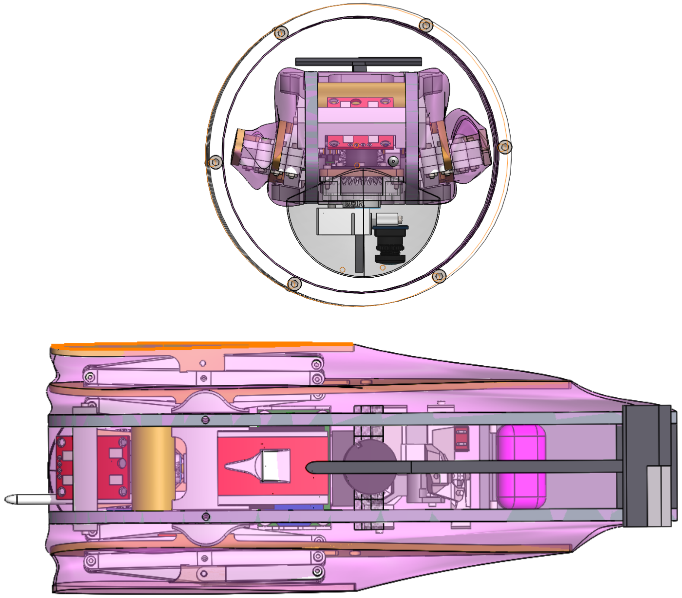
Note: Regarding RE B1, an outer structure will be required in order to accommodate the camera. This will create extra drag and lower the net Lift over Drag ratio.

Payload design

The payload is of a blended delta wing design with a rib frame and an extending X-frame wing spar. Descent control is passive in all configurations.

Stowed payload configuration

In the payload's stowed configuration, the X-frame and wings are collapsed and held in place by a string wound around the spool of the CCU. The X-frame was designed so that the collapsed wingspan fits within the container diameter.

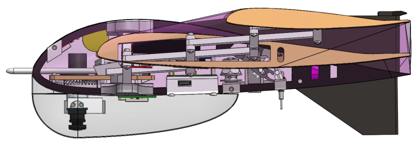


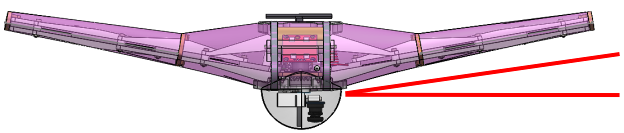
While stowed inside the container, payload descent control will be achieved by means of the container parachute, sized for the required descent rate.
The parachute is circular and is made of a ***fluorescent pink*** ripstop nylon. A spill hole with an area of 3% of the parachute's total projected area was chosen for added stability.

Payload Descent Control Hardware Summary

Deployed payload configuration & deployment method

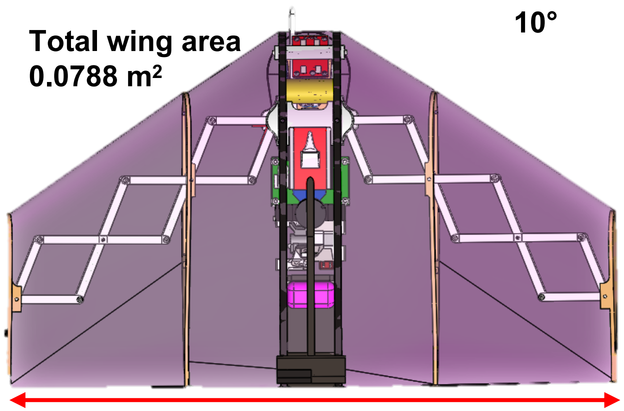
At an altitude of 450m, the payload is released from the container and the X-frame is allowed to deploy under the action of the CCU and the release of the force of the torsion springs. Upon deployment, the skin of ***fluorescent pink*** ripstop nylon is designed to stretch over the structure to form the aerodynamic surface.





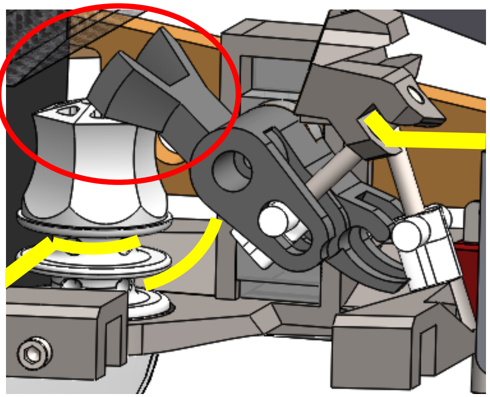
Dihedral angle 10°

Total wing area 0.0788 m²

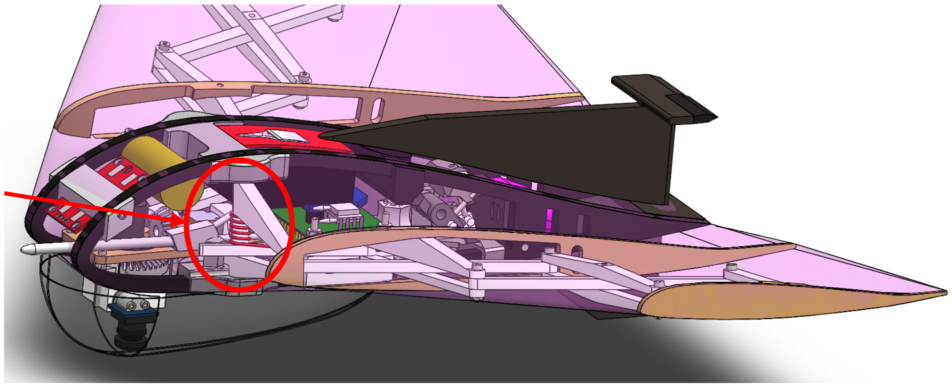


Wing span 400 mm

Spool allowed to spin, unwinds string to Wing rib



Torsion springs unfold wings

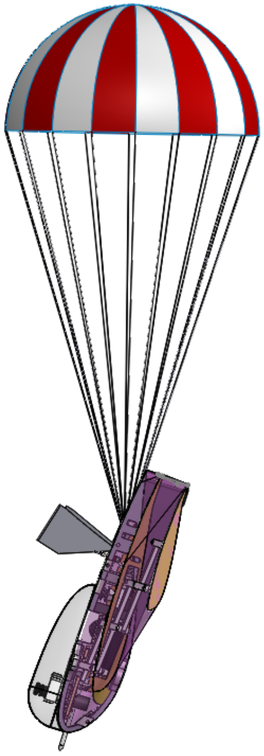


Payload Descent Control Hardware Summary

Component sizing & key design considerations

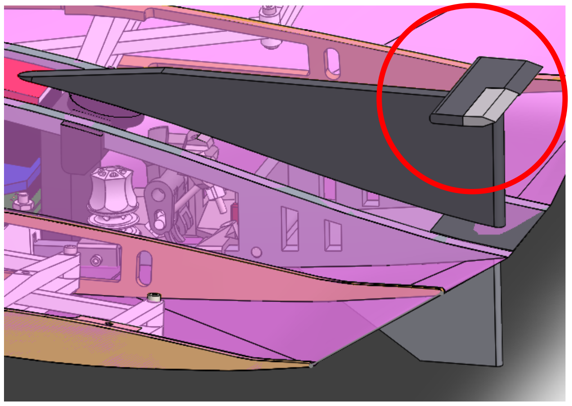
In the absence of testing opportunities to validate the design's performance, the sizing conducted at the PDR stage represents the most recent and final configuration of the design.

The airfoil profiles were selected to provide a sufficient lift-to-drag ratio for the required descent rate, given the maximum wing area achievable using the chosen wing deployment method. Longitudinal stability was also considered in their selection.



To achieve a turn with a radius of 250m, one elevon on the horizontal stabiliser is deflected by a small amount to create a rolling moment. From simulations, the required angle was determined to be approximately **3 degrees**.

Deflected elevon

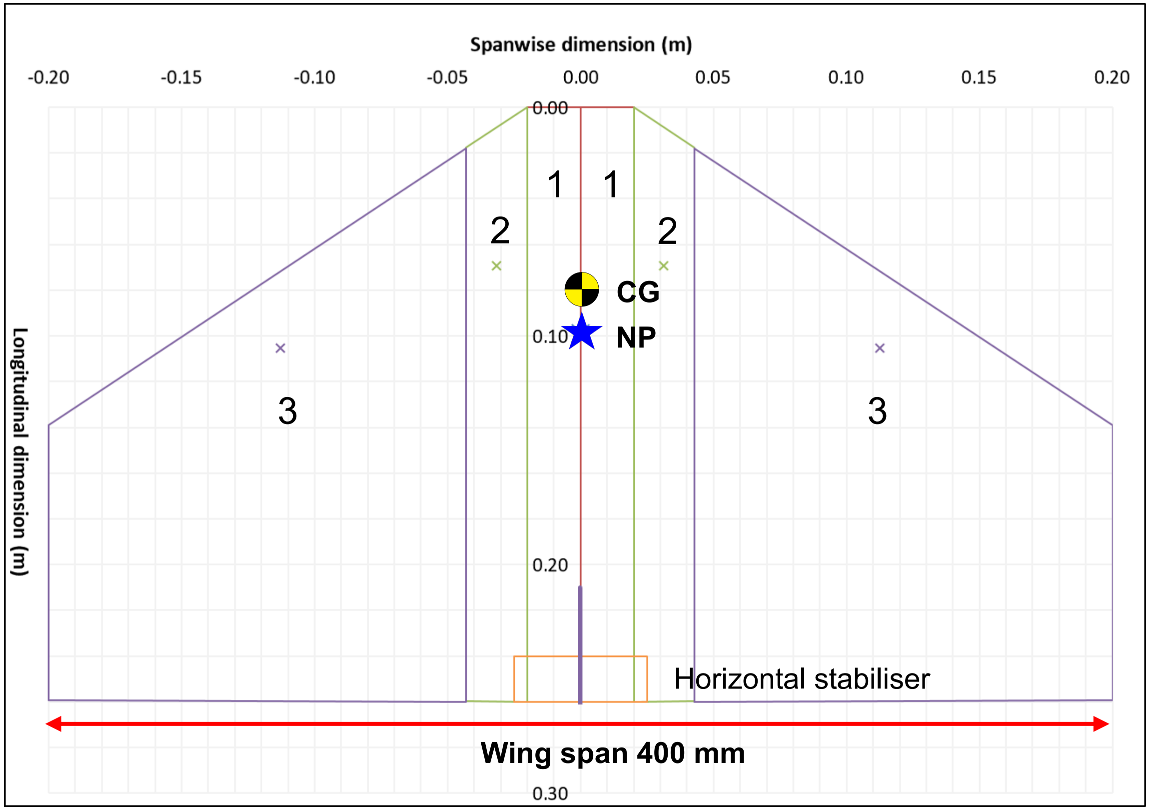


Following the 60 seconds of gliding, the CCU will be actuated into its third position and the glider parachute will be deployed. The glider's parachute is circular and is made of a ***fluorescent pink*** ripstop nylon. A spill hole with an area of 3% of the parachute's total projected area was also chosen.

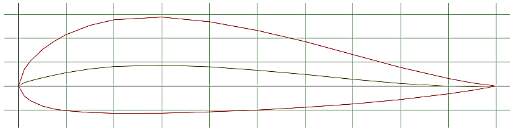
Longitudinal stability

No active mechanisms are used for stability; stability is maintained via the passive balance of moments.

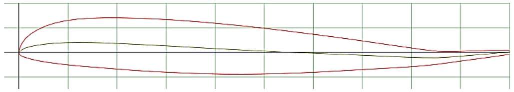
The balance of pitching moment contributions from the individual wing panels was evaluated using Prandtl's lifting line theory in order to ensure longitudinal stability in the absence of active controls. A static margin of 30% of the mean aerodynamic chord between the glider's CG and NP was chosen based on analysis in XFLR5. Predictions from XFLR5 analysis also indicate positive longitudinal stability of the glider.



For the inboard panels (1, 2): the GOE735 airfoil was chosen for its internal volume. Data was obtained from XFLR5 airfoil analysis.



For the outboard panels (3): The ESA40 was chosen as a reflex airfoil with high L/D. Data was obtained from Selig Low Speed Airfoil Data Vol.3.



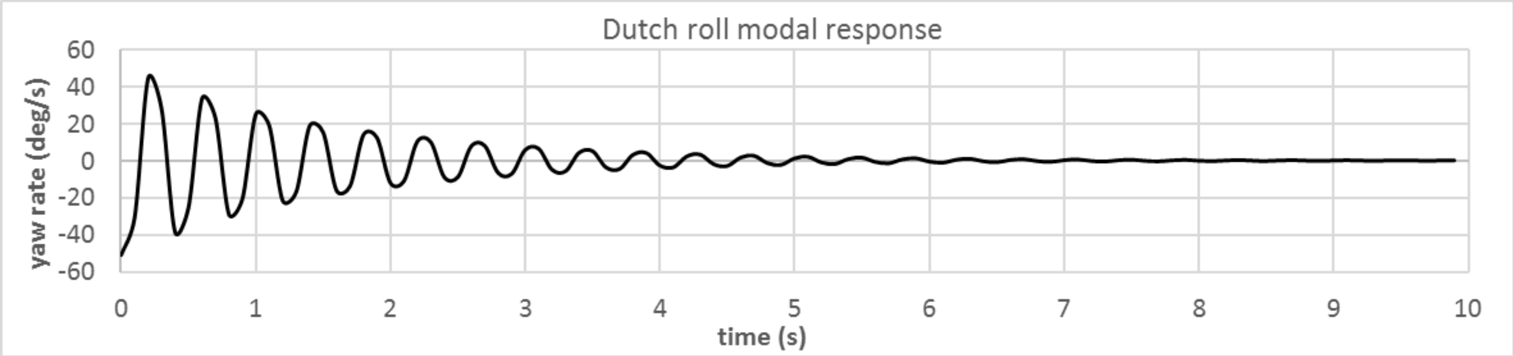
Payload Descent Stability Control Design

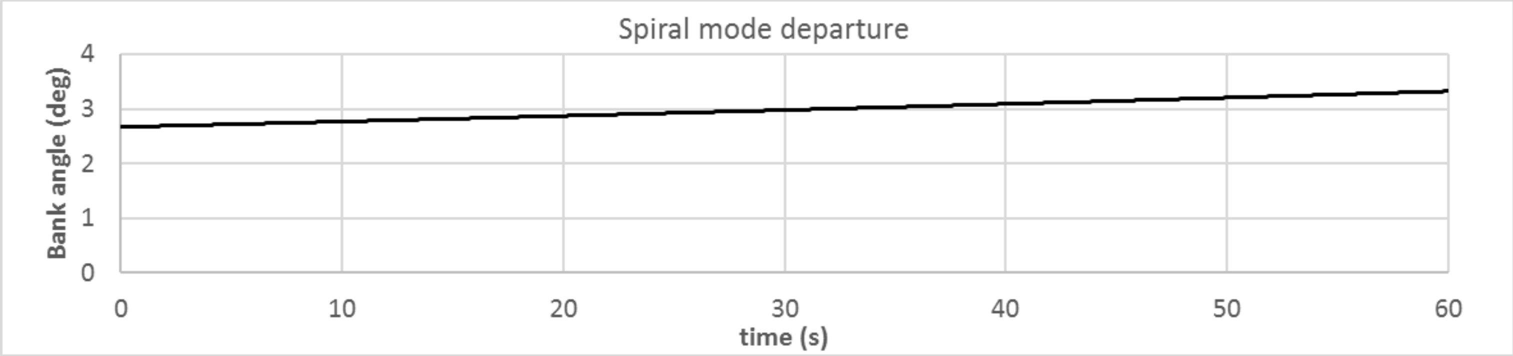
Lateral stability

Lateral stability is also assured passively.

Lateral stability was evaluated using the stability analysis function of XFLR5. The vertical fin size and wing dihedral angle were determined based on the predicted dynamic behaviour.

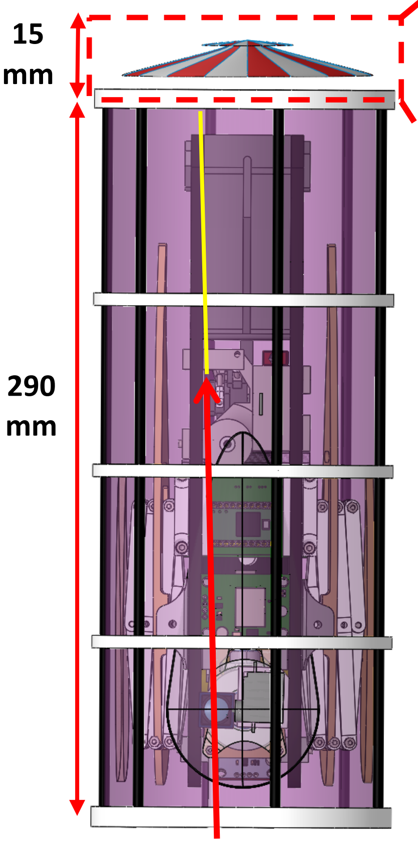
Damping of the Dutch roll mode is predicted, however the spiral mode diverges slightly over the descent time, indicating a slight gradual tightening of the turn radius.



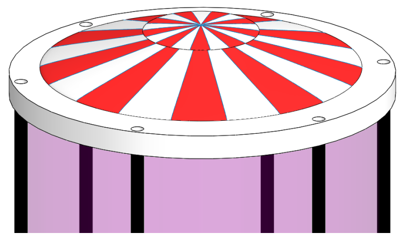


Container Descent Control Hardware Summary

Stowed Configuration:



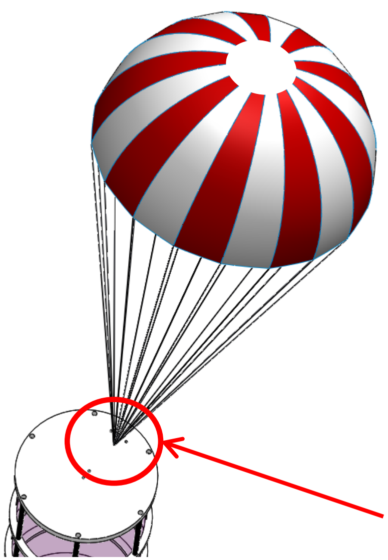
Key Components



Passive deployment system

The Container Parachute is attached to the Container via a shock cord and a swivel pin. It will not be enclosed by the Container structure to ensure full deployment. Air flow will cause the Parachute to deploy and slow the descent rate of the CanSat to 20 m/s

Deployed Configuration:

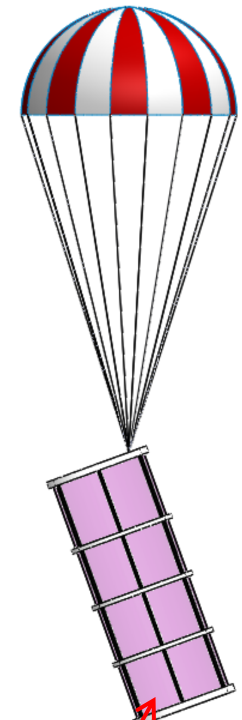


Component Sizing & Key Considerations

The Container is sized to encompass the volume of the payload, with the minimum mass possible. Hence a carbon fibre and 3D printed ABS structure is used, which is covered with a fluorescent pink PE cover.

The swivel pin will prevent the parachute string from tangling, thus preventing parachute collapse.

Container with Fluorescent Pink Parachute Deployed



Descent Rate Estimates

<u>***Parachute Calculations:***</u>

Assumptions made:

1. *Weight of falling object is equal to drag when it travels at terminal velocity.*
2. *Density of air is assumed to be 1.225 kg/m^3*
3. *No wind or air currents.*

Using the Drag Equation $D = \frac{1}{2} \cdot Cd \cdot \rho \cdot V^2 \cdot A$

From first assumption $\boldsymbol{W = mg = D}$

$$\boldsymbol{A = \frac{2 \cdot m \cdot g}{Cd \cdot \rho \cdot V^2}}$$

$\boldsymbol{mass, m\ [kg]}$

$\boldsymbol{gravitational\ acceleration, g = 9.81\ m/s^2}$

$\boldsymbol{coefficient\ of\ drag, Cd = 0.75}$ $(including\ spill\ hole)$

$\boldsymbol{density, \rho = 1.225\ kg/m^3}$ $(ISA\ value\ for\ air\ density)$

$\boldsymbol{pi, \pi = 3.1416}$

$\boldsymbol{projected\ area\ of\ parachute, A = \frac{\pi \cdot d^2}{4}}$ $(area\ of\ a\ circle)$ $\boldsymbol{[m^2]}$

$where\ \boldsymbol{d = diameter\ of\ parachute\ [m]}$

$\boldsymbol{V = velocity\ \ [m/s]}$

$\boldsymbol{D = aerodynamic\ drag\ [N]}$

*Estimates for **Coefficient of Drag (Cd**=0.75) obtained from drag coefficient of circular shape*

Note that the assumptions and the values in this slide will be used in the following slide throughout the calculations

Descent Rate Estimates

- **Container + Payload Parachute Calculation:** $mass, m = 0.6\ kg\ (Science\ Payload + Container\ mass)$

The area of the spill hole is chosen to be equal to 3% of the total parachute projected area ***(A·103%)***

For V=15 m/s

$$A = \frac{2 \cdot m \cdot g}{Cd \cdot \rho \cdot V^2} = 0.057\ m^2$$

For V=25 m/s

$$A = \frac{2 \cdot m \cdot g}{Cd \cdot \rho \cdot V^2} = 0.021\ m^2$$

$$0.022\ m^2 < A < 0.059\ m^2$$

$$\mathbf{0.164\ m < d < 0.274\ m}$$

A diameter of 0.229 m has been chosen as it can easily be purchased (9'')

$$V = \sqrt{\frac{8 \cdot m \cdot g}{\pi \cdot Cd \cdot \rho \cdot d^2}} = 17.6\ m/s$$

- **Container Parachute Calculation (After Payload is released):**

Mass is reduced by 394g as payload is released from container.
Hence only the mass of the container is accounted for

$$mass, m = 0.206\ kg (Container\ mass)$$

$$V = \sqrt{\frac{8 \cdot m \cdot g}{\pi \cdot Cd \cdot \rho \cdot d^2}} = 10.3\ m/s$$

- **Science Payload Parachute Calculation (After separation from Container):** $mass, m = 0.394\ kg (Payload\ mass)$

The area of the spill hole is chosen to be equal to 3% of the total parachute projected area ***(A·103%)***

For V=5 m/s

$$A = \frac{2 \cdot m \cdot g}{Cd \cdot \rho \cdot V^2} = 0.337 m^2$$

For V=15 m/s

$$A = \frac{2 \cdot m \cdot g}{Cd \cdot \rho \cdot V^2} = 0.037 m^2$$

$$0.038 m^2 < A < 0.347 m^2$$

$$\mathbf{0.220 m < d < 0.665\ m}$$

A diameter of 0.457 m has been chosen as it can easily be purchased (18'')

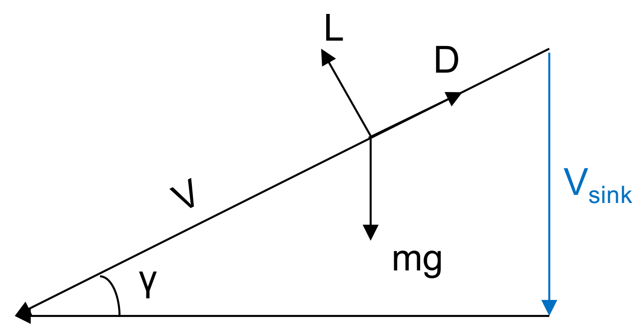
$$V = \sqrt{\frac{8 \cdot m \cdot g}{\pi \cdot Cd \cdot \rho \cdot d^2}} = 7.2\ m/s$$

Descent Rate Estimates

Payload descent during glide

Assumptions made:

- Descent rate is assumed constant
- The turn has a negligible effect on the descent rate
- The initial deployment is not considered
- Small-angle approximations for γ



Glide ratio $\gamma = \text{atan}\left(\frac{1}{\frac{L}{D}}\right) = 8.7°$

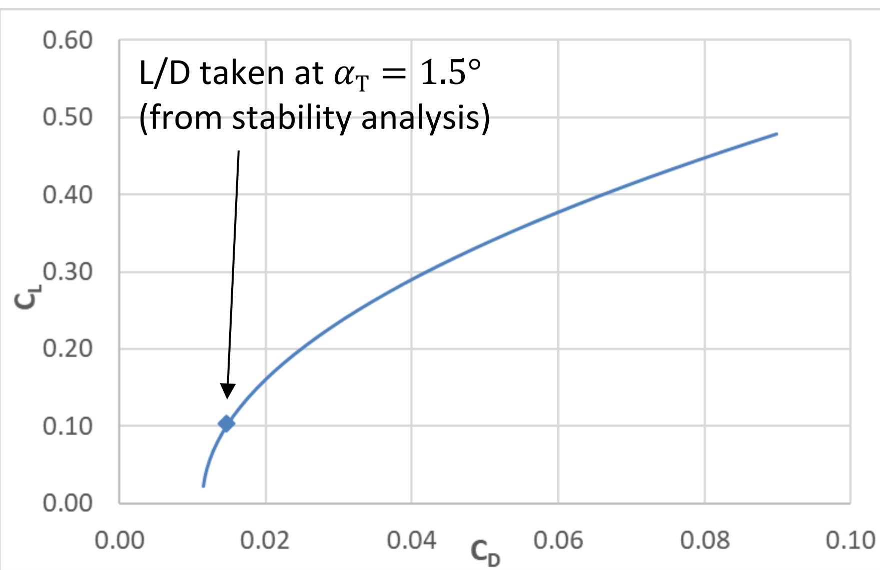
Total lift $L = mg\cos(\gamma) = 3.8\ N$

$$L = \frac{1}{2}\rho V^2 S C_L \Rightarrow V = \sqrt{\frac{2L}{\rho S C_L}} = 30.4\ m/s$$

$$V_{sink} = \frac{V}{\frac{L}{D}} = 4.7\ \text{m/s}$$

Maximum allowed descent speed (V_{sink}):

$$\frac{350\ metres}{60\ seconds} = 5.8\ m/s$$



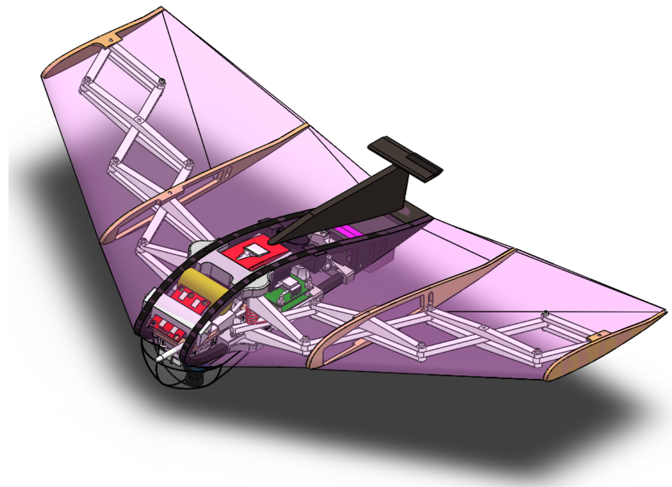
Descent Rate Estimates

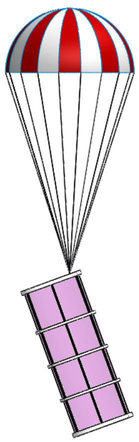
Summary

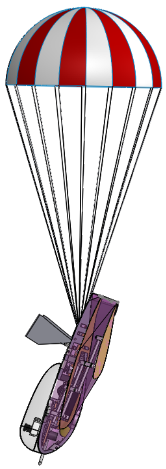
- Stage 1 Container + Payload
  - Parachute diameter is 0.229 m
  - Estimated descent rate is **17.6 m/s**
- Stage 2A Payload while gliding
  - Glider wing area is 0.0788 m^2
  - Lift-to-drag ratio is 6.50
  - Estimated descent rate is **4.7 m/s**
- Stage 2B Container after Payload release
  - Estimated descent rate is **10.3 m/s**
- Stage 3 Payload with parachute deployed
  - Parachute diameter is 0.457 m
  - Estimated descent rate is **7.2 m/s**

Container mass	206 g
Payload mass	394 g
Total mass	**600 g**


Stage 1


Stage 2A


Stage 2B

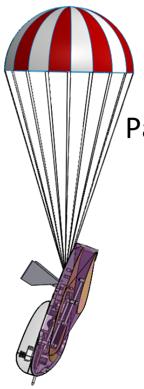

Stage 3

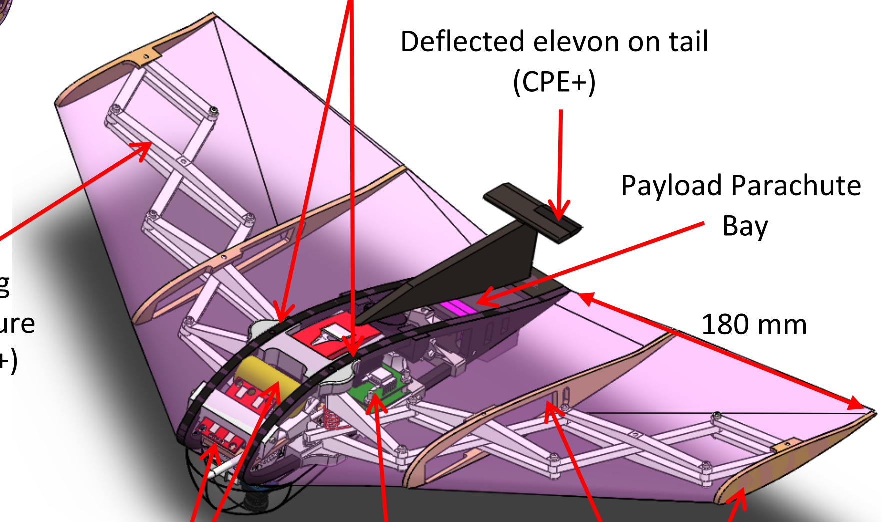
Mechanical Subsystem Design

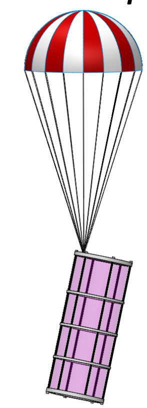
May Ling Har

Mechanical Subsystem Overview

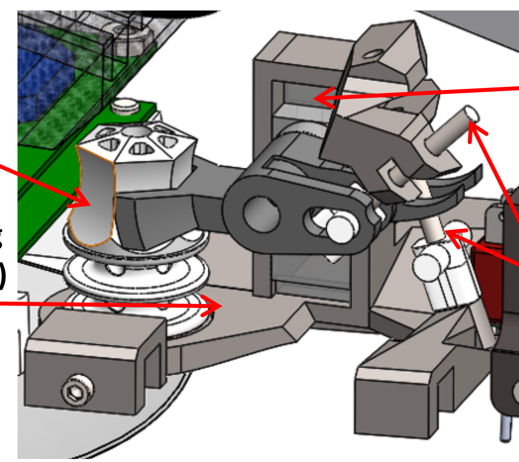
Key Aspects and Materials







Central Control Unit (CCU) Mechanism



Mechanical Subsystem Changes Since PDR

PDR	CDR	Rationale	Prototype Testing
All 3D printed components made of ABS	Payload X-frame arms, tail, parachute bay and frame attachment to be made of CPE+	Compared to ABS, CPE+ offers higher toughness lowering risk of brittle fracture at arm joints, much lower warping which is beneficial for the stabilisers on tail and parachute bay where surface warping could lead to aerodynamic instability.	Several X-frame arm prototypes were manufactured in ABS, however they were warped due to low thickness of the components and imperfect bed setup rendering them unusable.
Mounts for PCB v1	Mounts for PCB v2	Redesigned mounts to accommodate new PCB designed by electronics team.	N/A due to COVID-19 lockdown.
FPVDVR mounted with casing in front of CCU	FPVDVR mounted under frame attachment without casing	Due to larger footprint of the PCB v2 FPVDVR had to be relocated, the casing removed so that the view of the camera was not obstructed.	N/A due to COVID-19 lockdown.
Container plates secured with epoxy and bolts	Container plates secured with epoxy	Removing bolts would remove unnecessary mass on the CanSat, and any potential sharp protrusions due to the bolts would not be a concern.	A full Container prototype was assembled using only epoxy, and was found to be stronger than necessary.

Mechanical Sub-System Requirements

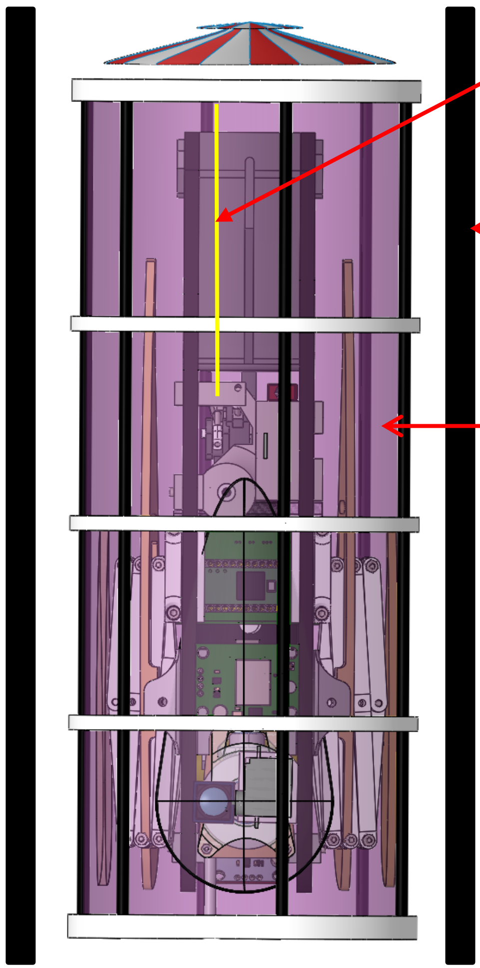
RE#	Requirement	Verification A	I	T	D
1	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.		X		X
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included to facilitate container deployment from the rocket fairing.		X		X
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.	X	X		X
4	The container shall be a fluorescent color; pink, red or orange.	X	X		
5	The container shall be solid and fully enclose the science payload. Small holes to allow access to turn on the science payload is allowed. The end of the container where the payload deploys may be open.	X	X		
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	X			X
7	The rocket airframe shall not be used as part of the CanSat operations.	X			X
8	The container 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.	X	X	X	
12	The science payload shall be a delta wing glider.	X	X	X	
13	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10 meters/second, +/- 5 m/s	X		X	X
14	All descent control device attachment components shall survive 30 Gs of shock.	X		X	
15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.		X		
16	All structures shall be built to survive 15 Gs of launch acceleration.	X		X	
17	All structures shall be built to survive 30 Gs of shock.	X		X	

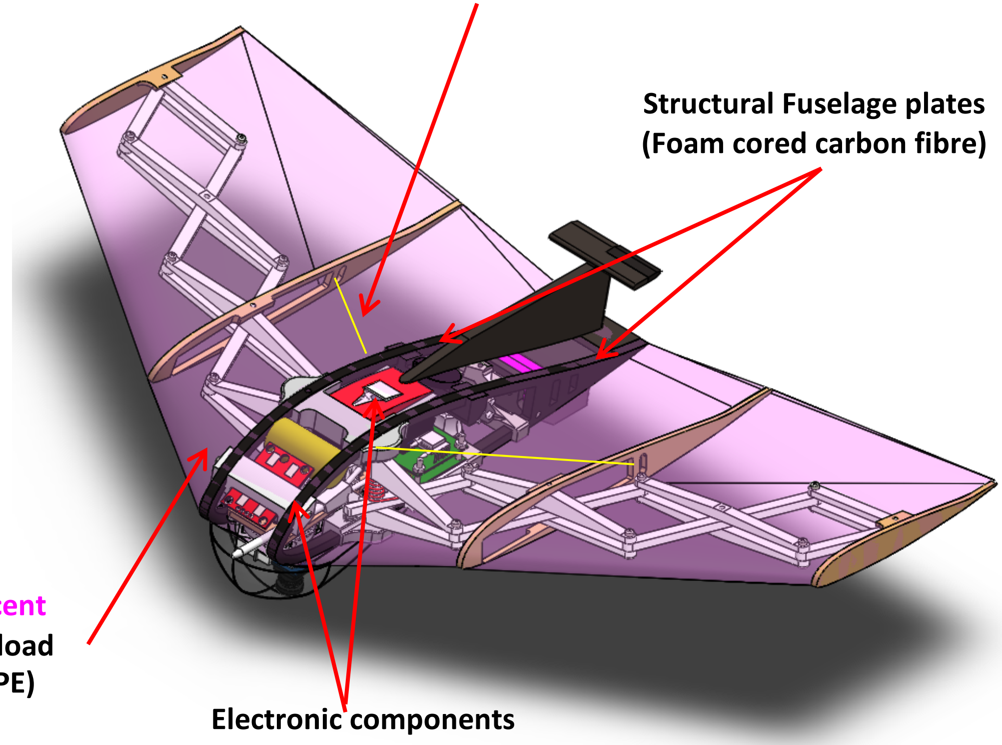
Mechanical Sub-System Requirements

RE#	Requirement	Verification			
		A	I	T	D
18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.		X		
19	All mechanisms shall be capable of maintaining their configuration or states under all forces.			X	
20	Mechanisms shall not use pyrotechnics or chemicals.	X			
21	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.	X		X	X
30	The Parachutes shall be fluorescent Pink or Orange .	X	X		
38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	X	X		
46	Both the container and probe shall be labeled with team contact information including email address.				X
48	No lasers allowed.	X			X
49	The probe must include an easily accessible power switch that can be accessed without disassembling the CanSat and in the stowed configuration.	X	X		X
54	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.	X	X		X
56	The CANSAT must operate during the environmental tests laid out in Section 3.5.			X	X
B1	*Bonus: A video camera shall be integrated into the science payload and point toward the coordinates provided for the duration of the glide time. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the science payload is retrieved. Points will be awarded only if the camera can maintain pointing at the provided coordinates for 30 seconds uninterrupted.*	X		X	X

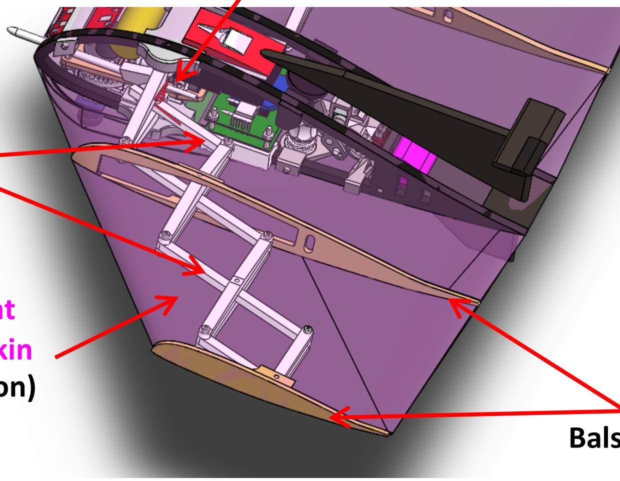
Payload Mechanical Layout of Components

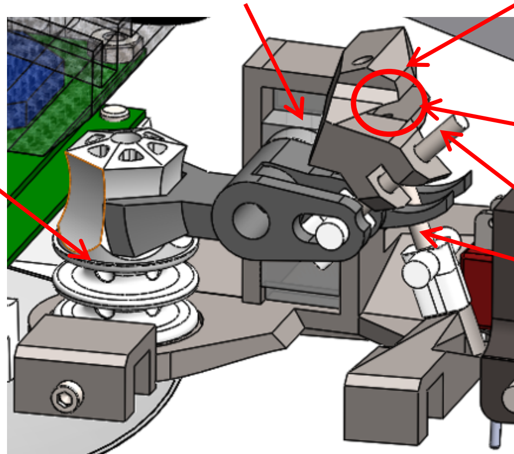
The five following slides discuss the design for the mechanical layout of the payload.



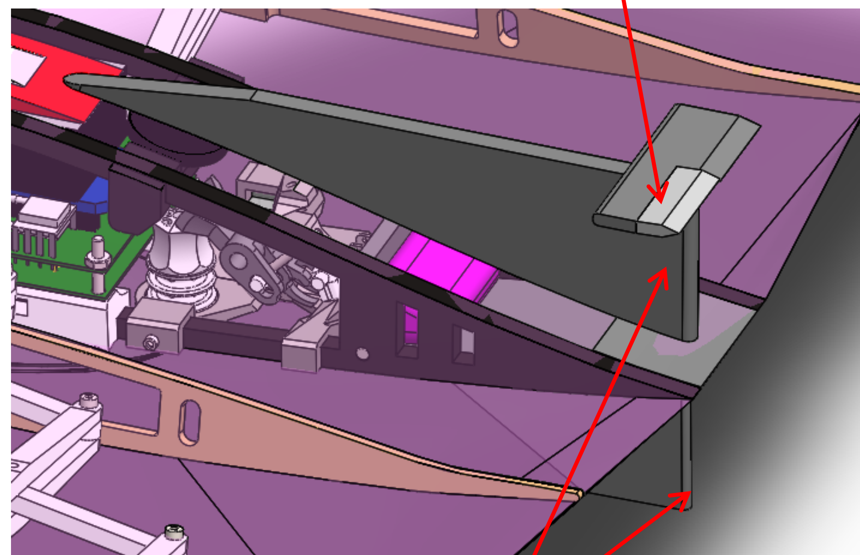


Payload Mechanical Layout of Components

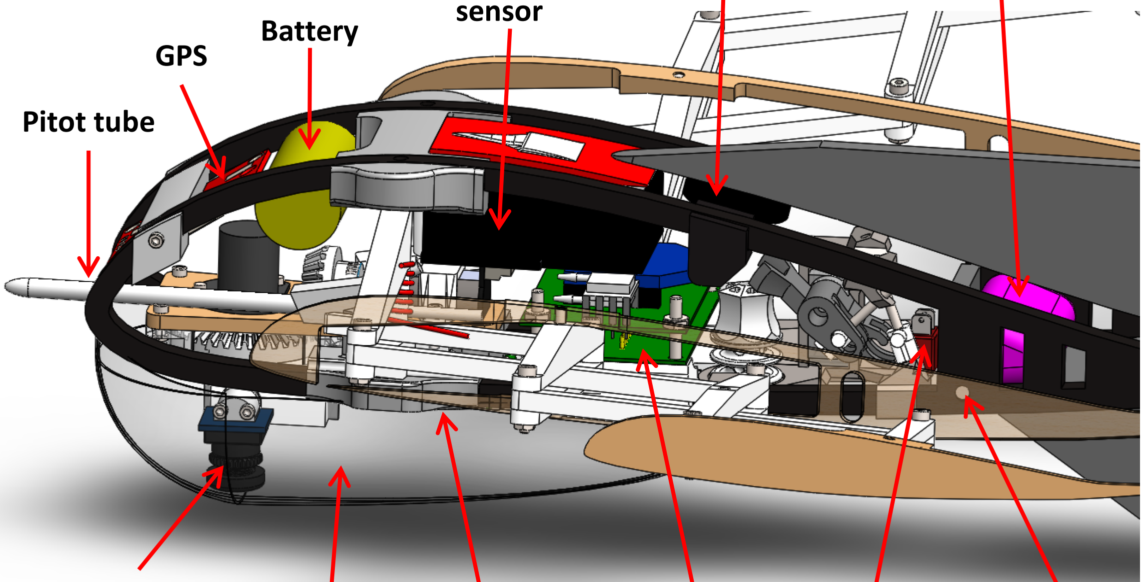


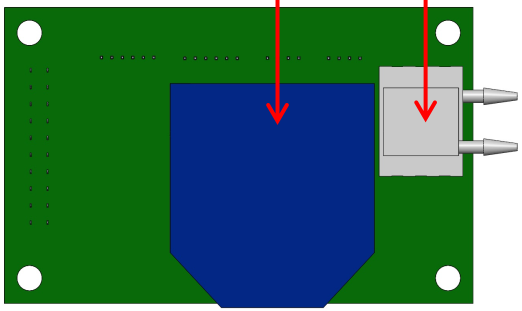


Central Control Unit (CCU) Mechanism

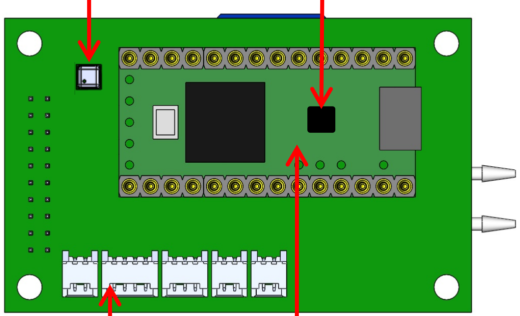


Payload Mechanical Layout of Components

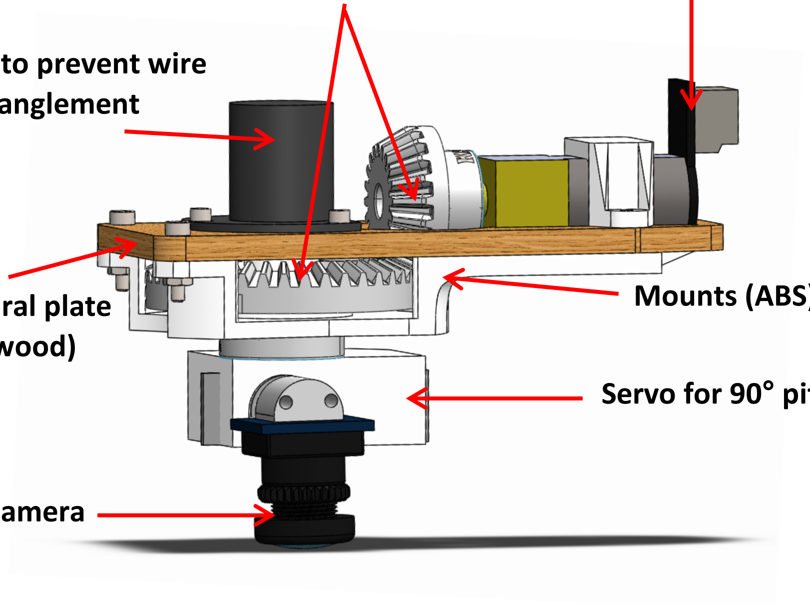




Stacked PCBs for mounted electronics



Payload Mechanical Layout of Components

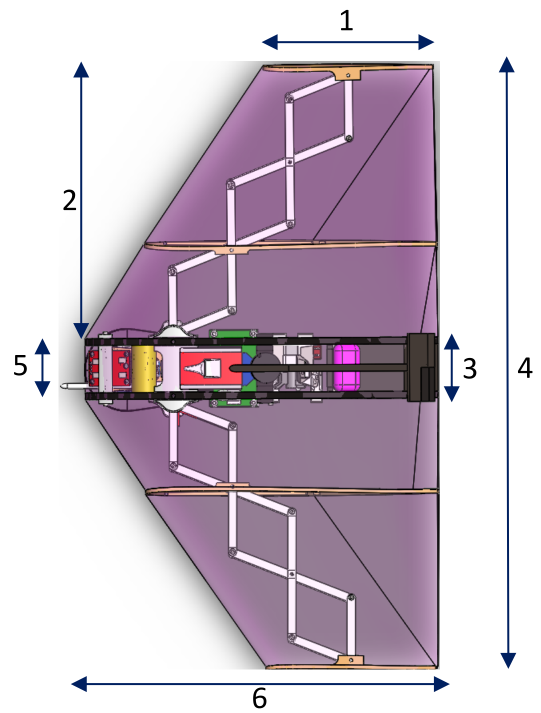


Payload Key Features:

- ‘X’ wing structure for folding, aided by torsion springs and string connected to a spool
- Camera with 360° continuous rotation and 90° pitch.
- Central Control Unit (CCU) mechanism for Payload Release, Payload Wings Deployment, and Payload Parachute Deployment.
- Deflected elevon on T-tail.
- Airfoil-shaped fuselage with transparent dome for camera mechanism.

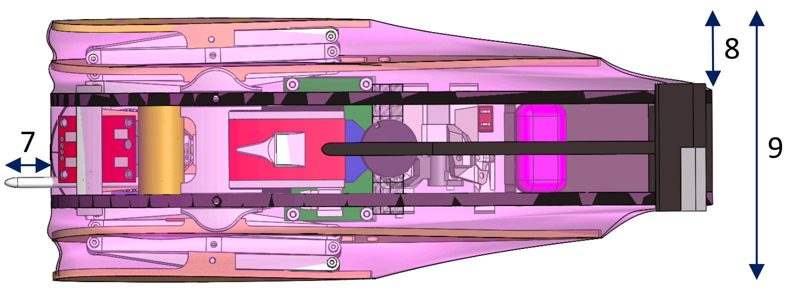
Note: Initially, the PCB along with its mounts was designed to be a load bearing member of the structure. Due to an increase in PCB size and consequent mount design change, the rigidity has been compromised. This is less than ideal for the final design but was deemed acceptable for initial testing phase. A new smaller version of the PCB was being developed for the final CanSat before the COVID-19 outbreak put a pause on it.

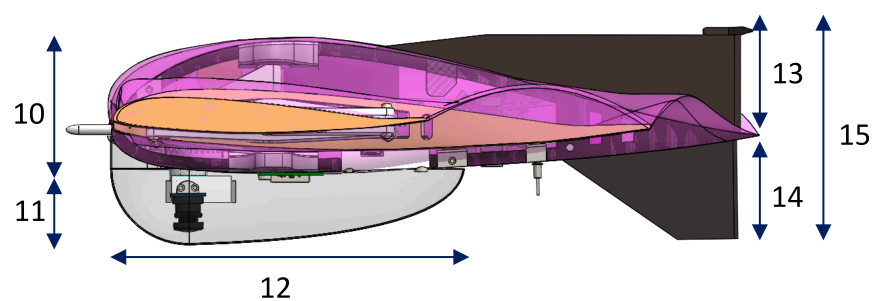
Payload Mechanical Layout of Components



Payload Key Dimensions (in mm):

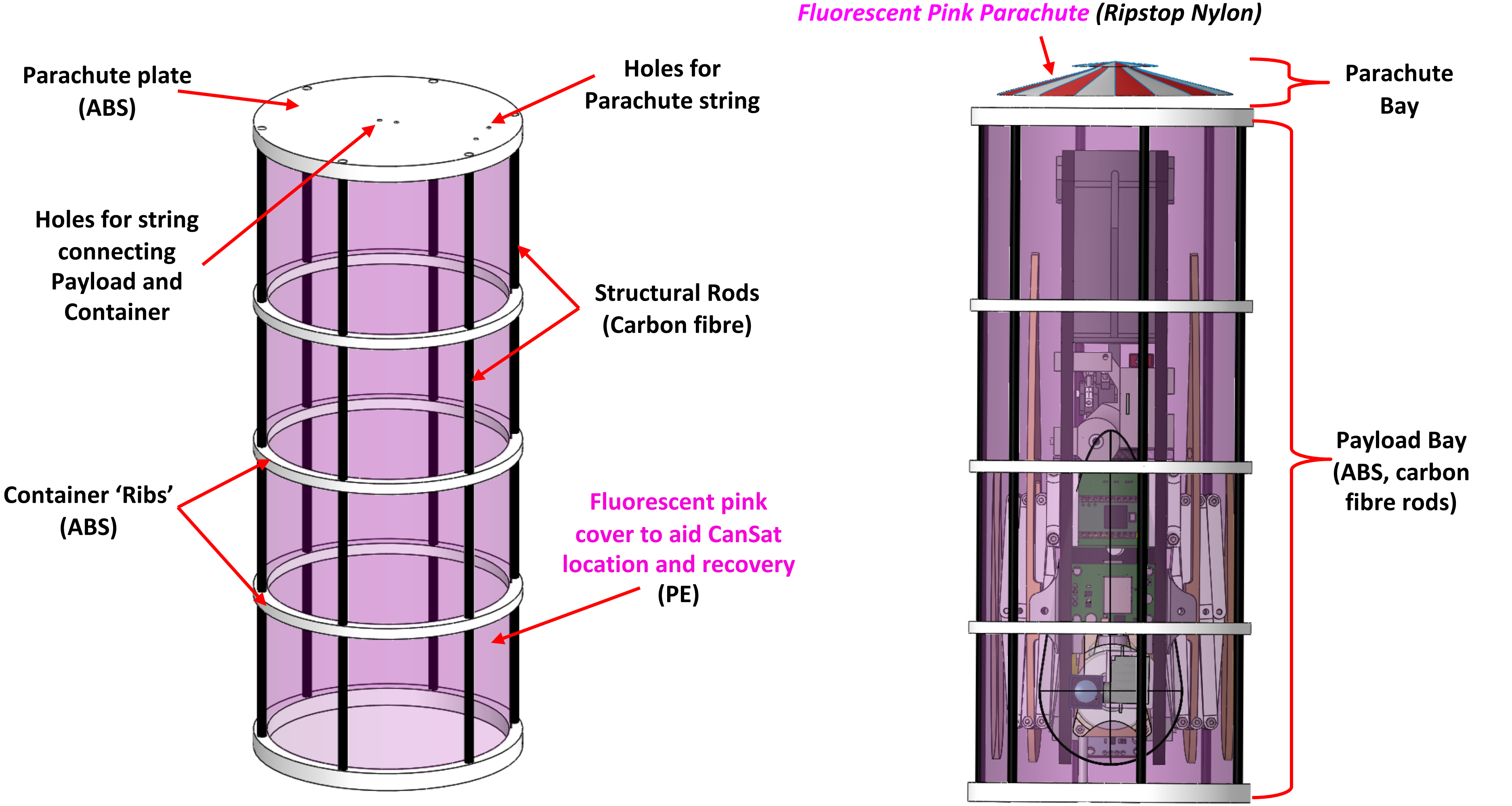
1 – 120
2 – 180
3 – 50
4 – 400
5 – 40
6 – 280
7 – 18
8 – 28
9 – 106
10 – 52
11 – 31
12 – 142
13 – 42
14 – 40
15 – 85



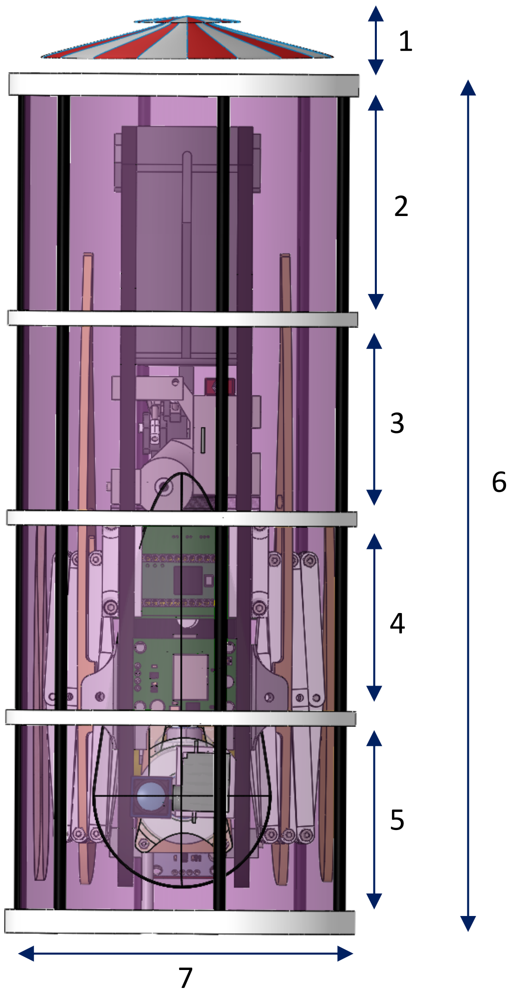


Container Mechanical Layout of Components

The following two slides discusses the design for the mechanical layout of the Container.



Container Mechanical Layout of Components



Container Key Dimensions (in mm):

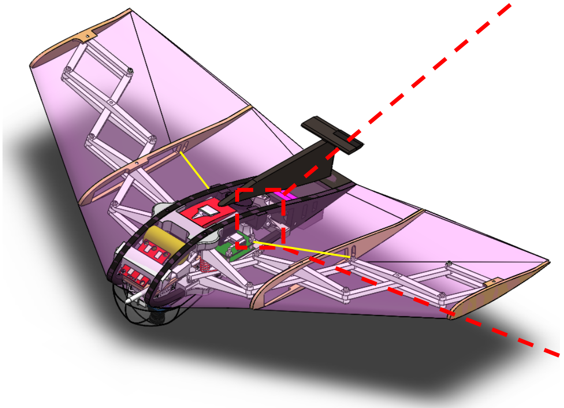
1 – 15
2 – 71
3 – 65
4 – 65
5 – 65
6 – 290
7 – 120

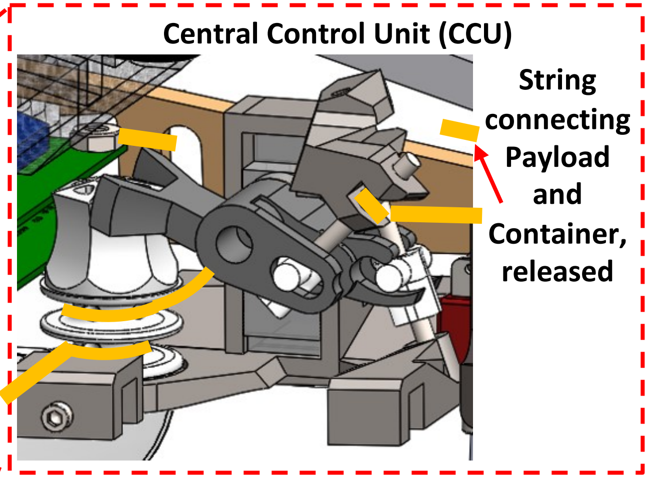
Container Key Features:

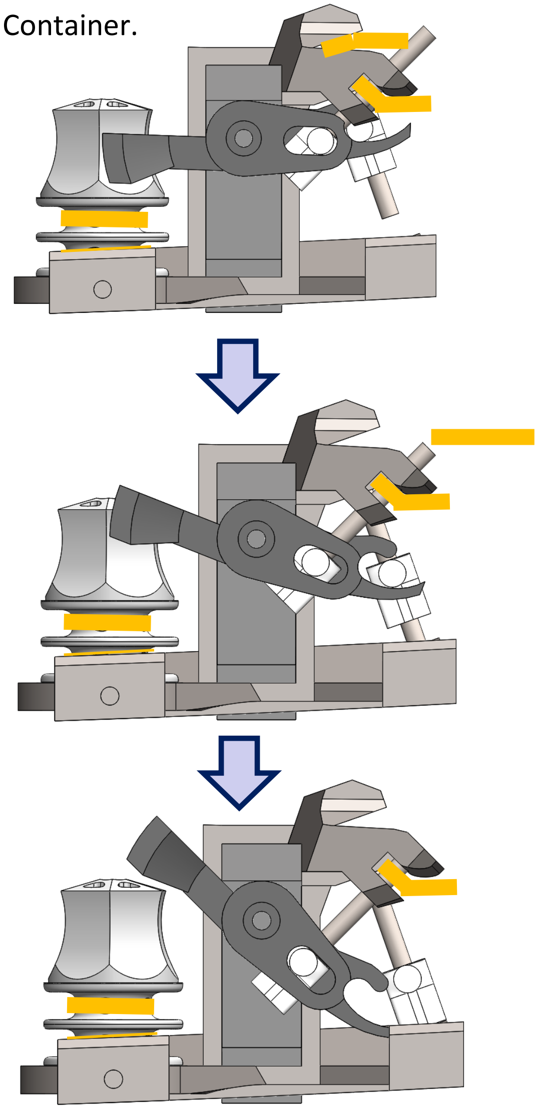
- Passive parachute deployment.
- Primarily made of carbon fibre rods and 3D printed ABS 'ribs'.
- Fluorescent pink cover and parachute to aid CanSat location and recovery.

Payload Release Mechanism

The following page discusses the mechanism conceptualized for the release of the Payload from the Container.







The Central Control Unit (CCU) is designed such that Payload Release, Wing Deployment, and Payload Parachute Deployment can be actuated from a single location with a servo. The first operation performed by the CCU servo will be to release the Payload from the Container.

Sequence of Events:

1. The CCU Servo is sent a signal determined by altitude to actuate Payload Release.
2. The CCU Servo rotates and retracts the rod by a specific margin, releasing the string from the CCU.
3. Once the string is no longer attached to the CCU, the Payload is free to fall from the Container.
4. When the Payload is fully separated from the Container, the CCU Servo rotates again, and raises the CCU arm.
5. The spool spins and unwinds the string connecting to the wing ribs, allowing the wings to deploy.

Container Parachute Attachment Mechanism

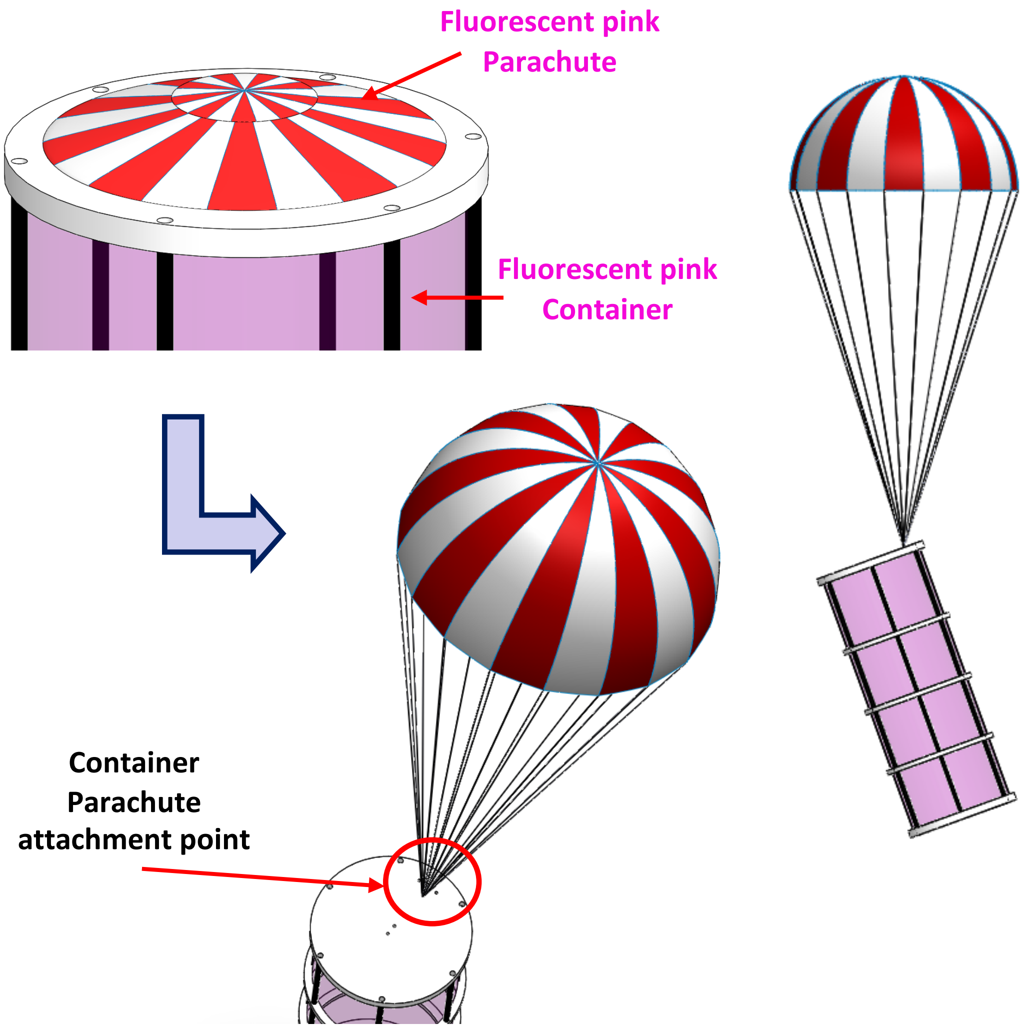
The following slide discusses the Container Parachute Attachment and deployment mechanism.

The Container Parachute is attached to the Container via string, shock cord and a swivel pin. It will not be enclosed by the Container structure to ensure deployment after the CanSat is released from the rocket.

In Launch Configuration, the Parachute will be folded such that it will deploy effectively after CanSat release from the rocket, and that it will not cause the CanSat dimensions to exceed the given dimensional constraints.

After the CanSat is released from the rocket, air flow will cause the Parachute to **passively** deploy and slow the descent rate of the CanSat to 20 m/s. The swivel pin will prevent the Parachute strings from tangling, thus preventing Parachute collapse as this was found to be an issue in the 2019 Competition. The shock cord will absorb the shock caused by the Parachute opening, thus reducing stress on the Container structure.

After the Payload is released from the Container, the Container will continue to descend separately with its Parachute.



Structure Survivability

Criteria	Method	Rationale
Electronic component mounting methods	Heavy duty Velcro will be used to secure the battery.	Heavy duty Velcro is easy to apply and remove, and lightweight, hence it is ideal to keep the battery in place while allowing the battery to be installed or removed easily.
	The electronics will be mounted onto PCBs, which will be secured to a 3D printed ABS mount via bolts.	PCBs provide a reliable method for mounting the electronics, and also reduces the likelihood of short circuits. It is also quicker to mount the electronics onto.
	Bolts will be used to mount the buzzer, pitot tube, particulate sensor, GPS, slip ring, the camera servo and motor to the structure.	Bolts are easy to integrate and are lightweight, thus is ideal for securing the mentioned electronic components.
	The CCU servo will be held in place by a 3D printed ABS casing.	The ABS casing of the CCU holds the servo in place, while providing adequate protection for the servo.
	A heavy duty cable tie will be used to secure the FPVDVR to the Payload structure.	A cable tie is lightweight and easy to apply, while being sufficiently secure.

Structure Survivability

Criteria	Method	Rationale
Electronic component enclosures	The electronics in the Payload are covered with ripstop nylon.	A ripstop nylon cover was chosen to cover the electronics in the Payload as it is lightweight and does not need to be structurally supporting any components/parts. It is also easy to remove and replace when replacing the battery.
	The Container will have a plastic cover to shield the payload.	A plastic cover was chosen to shield the payload in the Container due to its low mass while being easily removable and replaceable.
Acceleration and shock force requirements and testing	The fully assembled CanSat prototype will be tested in a full systems test launch.	Testing for acceleration and shock force requirements will occur during the full systems test launch, dedicated system tests, and the drop test.
Securing electrical connections	Epoxy will be used to secure electrical connections.	As the majority of electrical components will be mounted onto a PCB, there is no worry about components becoming disconnected. For connections that are liable to it, epoxy will be used for cases where the wires are better suited to being secured permanently. Otherwise, they will be left to be loose to make remedial actions easier.

Structure Survivability

Criteria	Method	Rationale
Descent control attachments	The servo used in the CCU located in the Payload is the only electrical component used to connect attachments. The servo retracts a rod, releasing the string connecting the Payload to the Container and thus releasing the Payload. It also connects to the Payload's parachute and is responsible for deploying the parachute.	The servo mechanism (CCU) has been tested numerous times for the release of the Payload in test launches and Competitions, and has proved to be reliable. It is believed that the mechanism will be reliable enough to deploy the payload parachute.
	The parachute is attached to the 3D printed ABS plate of the Container with the assistance of a shock cord.	This method has been successfully used by the team at previous Competitions and is believed to be the simplest method available. The shock cord aids this by distributing load away from the parachute plate.

Mass Budget

<table>
<tr><th colspan="5">Container Mass Breakdown</th></tr>
<tr><th>Subsystem</th><th colspan="2">Component</th><th>Mass (g)</th><th>Justification</th></tr>
<tr><td rowspan="8">ME/DCS</td><td colspan="2">Structural Carbon Fibre Rods (x6)</td><td>10.03</td><td>Datasheet</td></tr>
<tr><td colspan="2">Container Cover (PE)</td><td>5.00</td><td>Estimated</td></tr>
<tr><td colspan="2">Parachute (Ripstop Nylon)</td><td>3.45</td><td>Measured</td></tr>
<tr><td rowspan="3">3D Printed Parts (ABS)</td><td>Container ‘Ribs’ (x3)</td><td>28.50</td><td>Datasheet</td></tr>
<tr><td>Container top plate</td><td>90.32</td><td>Datasheet</td></tr>
<tr><td>Container bottom rib</td><td>15.10</td><td>Datasheet</td></tr>
<tr><td colspan="2">String</td><td>3.00</td><td>Estimated</td></tr>
<tr><td colspan="2">Epoxy</td><td>4.00</td><td>Estimated</td></tr>
<tr><td colspan="3">Total</td><td colspan="2">159.40 g</td></tr>
</table>

Mass Budget

Payload – Electronics Mass Breakdown (1/2)			
Subsystem	**Component**	**Mass (g)**	**Justification**
EPS	**Core PCB (excluding headers)**	5.52	Measured
SE	**GPS**	4.30	Measured
EPS	**Battery**	15.45	Measured
CDH	**Buzzer**	1.40	Measured
SE	**Camera**	3.20	Measured
ME	**Motor**	11.61	Measured
ME	**Servo**	10.48	Measured
SE	**Pitot tube**	7.78	Measured
SE	**PM sensor**	15.17	Measured
EPS	**Switch**	2.70	Measured
ME	**Slip Ring**	10.00	Measured
CDH/SE/FSW	**Teensy**	4.80	Measured

Mass Budget

Payload – Electronics Mass Breakdown (2/2)			
Subsystem	**Component**	**Mass (g)**	**Justification**
CDH	**XBee**	3.68	Measured
EPS	**Add on PCB (excluding headers)**	5.86	Measured
SE/CDH	**FPVDVR (without case)**	4.38	Measured
EPS	**Headers**	7.15	Measured
EPS	**Wiring**	6.00	Measured
Total		**119.48 g**	

Mass Budget

Payload – Structure Mass Breakdown (1/3)				
Subsystem	**Component**		**Mass (g)**	**Justification**
ME/DCS	**3D printed CPE+**	**X frame arms**	51.57	Datasheet
		Fuselage – X frame attachment	24.39	Datasheet
		Tail	23.31	Datasheet
		Parachute bay	18.37	Datasheet
	3D printed ABS	**Buzzer mount**	6.49	Datasheet
		PCB mount	5.24	Datasheet
		CCU housing + spool	12.30	Datasheet
		Camera mechanism mount	7.70	Datasheet
		GPS mount	3.21	Datasheet
		Roof scoop	3.42	Datasheet
	1mm CF Fuselage airfoil (x4)		22.70	Datasheet
	3mm Rohacell foam Fuselage airfoil (x2)		0.55	Datasheet
	Laser cut Balsa	**Wing ribs (x4)**	3.00	Datasheet
		Camera mechanism mount	0.63	Datasheet

Mass Budget

Payload – Structure Mass Breakdown (2/3)			
Subsystem	**Component**	**Mass (g)**	**Justification**
ME/DCS	**Torsion spring (x2)**	2.05	Datasheet
	Motor bevel gear	1.87	Datasheet
	Servo bevel gear	6.26	Datasheet
	Kevlar string	0.50	Estimated
	Ripstop nylon (glider cover)	5.90	Estimated
	PETG sheet (camera bubble)	7.10	Estimated
	M3x10 bolt (x4)	1.84	Datasheet
	M3 nut (x4)	1.27	Datasheet
	M2.5x6 bolt (x3)	1.23	Datasheet
	M2.5 nut (x3)	0.97	Datasheet
	M2x12 bolt (x12)	6.48	Datasheet

Mass Budget

Payload – Structure Mass Breakdown (3/3)			
Subsystem	**Component**	**Mass (g)**	**Justification**
ME/DCS	**M2 nuts (x12)**	4.10	Datasheet
	M1.6x10 bolts (x8)	6.11	Datasheet
	M1.6 nuts (x8)	5.21	Datasheet
	2mm dia. Steel shaft (CCU, Ribs)	3.00	Estimated
	3mm dia. Steel shaft (fuselage attachment, parachute bay)	5.26	Estimated
	Epoxy	8.00	Estimated
	Cable ties	4.00	Datasheet
	Parachute	20.00	Datasheet
Total		**274.03 g**	

Mass Budget

TOTAL BUDGET

System	Mass (g)
Container	159.40
Payload (Electronics + Structure)	393.51
Payload + Container	**552.91**

Mass Margin		
Mass (g)	**Available mass (g)**	**Margin (g)**
552.91	600 ± 10	**47.09**

Currently, the mass is **below** the mass budget requirement at **552.91 g**. Once the first prototype is fully assembled, the team can assess where mass can be added so that it will meet the required mass budget.

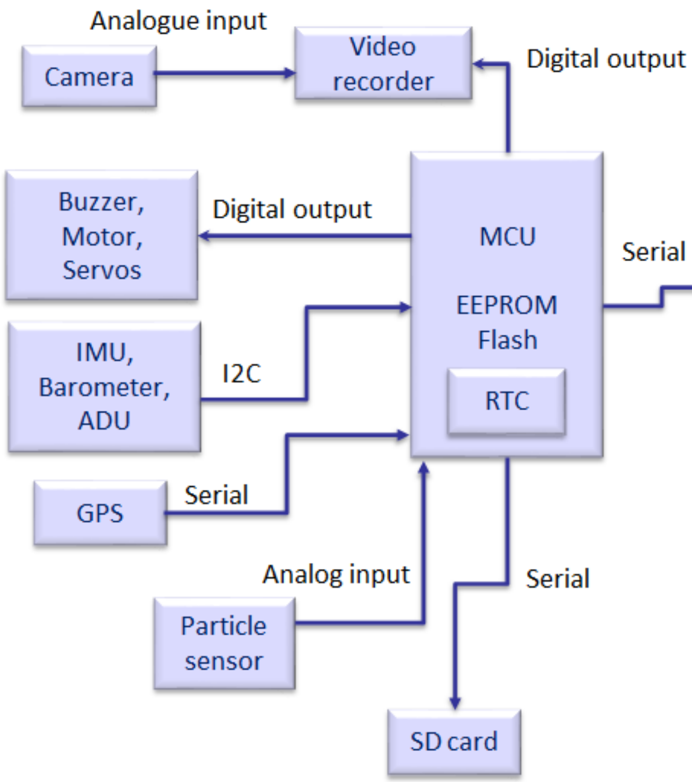
A **source of uncertainty** is that each prototype assembled by the team will have varied masses due to different lengths of wires and strings. Another **source of uncertainty** is the use of high-performance adhesives in the assembly of prototypes. As the CanSat will be assembled by hand, the amount of adhesive used will vary between prototypes, and thus the mass of the prototypes will vary. Furthermore, another **source of uncertainty** present in the mass budget is the masses provided for 3D printed components. Majority of these components have been manufactured; however masses cannot be measured and recorded as the components are kept within University Facilities and no access is allowed due to the COVID-19 lockdown. Hence, datasheet sources are used to provide these masses, but it is expected that measured masses will vary from datasheet sources.

To increase the mass of the CanSat, ballast will be added to the Payload to ensure that the Payload is aerodynamically stable. Ballast can also be added to the Container to ensure that the design is compliant with the mass budget requirement. The team will also replace certain structural materials with materials that are heavier yet stronger (such as replacing balsa wood with plywood). The thickness of structural elements and infill percentages of 3D printed components can also be increased. Furthermore, additional adhesive can be applied. This will increase the structural strength and integrity of the CanSat.

Communication and Data Handling (CDH) Subsystem Design

May Ling Har

CDH Overview



Component	Function
Teensy 4.0 internal RTC	Real-time clock
Teensy 4.0	Microcontroller (MCU)
ICM-20948 9-axis	IMU
8 GB SD card	For local data storage
Taoglas FXP290 915 MHz	Antenna
XBee Pro 900HP	Radio
NEO M8N	GPS radio and antenna
BMP 388	Pressure and temperature sensor
GP2Y1014AU0F	Particulate sensor
4525DO	ADU – for differential pressure

CDH Changes Since PDR

No changes to the CDH Subsystem have been made since the PDR.

CDH Requirements

RE#	Description	Verification A	Verification I	Verification T	Verification D
1	Total mass of the CanSat (science payload and Container) shall be 600 grams +/- 10 grams.		X		X
2	CanSat shall fit in a cylindrical envelope of 125 mm diameter x 310 mm length. Tolerances are to be included the rocket fairing.		X		X
15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.		X		
18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.		X		
22	The science payload shall measure altitude using an air pressure sensor.	X	X	X	X
23	The science payload shall provide position using GPS.	X	X	X	X
24	The science payload shall measure its battery voltage.	X	X	X	X
25	The science payload shall measure outside temperature.	X	X	X	X
26	The science payload shall measure particulates in the air as it glides.	X	X	X	X
27	The science payload shall measure air speed.	X	X	X	X
28	The Science Probe shall transmit all sensor data in the telemetry	X	X	X	X
29	Telemetry shall be updated once per second.		X	X	X
31	The ground system shall command the science vehicle to start transmitting telemetry prior to launch.		X	X	X
33	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	X		X	X
34	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.		X	X	X
35	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.		X		
36	XBEE radios shall have their NETID/PANID set to their team number.		X	X	X
37	XBEE radios shall not use broadcast mode.	X	X		
38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	X	X		
39	Each team shall develop their own ground station				X
42	Teams shall plot each telemetry data field in real time during flight.			X	X
44	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		X		

Payload Processor & Memory Selection

Memory Storage Requirements:

- 1 kB of non-volatile memory is needed at least
  - For maintaining mission time and packet count In case of a processor restart
- 32 kB of program storage (flash) memory is needed at least. From previous years' experience 32kB is the minimum required. The chosen microcontroller has 64 times that amount. Additional program storage capacity allows for greater flexibility.
- An additional 8 GB non-volatile memory for telemetry data needed
  - External SD card reader will be used
- A non-volatile memory solution for video storage is required
  - A video recorder with a SD card will be used

Payload Processor & Memory Selection

Micro-controller	Processor Speed (MHz)	Data Interfaces	Non-Volatile Memory (kB)		Volatile Memory (kB)	Current (mA)	Size (mm)	Mass (g)	Boot time (s)
			Flash	EEPROM					
Teensy 4.0	600	7x UART 3x I2C 3x SPI	2048	64	1024 RAM	100 @ 5 V	36 x 18	4.8	1

Device chosen	Rationale
Teensy 4.0 Micro-controller 	This MCU has the fastest processing speed. Power consumption changes if device is underclocked or overclocked. It has outstanding flash storage for complex programs. In addition, it has a high RAM value and a high number of data interfaces. Teensy 4.0 is also compatible with the Arduino IDE which speeds up the software development. Lastly, it comes at an affordable price. The **data bus width** is 32 bits. **Max power consumption** is 500mW.

Teensy 4.0 MCU	GPIO Pins	Digital IO	PWM Pins	Analog Inputs	Analog Output
Pin Number	40	40 (All interrupt capable)	31	14	0

Payload Real-Time Clock

Name	Accuracy	Active Supply Current (μA)	Interface	Operating voltage (V)	Hardware/Software
Teensy 4.0 internal low speed clock	50 ppm	26	Internal to CPU	3.3 V	Can use both

Chosen RTC	Rationale
Teensy 4.0 RTC	• Low supply current • Does not require additional circuitry • Comes as part of the MCU • Does not add extra weight or occupy extra are since its already on the board

Reset Tolerance:

A hardware RTC will be used. At mission start, the time will be recorded and saved to the EEPROM on the MCU. In the event of a processor reset, the mission start time in EEPROM will be used as a reference. The Teensy 4.0 RTC will have an additional battery, so whenever the microcontroller resets or stops working, it will continue to operate. On the other hand, when the Teensy is on, the RTC will be powered by it.

Payload Antenna Selection

Antenna	Connector	Gain (dBi)	VSWR	Range (m)	Mass (g)	Size (mm)	Polarization	Cost (£)
Taoglas FXP 290 915 MHz	MHFII (U.FL compatible)	1.5	< 2:1	11646*	1.5	75 x 45	Linear	14.29

Chosen Antenna	Rationale
Taoglas FXP290 915 MHz	• Can be placed near the outside of the payload • Uniform gain pattern • No extra circuitry needed • Lighter than other options when extra PCB area is accounted for • Covers a wide range

This is an extremely light option at only 1.5 g whist still having great gain and relatively uniform radiation patterns compared to competitors.

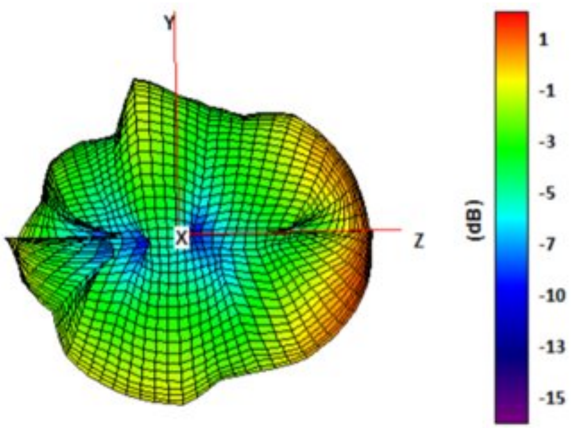
*Range estimated based on the Friis transmission equation with a -20 dBm link margin and non-optimal projection angle.

Payload Antenna Selection

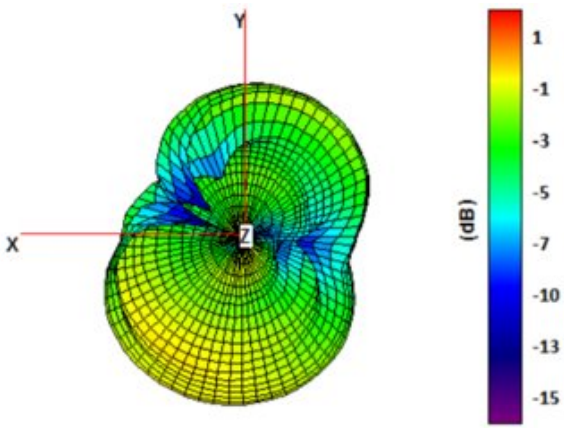
On this slide, the antenna patterns for the **Taoglas FXP290 915 MHz** are shown.

The plots were taken from the antenna datasheet.

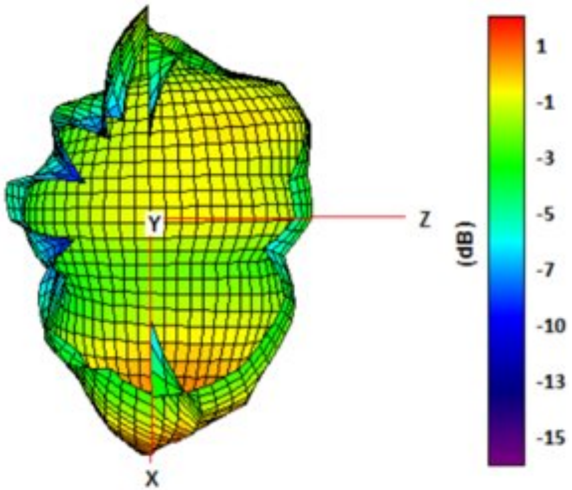
The antenna has relatively uniform radiation patterns relative to competitors.



Radiation pattern YZ plane.



Radiation pattern XY plane.



Radiation pattern XZ plane.

Payload Radio Configuration

Name	Operating Frequency (MHz)	Ant. Conn. Type	TX Current (mA)	RX Current (mA)	Tx Power (dBm)	Rx Sensitivity (dBm)	LOS Range (km)	Mass (g)	Dimensions (mm)	Cost (£)
Xbee-Pro 900HP	915	U.FL	215 @3.3V	29 @3.3V	+24	-101	15.5	42	32 x 22	41.66

Chosen Radio	Rationale
Xbee-Pro 900HP	• High Range • High Transmit (Tx) power • Good TX sensitivity • Previous Experience

NETID will be 4920.

Transmission will be handled within the FSW. GCS to Payload transmission will start on power on and stop on touchdown. Data will be transmitted every 1 s (**frequency** of 1 Hz) back to the GCS. Additionally, it will be saved locally to non-volatile memory. This will be burst transmission. **The XBEE will use direct addressing, not broadcasting.**

Payload Telemetry Format

Transmission format

Frame ID	Description	Example Value
<TEAM ID>	Unique assigned Team ID	4920
<MISSION TIME>	Time since power up of the payload in seconds	280
<PACKET COUNT>	number of transmitted packets which will be maintained even in the event of processor reset	59
<ALTITUDE>	altitude relative to ground level. Resolution 0.1m	103.3
<PRESSURE>	Atmospheric pressure in pascals. Resolution 0.1Pa	101358.5
<TEMP>	Measured temperature in degrees C. Resolution 0.1 degrees C	26.6
<VOLTAGE>	Voltage of CanSat power bus. Resolution 0.01V	5.02
<GPS TIME>	Time reported by GPS receiver, UTC time zone in seconds	12:38:47
<GPS LATITUDE>	Latitude reported by GPS receiver in decimal degrees. Resolution 0.0001 degrees	53.4851
<GPS LONGITUDE>	Longitude reported by GPS receiver in decimal degrees. Resolution 0.0001 degrees	-2.2748
<GPS ALTITUDE>	Altitude reported by GPS receiver in meters above mean sea level. Resolution 0.1m	103.3
<GPS SATS>	Number of GPS satellites being tracked, as reported by the GPS receiver. Integer number	5
<AIR SPEED>	The airspeed relative to the payload in meters/second	20.4
<SOFTWARE STATE>	Operating state of software. States include boot, idle, launch detection, deployed, landed	0 (idle)
<PARTICLE COUNT>	Decimal value showing the measured particle count in mg/m^3	0.025
<BONUS DIRECTION>	Current direction of camera relative to magnetic north as reported by magnetometer in degrees	30.1

Payload Telemetry Format

- Full Packet Makeup = <TEAM ID>,<MISSION TIME>,<PACKET COUNT>,<ALTITUDE>, <PRESSURE>,<TEMP>,<VOLTAGE>,<GPS TIME>,<GPS LATITUDE>,<GPS LONGITUDE>,<GPS ALTITUDE>,<GPS SATS>,<AIR SPEED>,<SOFTWARE STATE>,<PARTICLE COUNT>,<BONUS DIRECTION>

- Packet will be ASCII comma delimited format. Data rate of packets will be burst

- Sample telemetry packet:

  4920, 280,59, 103.3, 101358.5, 26.6, 5.02, 12:38:47, 53.4851, -2.2748, 103.3,5, 20.4, IDLE, 0.025, 30.1

Payload Telemetry Format

Receiving format

Frame ID	Description	Example Value
<TEAM ID>	Unique assigned team ID	4920
<TX START>	Transmission trigger	1

- Full Packet Makeup = <TEAM ID>, <TX START>
- Packet will be ASCII comma delimited format.
- When its idle,The Payload will be waiting for these commands from the GCS. Afterwards, it will no longer be listening.
- Example packet:
  4920, 1
- Transmission of the TX packet will only occur once.

Container Processor & Memory Selection

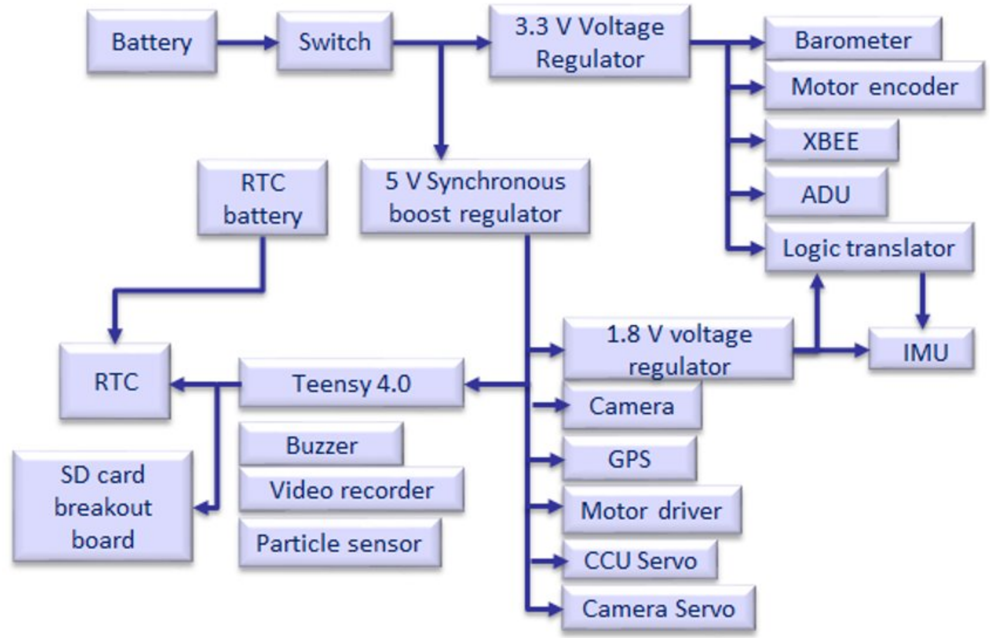
There will be no processor in the container.

Electrical Power Subsystem Design

Conor Shore

EPS Overview

Component	Function
RS PRO 6V dc	Buzzer
NEO M8N	GPS
BMP 388	Barometer
Qulit Fire 16340 3.7 Li-ion	Battery
GP2Y1014AU0F	Particle sensor
Runcam Nano 2	Camera (for the bonus)
ICM-20948	9-Axis IMU
HMDVR	Camera video recorder
Motor encoder	Camera bonus
Servo 1 4.8 g 180 degrees	Camera bonus
Servo 2 4.8 g 180 degrees	CCU mechanism
Teensy 4.0	MCU
XBEE 3 PRO	Radio
SD card breakout board	Interfacing SD card – for additional memory



The CanSat will be powered using only one Lithium-ion battery. The rationale for this choice is presented in the following slides.

Teensy 4.0 will act as the only MCU in the Payload. 5 V are required to power the component.

The system RTC will be powered by the MCU when MCU is on; when it is off or reseting it will be powered by an external battery.

The IMU requires 1.8 V, which will be supplied by another voltage regulator.

All the electronic components will be in the Payload, enclosed by the Payload cover. The Container will not have its own electronic components or enclose any of its own.

EPS Changes Since PDR

PDR	CDR	Rationale
No power multiplexer	Addition of a power multiplexer	To allow two power supplies to be connected simultaneously with an automatic switch over. This allows for an external power supply (USB) to be connected for testing and programming without draining or needing a battery.
PCB size at 48 mm x 30 mm	PCB Size at 57 mm x 35 mm	PCB has increased to fit in the extra components.

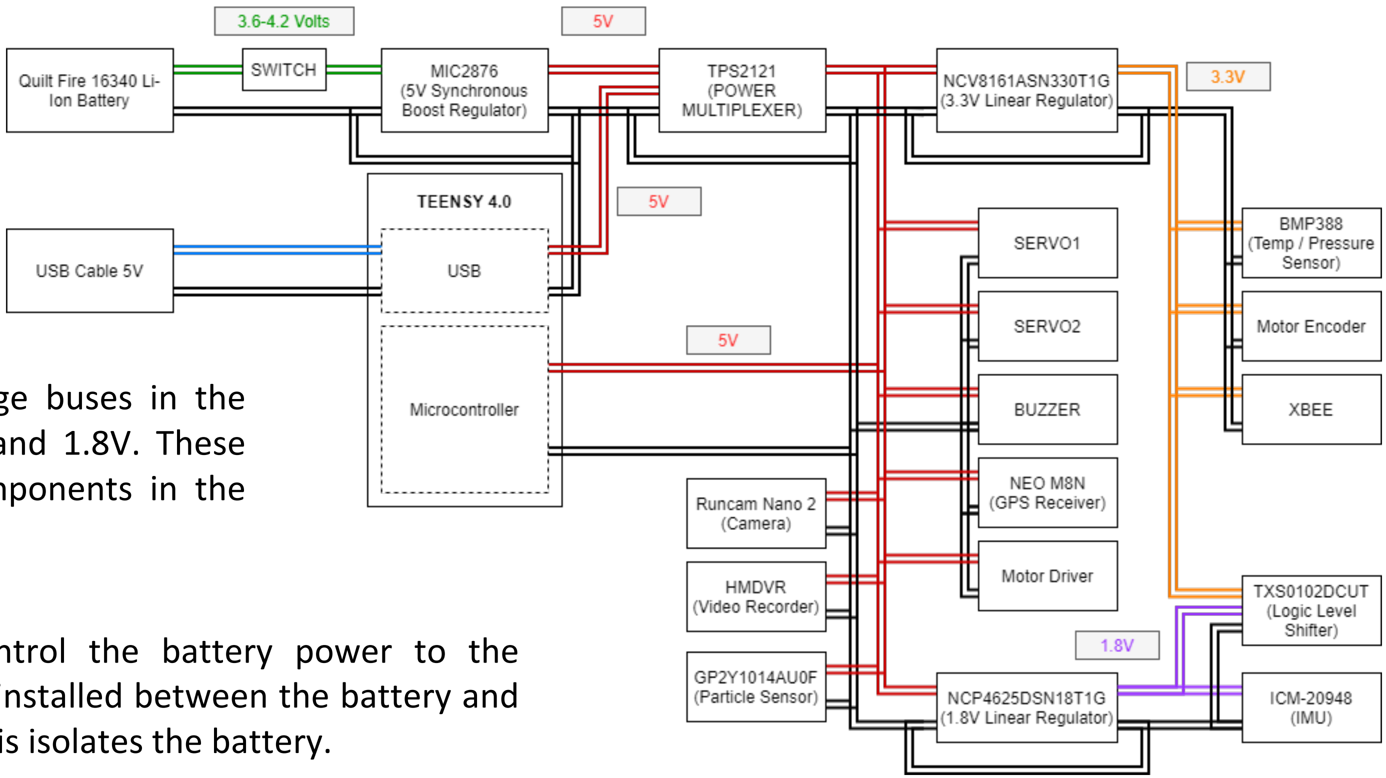
EPS Requirements

RE#	Requirement	Verification			
		A	I	T	D
1	Total mass of the CanSat (science payload and Container) shall be 600 grams +/- 10 grams.		X		X
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.		X		X
15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.		X		
18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.		X		
22	The science payload shall measure altitude using an air pressure sensor.		X	X	X
23	The science payload shall provide position using GPS.		X	X	X
24	The science payload shall measure its battery voltage.		X	X	X
25	The science payload shall measure outside temperature.		X	X	X
26	The science payload shall measure particulates in the air as it glides.		X	X	X
27	The science payload shall measure air speed.		X	X	X
35	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	X		X	
38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	X	X		
44	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.	X	X		X

EPS Requirements

RE#	Requirement	Verification			
		A	I	T	D
45	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.	X			X
48	No lasers allowed.		X		
49	The probe must include an easily accessible power switch that can be accessed without disassembling the cansat and in the stowed configuration.	X	X		X
50	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the cansat and in the stowed state.		X		
51	An audio beacon is required for the probe. It may be powered after landing or operate continuously.		X	X	X
53	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.		X		
54	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.	X	X		
55	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	X			X
56	The CANSAT must operate during the environmental tests laid out in Section 3.5.		X		
57	Payload/Container shall operate for a minimum of two hours when integrated into rocket.	X	X		
B1	Bonus : A video camera shall be integrated into the science payload and point toward the coordinates provided for the duration of the glide time. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the science payload is retrieved. Points will be awarded only if the camera can maintain pointing at the provided coordinates for 30 seconds uninterrupted.	X		X	X

Payload Electrical Block Diagram



There are 3 voltage buses in the system: 5V, 3.3V and 1.8V. These power all the components in the system.

To be able to control the battery power to the system, a switch is installed between the battery and the 5V regulator, this isolates the battery.

Umbilical cord: The system has two power supplies, the battery and the USB port of the TEENSY 4.0, the internal connection for the USB power to the microcontroller has been severed, this means that we can use USB port independently of the microcontroller. This allows for the power from the USB and the battery to pass through a power multiplexer. The power multiplexer prioritizes the USB power as to not discharge the battery unnecessarily.

Payload Power Source

Battery Name	Size (mm, L x Dia)	Mass (g)	Type	Voltage (V)	Capacity (mAh)	Price (£)	Max current (A)	Energy Consumption (Wh)
Qulit fire 16340 Li-ion Rechargeable	34 x 16	16	Li-ion	3.7	1400	4.99	1.4	5.18

The battery that is to be used is the Quilt fire 16340 Li-Ion rechargeable battery. This is a **single cell battery, configuration – 1p1s**.

Payload Power Budget

Component Name	Current (A)	Voltage (V)	Power (W)	Duty Cycle (%)	Duty Cycle (Hrs)	Duty hour (sec)	Required Capacity (W·h)
9-axis IMU	3.11×10^{-3}	1.8	5.6×10^{-3}	100	01:00:00	3600	11.2×10^{-3}
Barometer	3.4×10^{-6}	3.3	11.2×10^{-6}	100	01:00:00	3600	22.4×10^{-6}
GPS	0.023	5	0.115	100	01:00:00	3600	0.23
3.3 V Voltage regulator	18×10^{-6}	3.7	66.6×10^{-6}	100	01:00:00	3600	133.2×10^{-6}
1.8 V Voltage regulator	23×10^{-6}	5	115×10^{-6}	100	01:00:00	3600	230×10^{-6}
Synchronous boost regulator	109×10^{-6}	3.7	403×10^{-6}	100	01:00:00	3600	806×10^{-6}
2 x Servo 4.8g 180º	0.0612	5	0.306	100	01:00:00	3600	0.612
Buzzer	0.03	5	0.15	25	00:15:00	900	0.075
Teensy 4.0	0.1	5	0.5	100	01:00:00	3600	1
XBEE	0.229	3.3	0.7557	10	00:06:00	360	0.15114
ADU	0.003	3.3	0.01	100	01:00:00	3600	0.02

Payload Power Budget

Component Name	Current (A)	Voltage (V)	Power (W)	Duty Cycle(%)	Duty Cycle (Hrs)	Duty hour (sec)	Required Capacity (W·h)
Particle sensor	0.02	5	0.1	100	01:00:00	3600	0.2
Camera	0.11	5	0.55	10	00:06:00	360	0.11
Motor driver	0.85×10^{-3}	5	4.25×10^{-3}	100	01:00:00	3600	8.5×10^{-3}
Motor	0.07	5	0.35	10	00:06:00	360	0.07
Voltage level shifter	20×10^{-6}	3.3	6.6×10^{-5}	100	01:00:00	3600	13.2×10^{-5}
Video recorder	0.05	5	0.25	100	01:00:00	3600	0.5
Teensy 4.0 RTC	26×10^{-6}	3.3	85.8×10^{-6}	100	01:00:00	3600	171.6×10^{-6}
SD card breakout board	2×10^{-3}	3.3	6.6×10^{-3}	100	01:00:00	3600	0.0132

- All data was taken from components datasheets.
- Note : Servo current consumption was estimated combining servo being idle and servo operating.
- The only power source for the system is the selected battery. For the RTC an additional battery will be used when the Teensy is turned off.
- The total energy consumption is expected to be ***3.00 Wh for 2 hours (1.5Wh per hour)***, while the battery can supply ***5.18 Wh***. The margin is ***2.18 Wh,*** which is 42.1 % of the battery supply. **There will be enough power to supply the operation of the CanSat for more than 2 hours.**

Container Electrical Block Diagram

The Container will not contain any electronics, therefore no block diagram is required.

Container Power Source

The Container will not contain any electronics, therefore no power source is required.

Container Power Budget

The Container will not contain any electronics, therefore no power budget is required.

Flight Software (FSW) Design

Conor Shore

FSW Overview

Brief summary of the FSW tasks:

- **Throughout:** Collect data from sensors, GPS and camera, form data packets for transmission and save backup to SD card, ensure recovery in case of failure or reboot.
- **Launch Pad:** Calibrating sensors, setting up SP, ensuring working condition, detecting launch, starting the telemetry collection and transmission loop
- **Before Apogee:** Transmit telemetry
- **At Apogee:** Detect apogee and release of CanSat from rocket (and parachute release)
- **Above 450 metres:** Detect reaching 450 metres above ground
- **Below 450 metres:** Deploy SP from Container
- **Landed:** Detect landing, turn on buzzer and switch off other components

Bonus objective:

- A video camera will be integrated into the science payload and point toward the coordinates provided by the GPS for the duration of the glide time.

FSW Overview

Language:

C++ is the main language of development

- **Encapsulation:** The ability to store different functions into specific structs or classes. Thus the code will be easier to be understood by all team member.
- **Low level:** It gives us the ability to manipulate variables and function via pointers to the memory address.
- **Light weight:** C++ follows a philosophy where only the important metadata is stored.

Development environment:

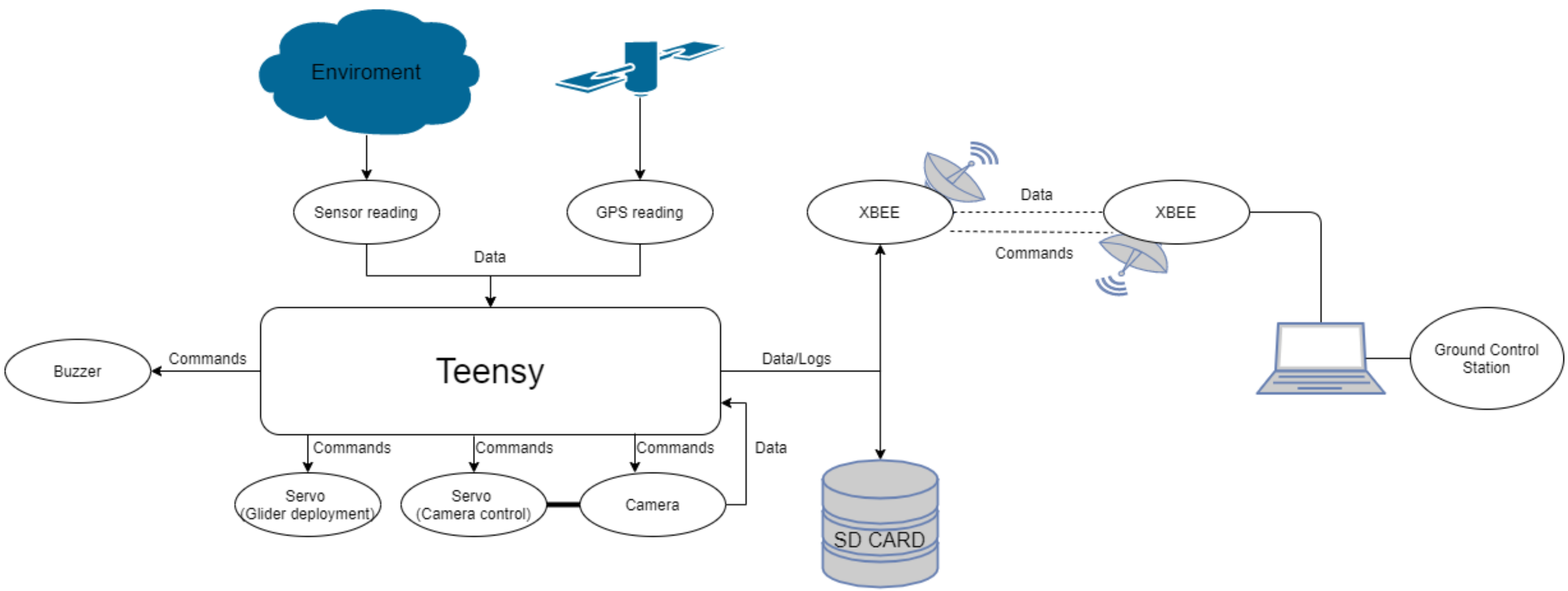
Arduino IDE for Teensy 4.0

- **Community support:** The Arduino project has a lot of community backing, making it easy to troubleshoot common problems.
- **Library friendly**: It allows for easy implementation of pre-existing libraries or even custom ones.

FSW Overview

Basic FSW architecture:

The basic FSW architecture has remained the same since the PDR. We have observed it to be quite advantageous and it fufills all the requirements of the Competition.



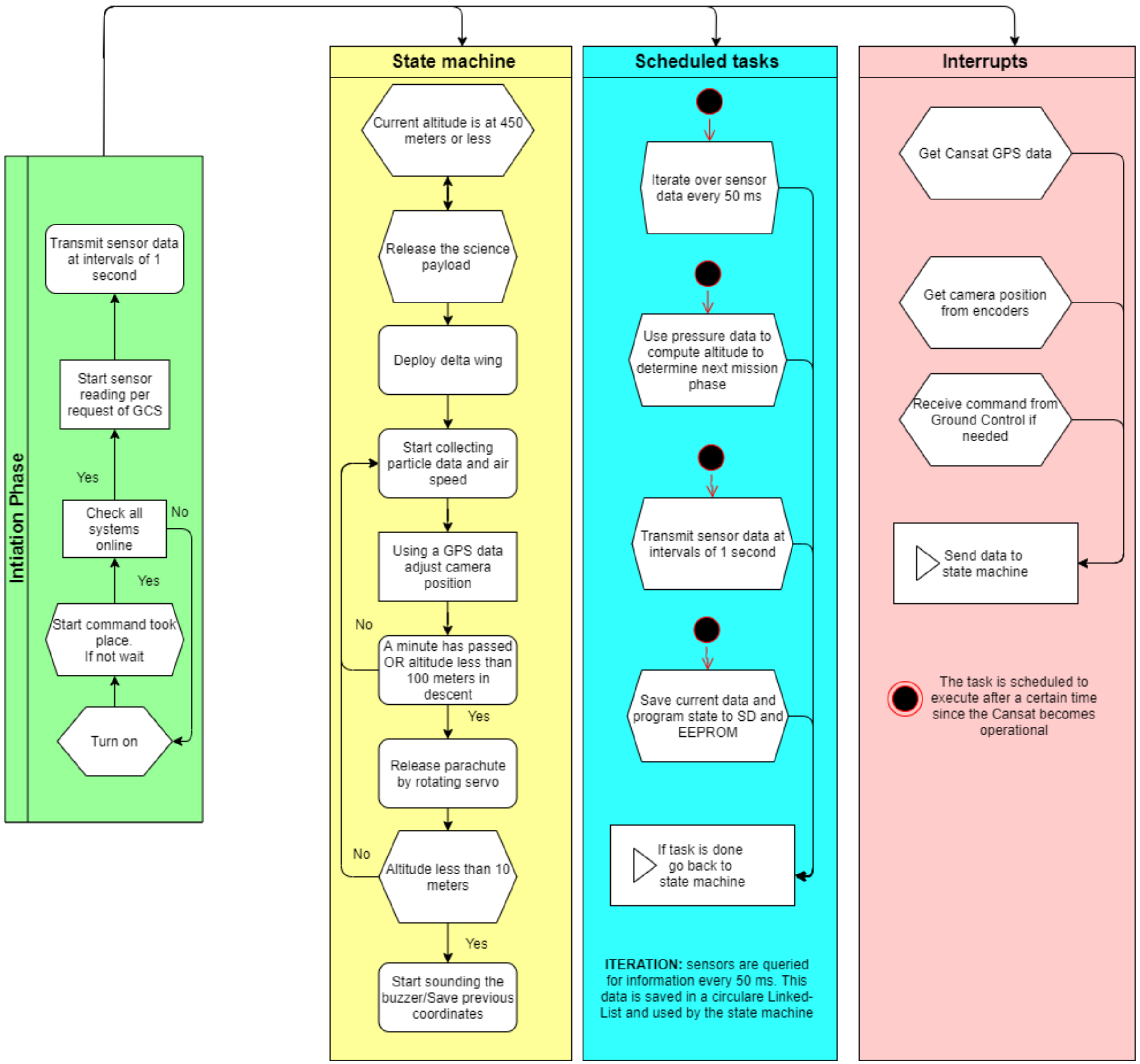
FSW Changes Since PDR

No changes to the FSW Subsystem have been made since the PDR.

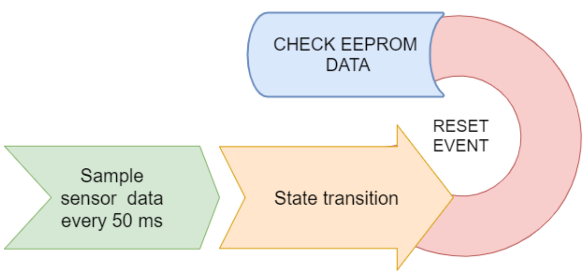
FSW Requirements

RE#	Requirement	Verification			
		A	I	T	D
23	The science payload shall provide position using GPS.	X	X	X	X
24	The science payload shall measure its battery voltage.	X	X	X	X
28	The science payload shall transmit all sensor data in the telemetry.	X	X		X
29	The science payload shall transmit all sensor data in the telemetry.	X	X	X	
33	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.	X	X	X	X
34	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	X	X	X	
47	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.	X	X	X	X
48	No lasers allowed.	X			X
50	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the cansat and in the stowed state.	X	X	X	
51	An audio beacon is required for the probe. It may be powered after landing or operate continuously.		X	X	X
25	The science payload shall measure outside temperature.	X	X	X	X
22	The science payload shall measure altitude using an air pressure sensor	X	X	X	X
26	The science payload shall measure particulates in the air as it glides.	X	X	X	X
27	The science payload shall measure air speed.	X	X	X	X
B1	Bonus : A video camera shall be integrated into the science payload and point toward the coordinates provided for the duration of the glide time. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the science payload is retrieved. Points will be awarded only if the camera can maintain pointing at the provided coordinates for 30 seconds uninterrupted.	X		X	X

Payload CanSat FSW State Diagram



RECOVERY: During the operation of the CanSat a processor reset might be caused by a short circuit or a one of the electrical motors drawing too much power.
In the case of reset, data will be saved in the EEPROM after every measurement and state transition, thus in case of processor reset the state of the FSW can be brought back.



Payload CanSat FSW State Diagram

Power Management:

The CanSat is in an idle state when turned on until it receives a command to start calibration and to get ready for launch. Since during this idle time no sensors are needed, the power consumption is lowered.

Container CanSat FSW State Diagram

There are no electronics in the Container. There is no processor, hence no flight software, in the Container. Thus a Container FSW state diagram is unnecessary.

Software Development Plan

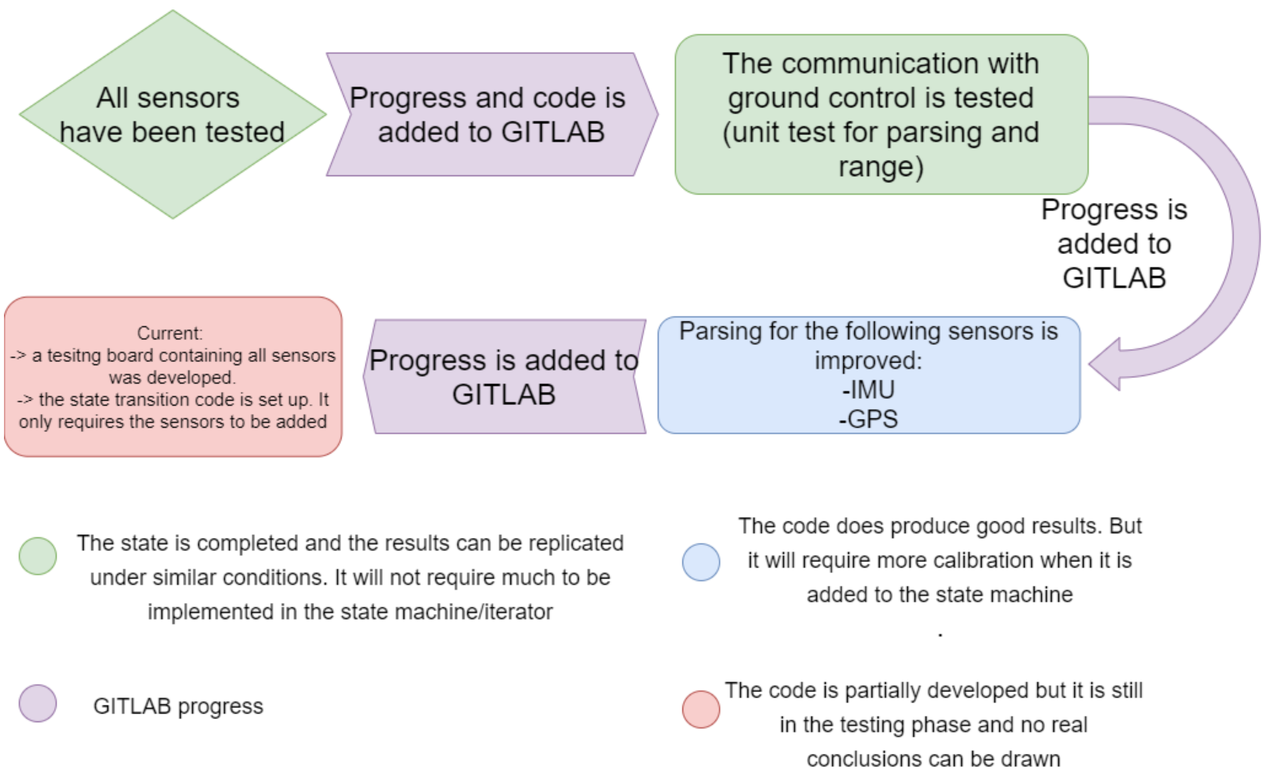
FSW Development Team: *MR, GA, TP, MD*

GITLAB will be the platform used to keep track of the development cycle.

The Software development will be divided into the:

- Flight Software branch
- Ground Control Station branch

Once the Software has been completed for each branch the two will be merged on the master branch creating a deployable FSW/GCS package.



Prototyping: will be done whenever possible using the components in isolation or in combination with others.

Divide work: work is divided into the two main branches. For further subdivisions different branches will be made with appropriate name of their main branch and given task. Example: FSW-StateMachine

In the case of problems arising: It will be possible to revert to a previous version from GitLab. Thus we avoid breaking dependent systems.

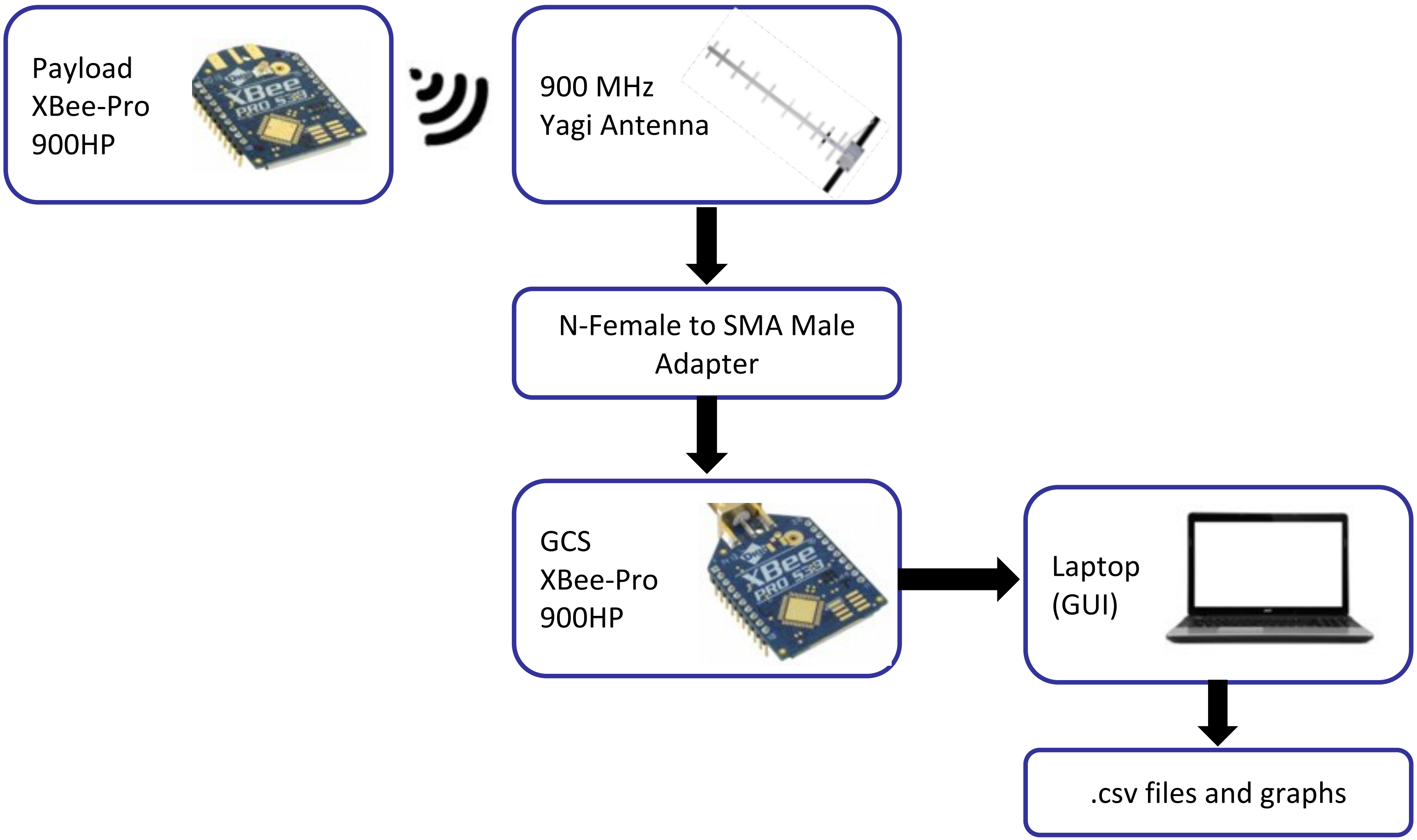
Prototyping environments: Before integration, some parts of the code like the State-Machine or the Sensor Iterator have undergone Unit-Testing

Progress since PDR: Code is partially developed, in testing phase

Ground Control System (GCS) Design

Conor Shore

GCS Overview



GCS Changes Since PDR

No changes to the GCS Subsystem have been made since the PDR.

GCS Requirements

RE#	Description	Verification			
		A	I	T	D
29	Telemetry shall be updated once per second.	x		x	x
31	The ground system shall command the science vehicle to start transmitting telemetry prior to launch.	x		x	x
32	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.			x	x
33	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.	x		x	x
34	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.	x		x	x
35	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.		x		
36	XBEE radios shall have their NETID/PANID set to their team number		x	x	x
37	XBEE radios shall not use broadcast mode.	x	x		
38	Cost of theCanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	x	x		
39	Each team shall develop their own ground station.				x

MANCHESTER CANSAT PROJECT

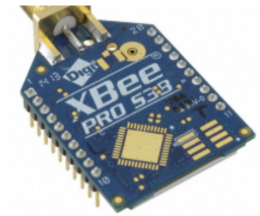
GCS Requirements

RE#	Description	Verification A	I	T	D
40	All telemetry shall be displayed in real time during descent.			x	x
41	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		x		x
42	Teams shall plot each telemetry data field in real time during flight.			x	x
44	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		x		
45	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.		x		
46	Both the container and probe shall be labeled with team contact information including email address.				x
56	The CANSAT must operate during the environmental tests laid out in Section 3.5.			x	x
57	The CANSAT must operate during the environmental tests laid out in Section 3.5.		x		

GCS Design

GCS Antenna

N-Female to SMA Male Adapter



GCS XBee-Pro 900 HP

Cable

GCS Laptop

Specifications	
Laptop Battery	3 hours from fully charged
Overheating mitigation	Sun shielding umbrella
	Laptop cooling pad
Auto update mitigation	Disable auto-update
	Disable Internet Connection

GCS Software

The team has developed their own Ground Control Station.
The GCS code was finished at the PDR stage – no progress to report.

Commercial Off The Shelf (COTS) Software Packages:

Python 2.7.15 - Computational environment of choice
XCTU – XBee Program Software
XBEE Python Library – real time access to XBee via USB interface
Matplotlib Python Library – real time plotting and data manipulation
SKlearn Python Library – simple data filtering and post-processing features

Command Software and Interface:

Commands (calibration commands) can be sent from the Ground Control Station to the CanSat via command.
The GCS uses the XBEE Python Library to access the XBee receiver through the USB interface.

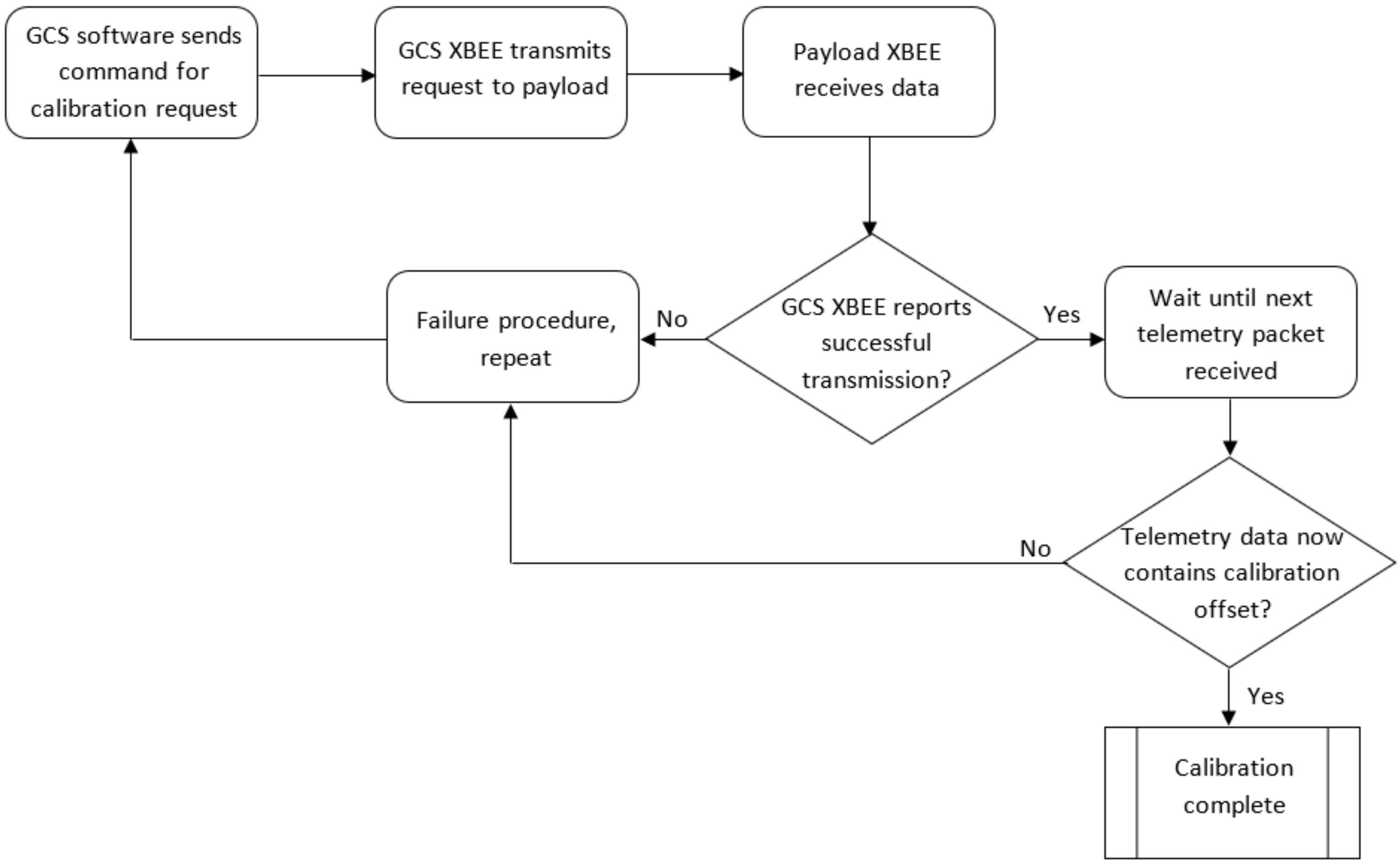
Telemetry Data Recording:

Telemetry will be recorded in a .csv file without processing after being read via USB interface.
.csv data will be analyzed in Python to present in PFR.

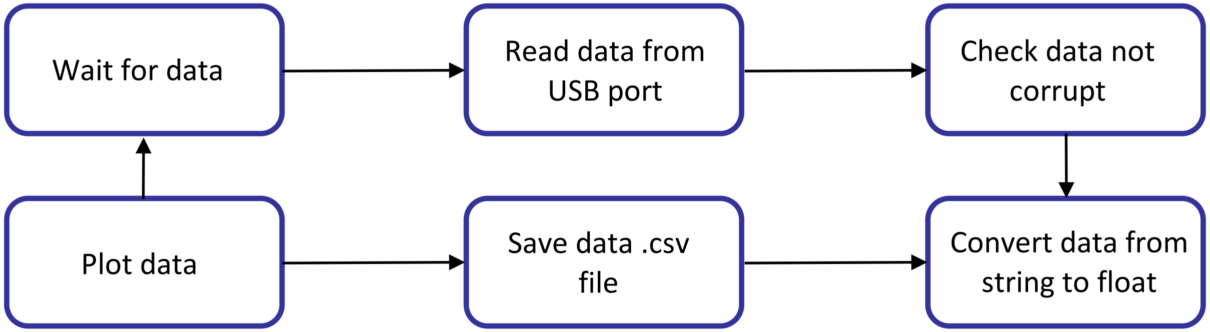
CSV File Generation:

.csv file will be generated in GCS Python software and data will be continuously appended to the file as it arrives in packets to GCS.

GCS Software



GCS Software




```python
while True:

    time1 = time.time()

    while (serial_stuff.inWaiting()==0):
        #break
        pass #do nothing
    xbee = XBee(serial_stuff)
    response_full = xbee.wait_read_frame()
    response_payload = response_full['rf_data']
    response_payload = response_payload.decode('utf-8')
    response_array = response_payload.split(',')
    log_target.write(response_payload)
    log_target.write("\n")
    print(response_array)

    if (len(response_array) == 16):
        time2 = time.time()
        convert_and_append(response_array)
        time3 = time.time()
        drawnow(makeFig)
        plt.pause(.001)
        time4 = time.time()

        # print for checking
        print("1-2:")
        print(time2-time1)
        print("2-3:")
        print(time3-time2)
        print("3-4:")
        print(time4-time3)

        k += 1

    if (k>12):
        team_id.pop(0)
        mission_time.pop(0)
        packet_count.pop(0)
        altitude.pop(0)
        pressure.pop(0)
        temp.pop(0)
        voltage.pop(0)
        gps_time.pop(0)
        gps_latitude.pop(0)
        gps_longitude.pop(0)
        gps_altitude.pop(0)
        gps_sats.pop(0)
        air_speed.pop(0)
        software_state.pop(0)
        particle_count.pop(0)
```

GCS Architecture

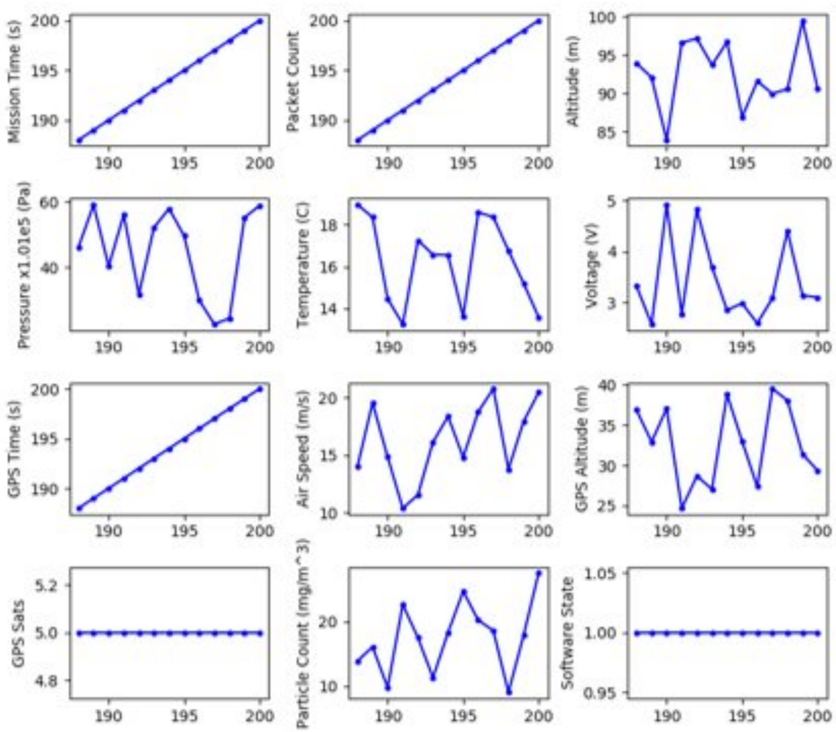
- Flowchart above
- Implementation in Python on the right
- cvs. log file of test data from unit testing below

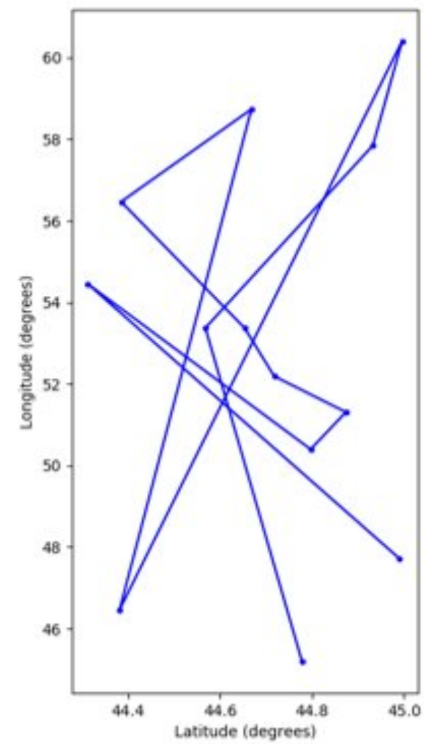
TEAM ID	MISSION TIME	PACKET COUNT	ALTITUDE	PRESSURE	TEMPERATURE	VOLTAGE	GPS TIME	GPS LATITUDE	GPS LONGITUDE	GPS ALTIUDE	GPS SATS	AIR SPEED	STATE	PARTICLE COUNT	PITCH	ROLL	CAMERA ANGLE
4920	8	0	93	213000	130	32	0	32.1826	-98.2647	93.458	7	338.044	ASCENDING	0.0041	124.232	-52.2494	70
4920	108	1	94	213000	129	31	100	32.0546	-98.2262	94.1083	7	507.016	ASCENDING	0.0144	114.566	-52.8731	70
4920	208	2	94	212000	128	31	200	32.186	-98.2651	94.735	9	338	ASCENDING	0.0059	105.212	-53.4967	71
4920	308	3	94	212000	127	30	300	32.0535	-98.2253	94.5724	7	511.004	ASCENDING	0.0145	96.4811	-54.1203	71
4920	408	4	95	212000	127	29	400	32.0974	-98.2176	95.2251	7	568.655	ASCENDING	0.0093	87.7506	-54.7439	71
4920	508	5	95	211000	126	29	500	32.0451	-98.2009	95.5171	7	677.145	ASCENDING	0.0162	79.3318	-55.3675	71
4920	608	6	95	211000	125	28	600	32.1476	-98.2339	95.3456	7	480.105	ASCENDING	0.0183	71.2249	-55.6793	72
4920	708	7	96	211000	125	28	700	32.1008	-98.2192	96.4919	9	555.541	ASCENDING	0.0242	63.7416	-55.9911	72
4920	808	8	96	210000	124	27	800	32.1876	-98.2461	96.6998	7	435.718	ASCENDING	0.0105	56.2584	-56.3029	72
4920	908	9	97	210000	123	27	900	32.1381	-98.2305	97.9496	7	492.709	ASCENDING	0.0117	49.0869	-56.3029	72
4920	1008	10	97	210000	123	26	1000	32.137	-98.2911	97.6929	7	157.487	ASCENDING	0.0183	42.539	-56.6147	73
4920	1108	11	97	210000	123	26	1100	32.0529	-98.2911	97.0704	9	50.04	ASCENDING	0.0033	35.9911	-56.6147	73
4920	1208	12	98	209000	122	25	1200	32.1542	-98.2331	98.6832	7	482.437	ASCENDING	0.0189	29.755	-56.6147	73
4920	1308	13	98	209000	122	25	1300	32.2411	-98.2295	98.8217	9	578.8	ASCENDING	0.001	23.5189	-56.6147	73
4920	1408	14	98	209000	121	24	1400	32.1448	-98.2914	98.1914	7	168.134	ASCENDING	0.0172	17.9065	-56.6147	74
4920	1508	15	99	208000	121	24	1500	32.0529	-98.2914	99.4753	9	44.1814	ASCENDING	0.024	12.294	-56.3029	74
4920	1608	16	99	208000	121	23	1600	32.0813	-98.2128	99.5039	9	585.888	ASCENDING	0.0234	7.30512	-56.3029	74
4920	1708	17	100	207000	121	23	1700	32.0434	-98.2009	100.406	9	665.364	ASCENDING	0.0145	2.31626	-55.9911	74
4920	1808	18	100	207000	121	22	1800	32.1548	-98.2328	100.569	9	478.351	ASCENDING	0.0058	-2.67261	-55.6793	74

MANCHESTER CANSAT PROJECT

GCS Software

Telemetry display screen shots are shown below.





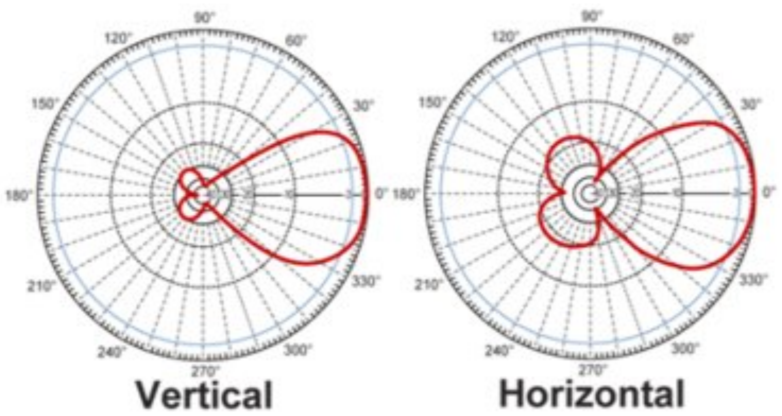
All x-axis units are in seconds.

GCS Antenna

Device Chosen	Rationale
900 MHz 9 dBi SS YagiAntenna SMA Male Connector	The largest horizontal beam width.

Gain	VSWR	Connector	Beam width horizontal/vertical	Polarization	Cost (£)
9dBi	≤1.5	SMA Male	54˚/48˚	Vertical/horizontal	65.24

Selected antenna radiation and gain patterns:



Distance Link Predictions and Margins:

- Range must still to be tested further under controlled conditions
- Margins must still be tested

Ideal Conditions Predicted Range: 11 km

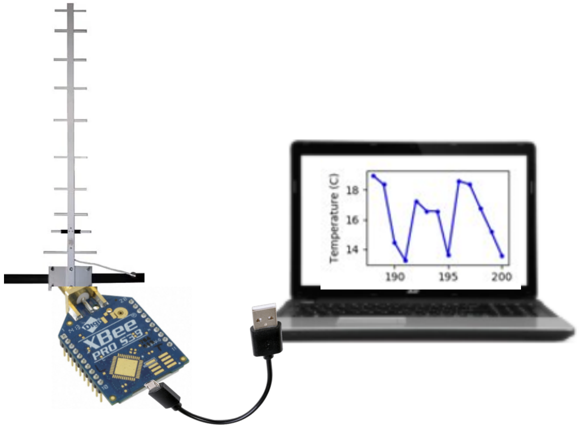
Predicted Margin:

- Range estimation is based on the Friis transmission equation with a -20 dBm link margin and optimal projection angle.

GCS Antenna

Compliance with hand-held requirement:

Antenna construction:



Antenna mounting design:

To ensure that connection between the antenna and GCS XBee is as short as possible (to reduce effect of noise), the XBee will be mounted on the antenna/boom and connected to the GCS Laptop by a long USB cable.

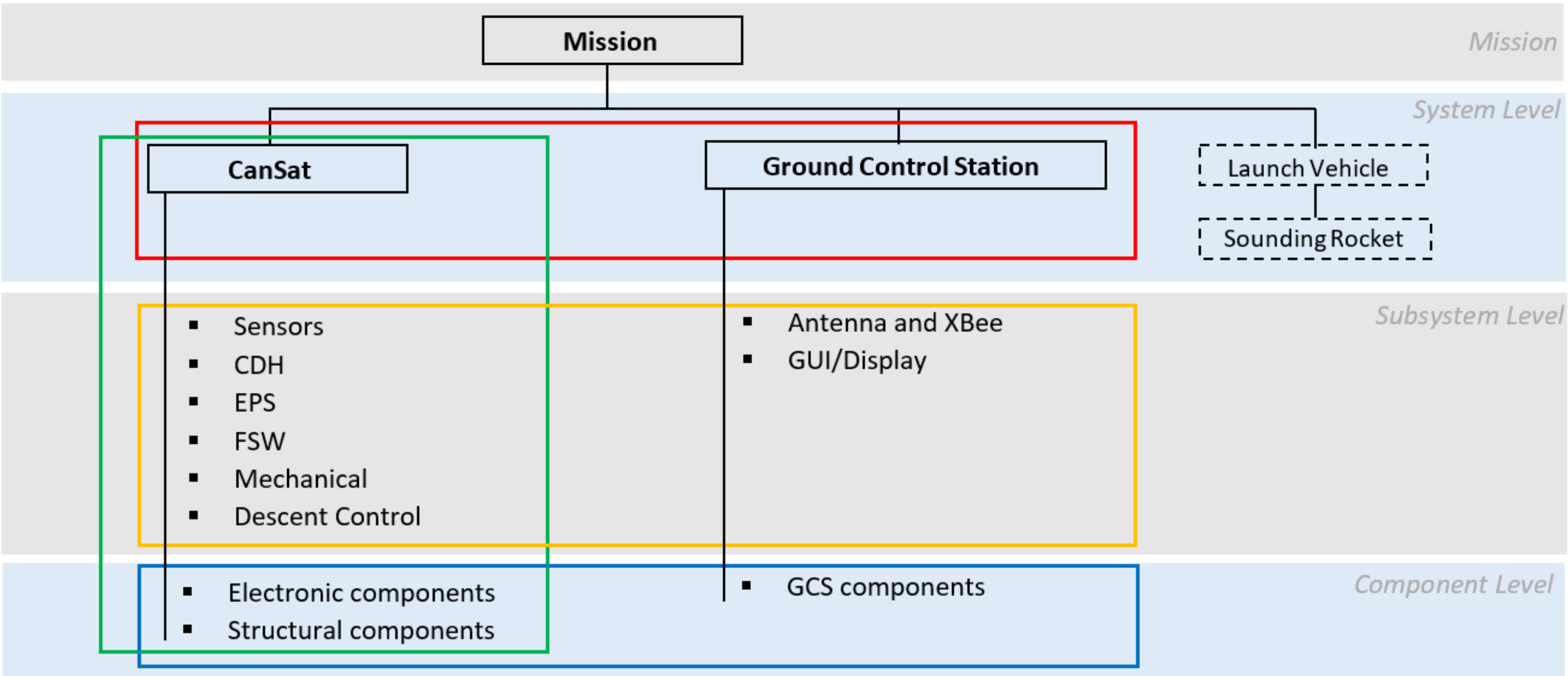
Antenna will be mounted on a wooden pole, as shown in the image above. This method was used in previous years and was found to be appropriate.

CanSat Integration and Test

Conor Shore

CanSat Integration and Test Overview

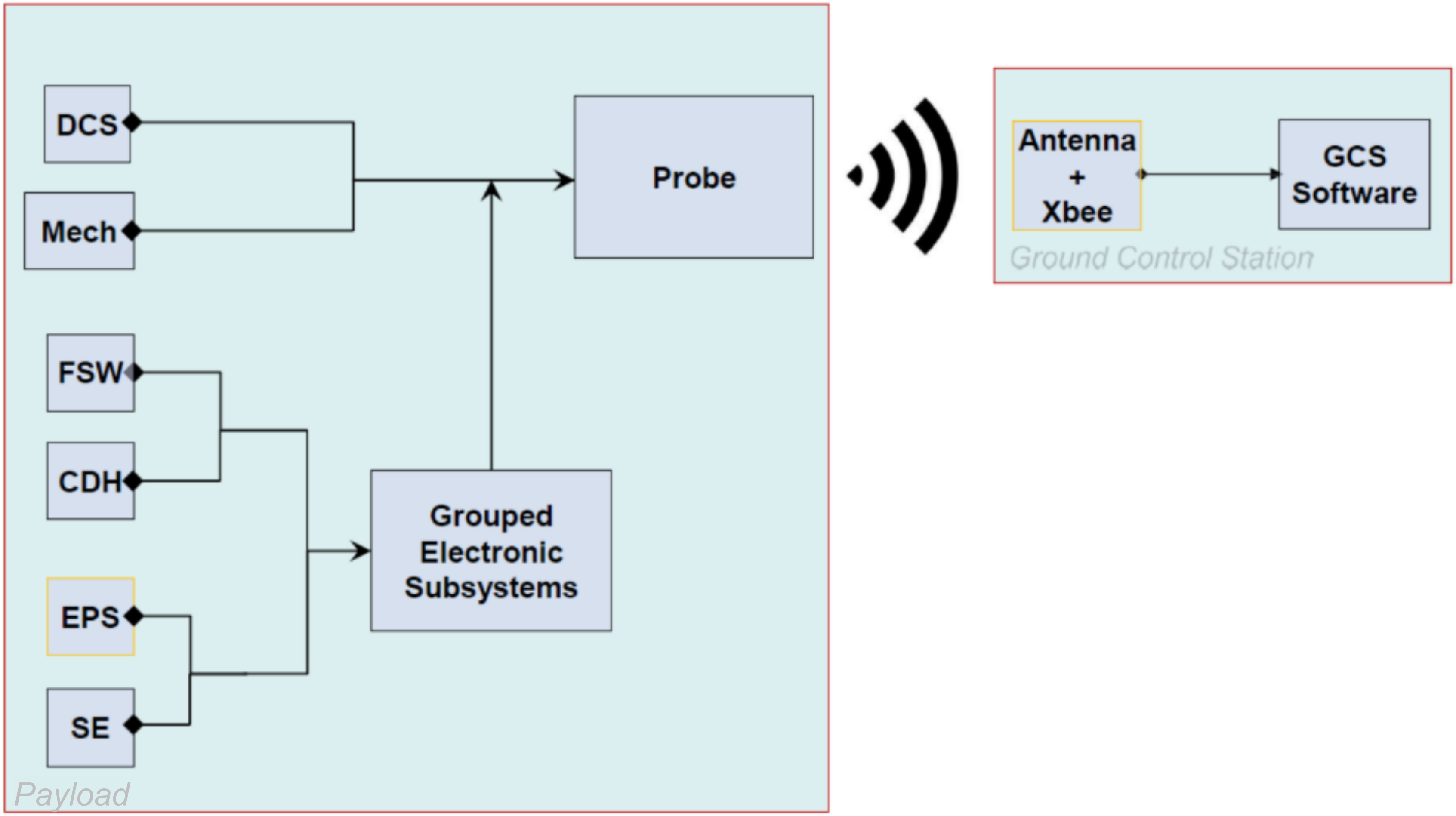
Mission integration and testing overview



Legend:
- Component Level Testing Plan (blue)
- Subsystem Level Testing Plan (yellow)
- Integrated Functional Level Testing Plan (red)
- Environmental Testing Plan (green)

CanSat Integration and Test Overview

Subsystem integration plan:



Subsystem Level Testing Plan

Subsystem	Testing description
SENSORS	Verify all sensors are correctly calibrated and configured for their respective functions
	Verify each sensor's range, resolution, sampling rate is as required to provide valid data at a rate of at least 1Hz
	Verify collected data is in suitable format for FSW
	BONUS: Check camera maintains directions towards coordinates when spinning
EPS	Verify power source provides required power level (current and voltage)
	Verify voltage divider provides required voltage to all components
CDH	Verify radio can be configures to transmit as required: burst or continuous transmission, API mode (not broadcast), correct PAN ID, correct team ID, correct packet
	Verify real time clock can retain data following system power loss
	Verify SD card can store the maximum expected volume of data (maximum telemetry packet size multiplied by maximum number of seconds)
	Verify data stored on SD card is presented correctly and can be analyzed.
	Verify full telemetry packet is transmitted correctly by the radio module at a rate of 1 Hz
	Verify microcontroller regains correct function and retains mission data (correct mission time using RTC) following power loss

Subsystem Level Testing Plan

Subsystem	Testing description
GCS (RADIO COMMUNICATIONS)	Verify GCS computer is suitable for competition final: portable, battery life is suitable for maximum expected mission time (>2 hours), with XBee radio and antenna assembly
	Verify GCS software is compatible with GCS computer
	Verify serial communication can be established between antenna and GCS computer
	Verify GCS can plot/present live data in real time during descent in SI units
	Verify GCS can send a command to start transmission.
FLIGHT SOFTWARE	Verify with each software design iteration that programming language, functions, libraries are compatible with chosen microcontroller
	Verify software state is valid and well defined at every conceivable point in mission sequence, including environmental variations
	Verify all FSW successfully counts the number of packets transmitted, including following power loss
MECHANICAL	Verify that in the event of component design iteration that resulting change in system specifications (e.g. dimensions, weight) is compliant with requirements
	Verify all materials, structures and mechanisms can withstand forces on the constructed CanSat

Subsystem Level Testing Plan

Subsystem	Testing description
DESCENT CONTROL	Verify that in the event of component design iteration that resulting change in system specifications (e.g. dimensions, weight) is compliant with requirements
	Verify passive control (all comprising materials, the interfaces between them and payload attachment components) can withstand forces required to provide required descent rate
	Verify parachute (all comprising materials, the interfaces between them and container attachment components) can withstand forces required to provide required descent rate
	Verify the glider maintains descent in a circular pattern within the radius of 250 m.
	Verify that assembled CanSat has no sharp edges.
	Verify that CanSat with clearances complies with rocket dimensions.
MECHANISMS	Verify CCU functions properly with wing and parachute deployment and does not become obstructed in any situation
	Verify camera mechanisms function properly with wing and parachute deployment and do not become obstructed in any situation

Integrated Level Functional Test Plan

Subsystem	Testing description
PAYLOAD: ENTIRE MISSION	Verify buzzer is of sufficient volume to help indicate the location of the payload following landing
	Verify battery compartment can be removed in less than 1 minute without total CanSat disassembly
	Verify full set of sensor data can be acquired at the required sampling rate simultaneously
	Verify power requirements are satisfied for the full mission sequence and maximum predicted mission time
	Verify that when code from Sensors, CDH and GCS subsystem are integrated the microcontroller has sufficient memory
	Verify fully assembled CanSat system weights within 10 g of 600 g
	Verify the glider release mechanism is activated within 10 m of 450 m
	Verify parachute deployment mechanism occurs 1 minute after glider release
	Verify all electronic components except sensors are fully enclosed when assembled
	Verify power switch is easily accessible and reliably activated the system

Integrated Level Functional Test Plan

Subsystem	Testing description
RELEASE TRIGGER	Verify triggering the CCU to release the payload from the container
	Verify CCU glider release and deployment mechanism performs as expected as part of the constructed CanSat structure
DESCENT CONTROL	Verify that with container parachute deployed the CanSat (container + glider) descents at the required descent rate
	Verify center of pressure of the payload is well above center of gravity to ensure stable descent
	Verify that the glider deploys at the required descent rate
MECHANISMS	Verify CCU glider release and deployment mechanism survive required force limits
	Verify CCU glider release and deployment mechanism performs as expected as part of the constructed CanSat structure and the glider is released without impedance
	BONUS: verify camera can be activated by the FSW
PAYLOAD PARACHUTE RELEASE	Verify parachute stays attached to the payload due to expected forces
	Verify CanSat can be easily identified from a distance by using fluorescent covers and parachutes
COMMUNICATIONS: GCS	Verify GCS software handles live data from antenna + XBee and plots it in real time in SI units
	Verify antenna receives data from assembled CanSat at and above the required range
COMMUNCATIONS: CDH	Verify full live telemetry transmission is of the current form for reception at the GCS
	Verify telemetry is updated once per second.

Environmental Test Plan

Subsystem	Testing description
VIBRATION TEST – CANSAT	CanSat is fixed to an orbit sander to provide up to 14,000 rpm of rotation equivalent to 233 Hz of vibration, to expose failure of CanSat structures/components if they vibrate at resonance.
THERMAL TEST – CANSAT	Fully assembled CanSat is placed in controlled thermal chamber and heated to ~60˚C while systems are active. This is conducted for 3 hours.
15 G LAUNCH ACCELERATION TEST – CANSAT	Fully assembled CanSat is placed in a sounding rocket for a test launch to simulate launch conditions. This means the integrity of the glider, its deployment mechanism, and container attachment subsequent to launch can be verified. This acceleration can be verified with the accelerometer within the Sensors subsystem.
>30 G DROP TEST – PAYLOAD	Whole assembled CanSat with parachute deployed is subjected to a drop from 61 cm with a cord attachment to result in a 30 G shock or greater acceleration, to simulate rocket body separation forces. This acceleration can be verified with accelerometer within the Sensors subsystem.
DIMENSIONS VERIFICATION – CANSAT	Fully assembled CanSat is subject to a fit check using a sheet of plywood with a hole of diameter 125 mm and another with dimensions of 310 x 125mm, to ensure clearances.

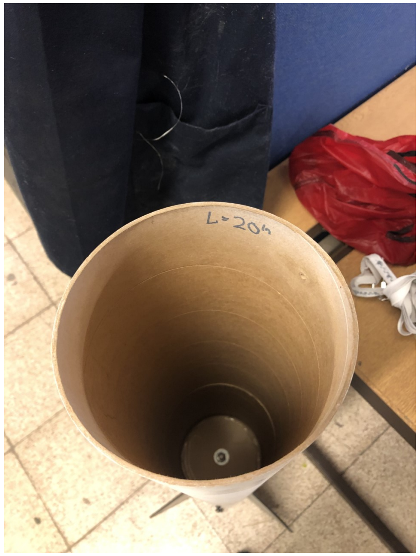
Environmental Test Plan

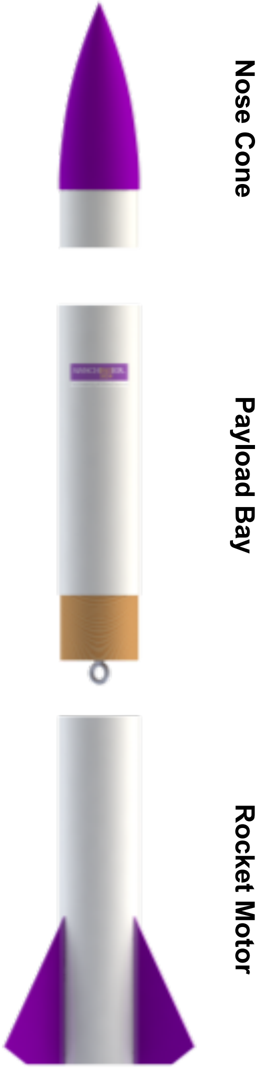
Subsystem	Testing description
WIND TUNNEL TEST	An Open Circuit Wind Tunnel test had been booked prior to the Covid-19 closure of all the University facilities. The tunnel is 1.2 m long, 0.9 m high and 2.0 m large and the airflow can reach a maximum speed of 50 m/s. A full-scale prototype of the glider's frame was 3D printed with the purpose of validating the aerodynamic quantities calculated analytically in the PDR. In fact, the wind tunnel test would have shown at which point the flow separates over the wing chord, over a range of angles of attack. The lift to drag ratio, would have also been investigated to determine whether the design needed to be modified. Moreover, the effect of the outer structure to accommodate for the camera would have been physically observed.
TEST LAUNCH	Verify compliance of both integrated functional level tests and environmental tests by launching the CanSat using a LocPrecision Minie-Magg sounding rocket, with a 20-inch Payload bay.

Environmental Test Plan

System-Level Environmental Testing: Test Launches

- Test launches allow the team to test the integrated system under launch conditions, verifying compliance of both integrated functional tests and environmental tests.
- The crucial advantage of a test launch is to carry out all environmental tests simultaneously, to ensure the payload, electronics, structures and mechanisms can perform on launch day.
- MCP planned to perform a test launch on 1st of April, 2020, using a LocPrecision Minie-Magg sounding rocket, with a 20-inch Payload bay. However this test was cancelled due to the COVID-19 nationwide lockdown.
- MCP was planning to carry out one further test launch on 10th of May 2020, which has also been cancelled.





Test Procedures Descriptions

Subsystem Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
SENSORS				
1	E	Verify all sensors are correctly calibrated and configured for their respective functions	22,23,24, 25,26,27	Sensors can provide correctly calibrated measurements of known values
2	E	Verify each sensor's range, resolution, sampling rate is as required to provide valid data at a rate of at least 1Hz	28	Sensors can provide valid data at 1Hz and can fulfill requirements
3	V	Verify collected data is in suitable format for FSW	28	Data should be in FSW compatible format
4	E	BONUS: Check camera maintains directions towards coordinates when spinning	BONUS	Verify that servo/FSW corrects the angle to correct coordinates when spinning
EPS				
5	V	Verify power source provides required power level (current and voltage)	-	5V and 3.3V supplies should not drop below 10% of nominal value during full load for more than 5ms
6	S, V	Verify voltage divider provides required voltage to all components	-	Microcontroller's ADC correctly coverts input voltage to a float value used within FSW

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Subsystem Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
CDH				
7	V	Verify radio can be configures to transmit as required: burst or continuous transmission, API mode (not broadcast), correct PAN ID, correct team ID, correct packet	32,33, 36,37	Test packets with these parameters are sent from XBee to XBee
8	E	Verify real time clock can retain data following system power loss	33	After removing DC power to RTC time information is retained when DC power is regained
9	S, V	Verify SD card can store the maximum expected volume of data (maximum telemetry packet size multiplied by maximum number of seconds)	-	From calculated data rate, the card's size should greatly exceed that of the data rate times the estimated mission time. Can be verified experimentally at test launch.
10	E	Verify data stored on SD card is presented correctly and can be analyzed.	-	Data confirms to telemetry requirements and is not corrupted post launch
11	V	Verify full telemetry packet is transmitted correctly by the radio module at a rate of 1 Hz	28	XBee can send a test packet at 1Hz
12	E	Verify microcontroller regains correct function and retains mission data (correct mission time using RTC) following power loss	33, 34	Upon microcontroller restart, the transmitted data stream should be contiguous with respect to time and packet count

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Subsystem Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
GCS (RADIO COMMUNICATIONS)				
13	V	Verify GCS computer is suitable for competition final: portable, battery life is suitable for maximum expected mission time (>2 hours), with XBee radio and antenna assembly	44,45	GCS computer qualifies for use on launch day
14	V	Verify GCS software is compatible with GCS computer	40,41,42	GCS software runs as required when used on GCS computer
15	E	Verify serial configuration can be established between antenna and GCS computer	40,41,42	Dummy telemetry can be received by the GCS software via antenna and XBee
16	E	Verify GCS can plot/present live data in real time during descent in SI units	41	Verify in accordance with telemetry format requirements
17	E, V	Verify GCS can send a command to start transmission.	31	Check the command is received
FLIGHT SOFTWARE				
18	V	Verify with each software design iteration that programming language, functions, libraries are compatible with chosen microcontroller	-	FSW uploads correctly to microcontroller
19	E	Verify software state is valid and well defined at every conceivable point in mission sequence, including environmental variations	34	FSW starts in a valid state at all times

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Subsystem Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
FLIGHT SOFTWARE (CONTINUED)				
20	E	Verify all FSW successfully counts the number of packets transmitted, including following power loss	47	Mission data is stored throughout power loss
MECHANICAL				
21	V	Verify that in the event of component design iteration that resulting change in system specifications (e.g. dimensions, weight) is compliant with requirements	-	New design retains compliance
22	S, E	Verify all materials, structures and mechanisms can withstand forces on the constructed CanSat	-	CanSat structure and materials can withstand forces in theory and are intact after testing
DESCENT CONTROL				
23	S, V	Verify that in the event of component design iteration that resulting change in system specifications (e.g. dimensions, weight) is compliant with requirements	-	New design retains compliance
24	E	Verify passive control (all comprising materials, the interfaces between them and payload attachment components) can withstand forces required to provide required descent rate	-	Passive control retains function during simulated descent

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Subsystem Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
DESCENT CONTROL				
25	E	Verify parachute (all comprising materials, the interfaces between them and container attachment components) can withstand forces required to provide required descent rate	-	Parachutes remain intact during simulated descent
26	S	Verify the glider maintains descent in a circular pattern within the radius of 250 m.	11	Radius maintained during descent
27	S, V	Verify that assembled CanSat has no sharp edges.	3	Sharp edges not present
28	S, V	Verify that CanSat with clearances complies with rocket dimensions.	2	Ensure CanSat passes through templates
MECHANISMS				
29	S, V	Verify CCU functions properly with wing and parachute deployment and does not become obstructed in any situation	10	CCU mechanism works properly in when manually tested
30	S, V	Verify camera mechanisms function properly with wing and parachute deployment and do not become obstructed in any situation	BONUS	Camera mechanism works properly in when manually tested

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Integrated Functional Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

In this section, the integrated systems are split into:

- Payload: entire mission
- Payload: pre-glider release
- Payload: post-glider release
- Communications: GCS
- Communications: CDH

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
PAYLOAD: ENTIRE MISSION				
31	V	Verify buzzer is of sufficient volume to help indicate the location of the payload following landing	51,52	Buzzer volume measured to be 92 dB
32	E	Verify battery compartment can be removed in less than 1 minute without total CanSat disassembly	54	Battery compartment is easily accessible and battery easily removed
33	E	Verify full set of sensor data can be acquired at the required sampling rate simultaneously	28	Sensor data are collected correctly
34	E	Verify power requirements are satisfied for the full mission sequence and maximum predicted mission time	44, 57	CanSat remains powered over duration of mission with power to spare
35	S, E	Verify Container parachute deployment occurs immediately after CanSat release from rocket	8	Parachute is deployed immediately after CanSat release

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Integrated Functional Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
PAYLOAD: ENTIRE MISSION (CONTINUED)				
36	S, E	Verify that when code from Sensors, CDH and GCS subsystem are integrated and that microcontroller has sufficient memory	-	Microcontroller has memory to spare after maximum expected mission time
37	S, V	Verify fully assembled CanSat system weights within 10 g of 600 g	1	CanSat is within 10 g of 600 g
38	S, E	Verify the glider release mechanism is activated within 10 m of 450 m	10	Glider is released within 10 m of 450 m
39	S, E	Verify wing deployment mechanism occurs immediately after glider release	10,11, 12	Wings deploy immediately after glider release
40	S, V	Verify all electronic components except sensors are fully enclosed when assembled	15	Electronics excluding sensors are enclosed
41	V	Verify power switch is easily accessible and reliably activated the system	49	Power switch is compliant
42	E,V	Verify CanSat is able to perform all tasks without assistance from external structures	6,7	CanSat maintains structure at all times
43	E,V	Verify all CanSat electronics remain in desired position during Mission	18	All electronics are securely attached to CanSat
44	S, E	Verify glider parachute deployment mechanism is activated after one minute of gliding	13	Glider parachute deployed after 60 seconds of gliding

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Integrated Functional Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
RELEASE TRIGGER				
45	E	Verify FSW triggering the CCU to release the payload from the container.		Glider is deployed
46	E	Verify CCU glider release and deployment mechanism performs as expected as part of the constructed CanSat structure	10	Glider is deployed
DESCENT CONTROL				
47	E	Verify that with parachute deployed the CanSat (container + glider) descents at the required descent rate	9	CanSat descends at between 15 to 25 m/s
48	E,S,V	Verify center of pressure of the payload is well above center of gravity to ensure stable descent	11,12,13	Glider descends in a stable fashion, allowing passive control to maintain course
49	E	Verify that glider parachute slows the glider's descent speed to the required descent rate	13	Glider descends at between 5 to 15 m/s after parachute deployment
MECHANISMS				
50	E	Verify CCU glider release and deployment mechanism survive required force limits	-	All structures and mechanisms are intact after release

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Integrated Functional Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
MECHANISMS (CONTINUED)				
51	E	Verify CCU glider release and deployment mechanism performs as expected as part of the constructed CanSat structure and the glider is released without impedance	10,11, 12,13	Glider is deployed without impedance
52	V	BONUS: verify camera can be activated by the FSW	BONUS	Camera operation is controlled by FSW
53	V	BONUS: verify camera can be activated by the FSW	BONUS	Camera operation is controlled by FSW
PAYLOAD PARACHUTE RELEASE				
54	E	Verify parachute stays attached to the payload due to expected forces	13	Parachute does not detach from the glider and retains its function after deployment
55	V	Verify CanSat can be easily identified from a distance by using fluorescent covers and parachutes	4, 30	CanSat is easily distinguished from the background/environment
COMMUNICATIONS: GCS				
56	E	Verify GCS software handles live data from antenna + XBee and plots it in real time in SI units	40,41,42	GCS software plots live data in real time
57	E	Verify antenna receives data from assembled CanSat at and above the required range	39, 44	Telemetry is received at test GCS

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Integrated Functional Level Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Req. No.	Pass/Fail Criteria
COMMUNICATIONS: CDH				
58	E	Verify full live telemetry transmission is of the current form for reception at the GCS	40,41,42	Telemetry is valid and successfully transmitted
59	E, V	Verify telemetry is updated once per second.	29	New packet received every second

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Environmental Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Test Subject	Req. No.	Pass/Fail Criteria
VIBRATION TEST: CANSAT					
60	E	CanSat is fixed to an orbit sander to provide up to 14,000 rpm of rotation equivalent to 233 Hz of vibration, to expose failure of CanSat structures/components if they vibrate at resonance.	Structures	56	CanSat structures comply with all expected tensile/compressive/torsional loads during and following test period, including performance of container, parachutes and their respective attachment components
			Mechanisms	56	CanSat mechanisms perform as required following test period
			Electronics	56	Electronics preform at a constant level during and following test period
THERMAL TEST: CANSAT					
61	E	Fully assembled CanSat is placed in controlled thermal chamber and heated to ~60˚C while systems are active. This is conducted for 3 hours.	Structures	56	CanSat structures comply with all expected thermal loads during and following test period, including performance of the container, parachutes and their respective attachment components
			Mechanisms	56	CanSat mechanisms perform as required following test period
			Electronics	56	Electronics perform at a constant level during and following test period

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Environmental Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Test Subject	Req. No.	Pass/Fail Criteria
15 G LAUNCH ACCELERATION TEST- CANSAT					
62	E	Fully assembled CanSat is placed in a sounding rocket for a test launch to simulate launch conditions. This means the integrity of the glider, its deployment mechanism, and container attachment subsequent to launch can be verified. This acceleration can be verified with the accelerometer within the Sensors subsystem.	Structures	16	CanSat structures comply with all expected tensile/compressive/torsional loads during and following test period, including performance of container, parachute, and their respective attachment components
			Mechanisms	19	CanSat mechanisms perform as required following test period
			Electronics	18	Electronics perform as required during and following test period
>30 G DROP TEST – PAYLOAD					
63	E	Whole assembled CanSat with parachute deployed is subjected to a drop from 61 cm with a cord attachment to result in a 30 G shock or greater acceleration, to simulate rocket body separation forces. This acceleration can be verified with accelerometer within the Sensors subsystem.	Structures	14, 17, 33, 56	CanSat structures comply with all expected tensile/compressive/torsional loads during and following test period, including performance of container, parachute, and their respective attachment components
			Mechanisms	14, 19, 56	CanSat mechanisms perform as required following test period
			Electronics	56	Electronics perform as required during and following test period

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

Environmental Testing

TEST PASSED	TEST ATTEMPTED, NOT PASSED	TEST NOT ATTEMPTED

Test No.	Test Type	Test Description	Test Subject	Req. No.	Pass/Fail Criteria
DIMENSIONS VERIFICATION: CANSAT					
64	S, E	Fully assembled CanSat is subject to a fit check using a sheet of plywood with a hole of diameter 125 mm and another with dimensions of 310 x 125mm, to ensure clearances.	Structures	2	CanSat passes through the template
WIND TUNNEL TEST					
65	S	A full-scale prototype of the glider's frame is 3D printed and placed in the wind tunnel with the purpose of validating the aerodynamic quantities calculated analytically. The lift to drag ratio is investigated to determine whether the design needs to be modified. The effect of the outer structure to accommodate for the camera is physically observed.	Structures	11	Lift to drag ratio is accurate
TEST LAUNCH					
66	E	Verify compliance of both integrated functional level tests and environmental tests by launching the CanSat using a LocPrecision Minie-Magg sounding rocket, with a 20-inch Payload bay. *Note: some requirements had to be altered due to launch height restrictions.*	Structures, Mechanisms, Electronics	1-4,6-19, 22-34,36-37,39-45,47, 49,51-52,54, 56-57	CanSat mechanisms preform successfully and accurate data is transmitted throughout flight while maintaining structural integrity.

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Test Procedures Descriptions

After subsystem, integrated functional level, and environmental testing, 47 of the 57 requirements are mapped to a test.

- It is also possible to test the bonus requirement.
- The remaining 10 requirements primarily require initial verification of designs and ongoing any subsequent design iterations.
- All tests that have not yet been attempted would have been completed after the test launches on 1st April and 10th May 2020 (excluding competition required tests which would have been conducted at a later stage once the CanSat would be in its final design stages).
- Responsibility for compliance of the system to these requirements falls to the Integration & Testing leader (TP), who will frequently confirm compliance.

Test Procedures Descriptions

Remaining Requirements

RE #	Requirement	Relevant subsystem	Evidence of Compliance
5	The container shall be solid and fully enclose the science payload. Small holes to allow access to turn on the science payload is allowed. The end of the container where the payload deploys may be open.	ME, DC	19, 53, 58
20	Mechanisms shall not use pyrotechnics or chemicals	ME/DC	53-61
21	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.	ME/DC	53-61
35	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.	CDH	81
38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	PM	170
46	Both the container and probe shall be labeled with team contact information including email address.	PM	150
48	No lasers allowed.	ME/DC/CDH/ Sensors	12-14
50	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the cansat and in the stowed state.	EPS	99
53	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.	EPS	92
55	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.	EPS/ME	91

Test Procedure: Experimental **E** Simulation **S** Verification **V**

Mission Operations & Analysis

Conor Shore

Overview of Mission Sequence of Events

Roles and Responsibilities:
Mission Control Officer: TC
Ground Station Crew: MLH, CS, TP, MR, GA, CR
Recovery Crew: GJ, MD, MWR
CanSat Crew: MLH, CS, TP, CR, MWR, GJ, MR, MD, GA

Additionally, MLH will be responsible for handing over telemetry data file to field judge for review.

Final Assembly, Integration and Testing:

- Between 08:00 and 12:00.
- Full team involved, excluding TC.
- Various CanSat I&T procedures are carried out prior to the competition to ensure that everything is in order. This is led by TP and performed by the *CanSat Crew*.
- Antenna and GCS set-up will be carried out by the *Ground Station Crew*. Simple plug-and-play philosophy stands behind the design of the GCS and Antenna systems.
- An I&T plan will be followed throughout this process to ensure that all procedures have been carried out sufficiently – see *Mission Operations Manual*.

Overview of Mission Sequence of Events

- **Arrival**
  - 08:00 – *Full Team*
- **Final Assembly, Integration and Testing**
  - *CanSat Crew*
- **Official Inspection**
  - 12:00 - TC
- **Collect CanSat**
  - *TC*
- **CanSat integration with rocket**
  - *MLH, CR*
- **Check Communications**
  - *CS, TP*
- **GCS & Antenna Set-Up**
  - *CS, TP*
- **Rocket with CanSat taken to Launchpad**
  - *MLH, CR*
- **Rocket Installation**
  - *Officials*
- **GCS operational**
  - *GCS Crew*
- **Launch Procedures Execution**
  - *TC*
- **Flight + GCS Operational**
  - *GCS Crew*
- **CanSat Launched**
- **Recovery**
  - *Recovery Team*
- **Handover CanSat for Final Judging**
  - *MD*
- **Terminate GCS Operation**
  - *TP*
- **Submit USB with collected and received data**
  - *MLH*
- **Begin PFR work and data analysis**

Field Safety Rules Compliance

The *Mission Operations Manual* is compiled at individual- and team-level to ensure suitable **accuracy** and **detail** of tests and procedures.

The *Mission Operation Manual* will contain instructions for the following procedures:

1. **CanSat Integration and Testing**	**TP, MLH, CS**
1.1. Integration Procedure	
1.2. Testing Procedure	
1.3. Operational Checks	
2. **GCS & Antenna Setup and Operation**	**Ground Station Crew**
2.1. Setup Procedure	
2.2. Operational Checks	
3. **CanSat-Rocket Integration**	**CanSat Crew**
4. **Launch**	**TC, Officials**
4.1. Preparation Procedure	
4.2. Launch Procedure	
5. **Other Procedures**	**TC**

The *Mission Operations Manual* has been completed in time for the first test launch that was scheduled for the 1st of April, but was cancelled due to the COVID-19 lockdown.

The *Mission Operations Manual* will be reviewed and approved by the full team prior to the launch. Multiple copies will be distributed to the team on test launch days and at the Competition. Modifications will be made where necessary.

CanSat Location and Recovery

The following measures will ensure that both the Container and the Payload will be recovered.

1. Audio Beacon
Continuous beeping on the Payload at 92 dB unobstructed.

2. Telemetry
Payload GPS position plotted on the GCS. Subject to errors and degree of accuracy.

3. Colour
The Container and the Payload will be *fluorescent pink* to make the CanSat easier to identify and locate.

4. Visually
Recovery Crew will track the Container and Payload as they descend.

In the event that the **CanSat is not recovered**, both the Container and the Payload will have Manchester CanSat Project's address and email address clearly labelled, along with any other relevant contact details. They are as follows:

Manchester CanSat Project, University of Manchester
Team 4920, cansat.manchester@gmail.com
George Begg Building, University of Manchester, M1 7DN,
Manchester, United Kingdom

Mission Rehearsal Activities

At the time of CDR submission, the University of Manchester and the United Kingdom is on lockdown due to the COVID-19 pandemic, and prototyping and testing efforts have ceased. It is expected that no test launches will be completed due to the lockdown. However, the mission rehearsal activities outlined below follow our initial schedule had the pandemic not taken place.

Weekly lab sessions have been completed thus far (labelled green).

Activities	Rehearsals		
	Weekly Lab Session	Full System Test Launch 1st of April	Full System Test Launch 10th of May
Ground system radio link check procedures	X	X	X
Powering on/off the CanSat	X	X	X
Launch configuration preparations (e.g., final assembly and stowing appendages)	X	X	X
Loading the CanSat in the launch vehicle		X	X
Telemetry processing, archiving, and analysis	X	X	X
Recovery		X	X

Mission Rehearsal Activities

The Mission Operations Manual has been created to guide the following parties during mission day. It would have been used during test launch days.

Mission Control Officer: TC
Ground Station Crew: MLH, CS, TP, MR, GA, CR
Recovery Crew: GJ, MD, MWR
CanSat Crew: MLH, CS, TP, CR MWR, GJ, MR, MD, GA

The **Chief Engineer** (MLH) will ensure the coordination of all parties.

Requirements Compliance

Conor Shore

Requirements Compliance Overview

The current design complies with all requirements.

The design shall be tested to ensure Requirement Compliance, following the procedure explained in the *Integration and Testing* section of this document.

The design has been altered since the PDR. As with the design at PDR stage, all requirements are compliant.

The following five slides trace and demonstrate compliance with all requirements. Comments have been included where necessary.

The legend provides an explanation as to the colour coding used throughout this section, with the goal of demonstrating if a requirement has been met.

Full Compliance
Partial Compliance
No Compliance

Requirements Compliance (Slide 1 of 5)

RE #	Requirement	Compliance	Reference Slides	Comments
1	Total mass of the CanSat (science payload and container) shall be 600 grams +/- 10 grams.		**71**	**552.91 g. Will add Ballast to Payload. See ref slide.**
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.		**14, 19, 49, 58**	**120 x 305**
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.		**19, 58**	
4	The container shall be a fluorescent color; pink, red or orange.		**34, 43, 49, 58**	
5	The container shall be solid and fully enclose the science payload. Small holes to allow access to turn on the science payload is allowed. The end of the container where the payload deploys may be open.		**19, 53, 58**	
6	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.		**19, 53**	
7	The rocket airframe shall not be used as part of the CanSat operations.		**19, 53**	
8	The container 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.		**19, 58, 60**	
9	The descent rate of the CanSat (container and science payload) shall be 20 meters/second +/- 5m/s.		**47**	**17.6 m/s**
10	The container shall release the payload at 450 meters +/- 10 meters.		**60, 99, 104**	
11	The science payload shall glide in a circular pattern with a 250 m radius for one minute and stay above 100 meters after release from the container.		**40, 47**	
12	The science payload shall be a delta wing glider.		**14, 34, 49**	

Requirements Compliance (Slide 2 of 5)

RE #	Requirement	Compliance	Reference Slides	Comments
13	After one minute of gliding, the science payload shall release a parachute to drop the science payload to the ground at 10 meters/second, +/- 5 m/s		**47, 56, 104**	**7.2 m/s**
14	All descent control device attachment components shall survive 30 Gs of shock.		**60, 61, 62, 128**	
15	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.		**14, 49, 53, 63**	
16	All structures shall be built to survive 15 Gs of launch acceleration.		**53-59, 64, 128**	
17	All structures shall be built to survive 30 Gs of shock.		**53-59, 64, 128**	
18	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.		**62**	
19	All mechanisms shall be capable of maintaining their configuration or states under all forces.		**60, 61, 64, 128**	
20	Mechanisms shall not use pyrotechnics or chemicals.		**53-61**	
21	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.		**53-61**	
22	The science payload shall measure altitude using an air pressure sensor.		**25**	
23	The science payload shall provide position using GPS.		**27**	
24	The science payload shall measure its battery voltage.		**28**	
25	The science payload shall measure outside temperature.		**26**	
26	The science payload shall measure particulates in the air as it glides.		**30**	
27	The science payload shall measure air speed.		**29**	

Requirements Compliance (Slide 3 of 5)

RE #	Requirement	Compliance	Reference Slides	Comments
28	The science payload shall transmit all sensor data in the telemetry.		**79-84, 104**	
29	Telemetry shall be updated once per second.		**104**	
30	The Parachutes shall be fluorescent Pink or Orange .		**34, 49, 55, 58, 61**	
31	The ground system shall command the science vehicle to start transmitting telemetry prior to launch.		**114-115**	
32	The ground station shall generate a csv file of all sensor data as specified in the telemetry section.		**114-116**	
33	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.		**78, 82-83**	
34	Configuration states such as if commanded to transmit telemetry shall be maintained in the event of a processor reset during launch and mission.		**82-84**	
35	XBEE radios shall be used for telemetry. 2.4 GHz Series radios are allowed. 900 MHz XBEE Pro radios are also allowed.		**81**	
36	XBEE radios shall have their NETID/PANID set to their team number.		**81**	
37	XBEE radios shall not use broadcast mode.		**81**	
38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.		**170**	
39	Each team shall develop their own ground station.		**113-119**	
40	All telemetry shall be displayed in real time during descent.		**104, 114, 117**	
41	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)		**114, 117**	
42	Teams shall plot each telemetry data field in real time during flight.		**117**	

Requirements Compliance (Slide 4 of 5)

RE #	Requirement	Compliance	Reference Slides	Comments
44	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand-held antenna.		**113, 119**	
45	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.		**113**	**Using laptop. Thus, portable.**
46	Both the container and probe shall be labelled with team contact information including email address.		**150**	
47	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.		**99, 133-134**	
48	No lasers allowed.		**12-14**	**No lasers used.**
49	The probe must include an easily accessible power switch that can be accessed without disassembling the CanSat and in the stowed configuration.		**49, 55**	
50	The probe must include a power indicator such as an LED or sound generating device that can be easily seen without disassembling the CanSat and in the stowed state.		**99**	
51	An audio beacon is required for the probe. It may be powered after landing or operate continuously.		**99**	
52	The audio beacon must have a minimum sound pressure level of 92 dB, unobstructed.		**136**	
53	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.		**92**	

Requirements Compliance (Slide 5 of 5)

RE #	Requirement	Compliance	Reference Slides	Comments
54	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.		**49, 55, 91**	
55	Spring contacts shall not be used for making electrical connections to batteries. Shock forces can cause momentary disconnects.		**91**	
56	The CANSAT must operate during the environmental tests laid out in Section 3.5.		**141-143**	
57	Payload/Container shall operate for a minimum of two hours when integrated into rocket.		**93-94**	
B1	*Bonus: A video camera shall be integrated into the science payload and point toward the coordinates provided for the duration of the glide time. Video shall be in color with a minimum resolution of 640x480 pixels and 30 frames per second. The video shall be recorded and retrieved when the science payload is retrieved. Points will be awarded only if the camera can maintain pointing at the provided coordinates for 30 seconds uninterrupted.*		**14, 31**	

Management

Conor Shore

Status of Procurements

All necessary components **have arrived** and were being tested and assembled prior to the COVID-19 lockdown. Composite structural components such as the foam cored carbon fibre have been assembled.

The team intended to purchase enough parts to build **3 CanSats** for the Competition. 2 will be built for the Competition. The third set of additional parts will be for any unforeseen circumstances during transport.

Procurement is not a concern for the team, as most components tend to arrive within one to two working days. The only concern is XBees, but the team has already ordered multiple spares so this is not a concern.

A full list of components and their costs can be found in the following slides.

CanSat Budget – Hardware

The following table shows the budget for hardware in terms of CanSat subsystems:

Subsystem	Cost (£)
Structures	164.24
Electronics	184.98
Tools	0
Total:	**£349.22**

Legend			
Estimated	XX	Actual	XX

CanSat Budget – Hardware

Electronic Components					
Part Name	**Function**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
u-blox NEO-M8N GPS Module	GPS	No	1	5.50	6.87
2.6 Arduplane Airspeed Sensor	Pitot tube		1	3.37	4.21
GP2Y1010AU0F Particle Sensor	Particulate count		1	2.87	3.59
Runcam Nano 2	Camera		1	10.21	12.76
HMDVR	Records video from camera		1	20.02	25.01
Hitec HS-40 180° Servo	CCU and camera pitch		2	17.58	21.96
Aslong JG-12	Stepper motor (camera rotation)		1	6.56	8.20
XBEE Pro 900HP u.fl	Communications		1	32.82	41.00
Switch	On/Off Switch		1	0.61	0.76
Teensy 4.0	Microcontroller		1	21.51	26.87
NCP4625DSN18T1G	1.8V Linear Voltage Regulator		1	0.69	0.86
Molex PicoBlade 53048	Connectors		9	3.53	4.41
Total Cost:				**£125.27**	**$156.5**

Legend			
Estimated	XX	Actual	XX

CanSat Budget – Hardware

Electronic Components					
Part Name	**Function**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
MIC2876	5V Boost Voltage Regulator	No	1	0.39	0.49
MS4525DO	Differential Pressure Sensor		1	31.57	39.44
ZXBM5210	Motor Driver		1	0.75	0.94
TPS2121	Power Multiplexer		1	1.60	2.00
PDTD113ZT	Power Transistor		1	0.30	0.37
TXS0102DCUT	Logic Level Shifter		1	0.57	0.71
BMP388	Temp and Pressure Sensor		1	2.48	3.10
ICM-20948	IMU		1	4.58	5.72
NCV8161ASN330T1G	3.3V Linear Regulator		1	0.43	0.54
Total Cost:				**£42.67**	**$53.31**

Legend			
Estimated	XX	Actual	XX

CanSat Budget – Hardware

Electronic Components					
Part Name	**Function**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
Slip Ring	Camera Mechanism	No	1	5.02	6.27
Buzzer	Payload Recovery		1	1.17	1.46
Headers	Board Interconnects		2	3.14	3.92
Capacitors	N/A		30	0.62	0.77
Inductors	N/A		1	0.79	0.99
Resistors	N/A		19	0.30	0.37
PCB	Component Mounting		2	4.00	5.00
Wiring	N/A		-	2.00	2.50
Total Cost:				**£17.04**	**$21.29**

Legend			
Estimated	XX	Actual	XX

CanSat Budget – Hardware

3D Printed Components						
Material	**Part Name**	**Function**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
ABS	Container top plate	Attachment for Container Parachute	No	1	2.12	2.65
	Container ribs	Structural integrity		3	0.67	0.84
	Container bottom rib	Structural integrity		1	0.35	0.44
	GPS mount	To mount GPS		1	0.08	0.10
	Roof scoop	To aid airflow for particulate sensor		1	0.08	0.10
	Buzzer mount	To mount buzzer		1	0.15	0.19
	PCB mount	To mount stacked PCBs		1	0.12	0.15
	CCU housing (inc. spool)	To mount Servo for Payload release, wings and Payload Parachute deployment mechanism		1	0.29	0.36
	Camera mechanism mount	To mount camera mechanism components		1	0.18	0.22
Total Cost:					**£4.04**	**$5.05**

Legend			
Estimated	XX	Actual	XX

CanSat Budget – Hardware

3D Printed Components						
Material	**Part Name**	**Function**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
CPE+	X-frame arms	Wing spar structure	No	2	£4.73	5.91
	Fuselage-X-frame attachment	Attaches wings to fuselage		3	£2.24	2.80
	Payload parachute bay	To enclose payload parachute		1	£1.68	2.10
	Tail	To ensure circular descent pattern		1	£2.14	2.67
Total Cost:					**£10.79**	**$13.48**

Legend			
Estimated	XX	Actual	XX

CanSat Budget – Hardware

Off-the-Shelf Components					
Part Name	**Function**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
Carbon fibre rods	Container structural support	No	3	7.20	8.99
Plastic file folder	Container cover		1	1.50	1.87
String	CCU mechanism		1	1.50	1.87
Nuts/Bolts Box	Various nuts and bolts		Assorted	11.00	13.74
1 mm CFRP	Fuselage airfoils		4	21.50	26.86
3 mm Rohacell foam	Fuselage airfoils		2	30.68	38.33
Balsa	Wing ribs, camera mechanism mount plate		1	6.45	8.06
Parachutes	N/A		2	17.23	21.53
PETG sheet	Camera bubble		1	4.75	5.93
Torsion springs	Wing deployment mechanism		2	6.00	7.50
Ripstop Nylon	Payload wing skin		1	19.99	24.97
Total Cost:				**£127.80**	**$159.66**

Legend			
Estimated	XX	Actual	XX

CanSat Budget – Hardware

Off-the-Shelf Components					
Part Name	**Function**	**Reuse**	**Quantity**	**Total Cost (£)**	**Total Cost ($)**
Steel shaft	CCU rods, wing ribs, fuselage attachment, parachute bay	No	2	5.89	7.36
Gorilla epoxy	High performance adhesive		2	11.00	13.74
Bevel gears	Camera mechanism rotation		2	4.72	5.90
Total Cost:				**£21.61**	**$27.00**

Legend			
Estimated	XX	Actual	XX

CanSat Budget – Hardware

Total Spent (£)	**349.22**
Total Spent ($)	436.28
Budget Left ($)	563.72
Exchange Rate (£1 =)	$1.24930
Exchange Rate Date	3 May 2020 13:21 GMT

CanSat Budget – Other Costs

	Detail	Description	Unit Cost (£)	Quantity	Total Cost (£)	Total Cost ($)
Travel, Accommodation and Sustenance Costs	Travel	Flights, rental car, train	758	10 people	7,580	9469.69
	Visas	Tourist Visa	128.07	4 people	541.68	640
		ESTA	11.21	6 people	67.24	84
	Housing	Based on preliminary information provided by Competition organisers	163.29	10 people	1632.91	2040
	Food	Based on preliminary information provided by Competition organisers	98.22	10 people	982.15	1227
GCS Hardware Cost	Display	Laptop (provided by team member)	N/A	1	N/A	N/A
	Telemetry	900 MHz 9 dBi SS Yagi Antenna SMA Male Connector	65.24	1	65.24	81.50
CanSats	All CanSat parts	3 CanSats: Main CanSat, backup CanSat and spare parts	349.22	3	1047.66	1308.84
Competition Entry Fee	N/A	N/A	160.09	1	160.09	200
Total Mission Cost:					12,077	15087.80

Legend			
Estimated	XX	Actual	XX

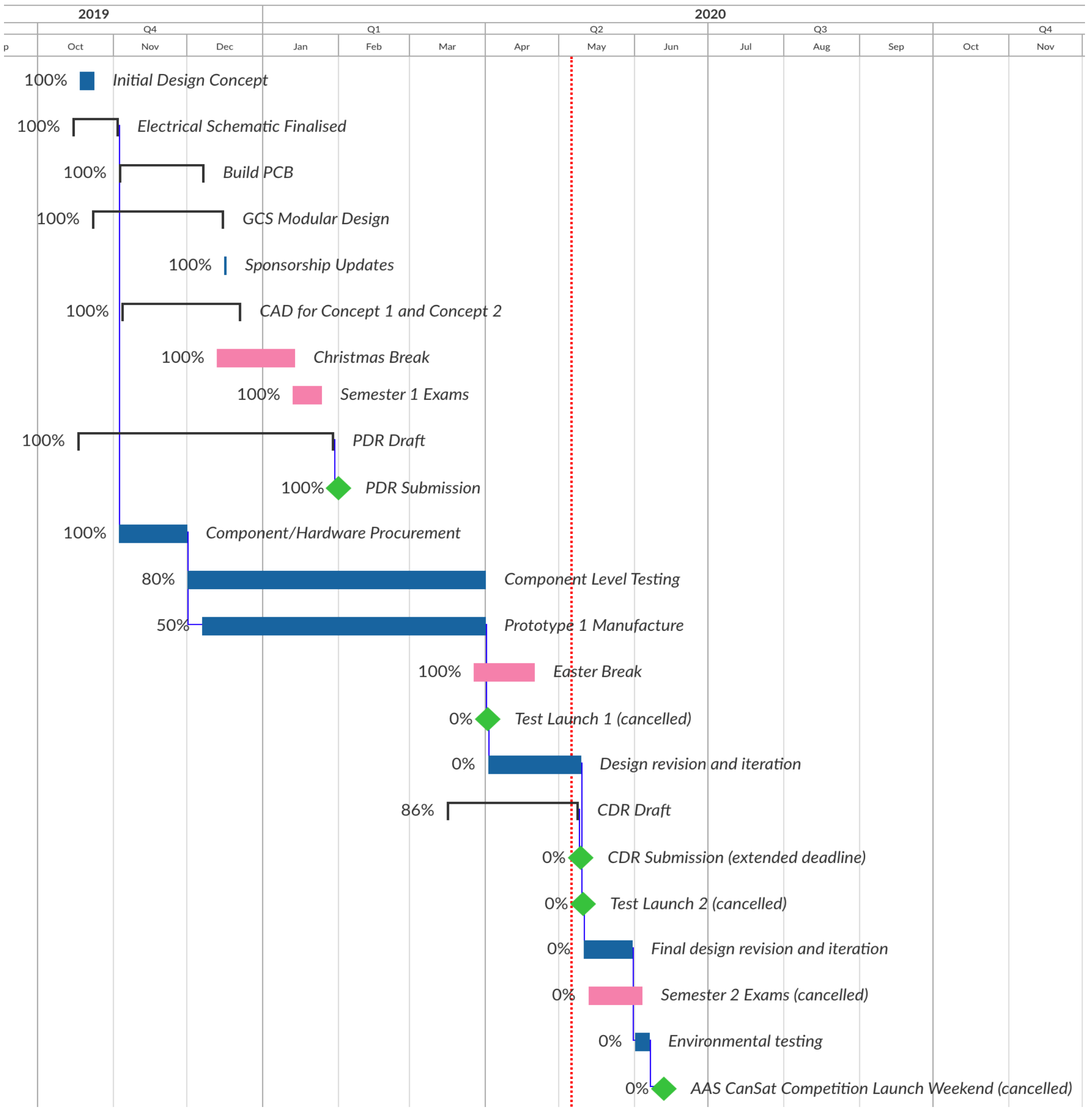
CanSat Budget – Other Costs

Source	Amount (£)	Additional Information
Department of MACE	6500	
Department of EEE	2000	
Department of Computer Science	500	
Aerospace Research Institute	1000	
MANSEDS	620	
BAE Systems	2,500	TBC
Airbus	6,000	Funding was expected to be provided had the Launch Weekend not been cancelled

Total Income Confirmed (£)	10,620
Total Income Confirmed ($)	13,267.55

Legend			
Estimated	XX	Actual	XX

Program Schedule Overview



The Gantt chart on the left shows MCP's Program Schedule Overview, including major Competition milestones.

OpenProject is used as MCP's primary project management tool.

The Program Schedule has been updated to reflect the COVID-19 lockdown beginning on the 18th of March, the CDR deadline extension to the 8th of May and the cancellation of the June Launch Weekend.

Task completion is also indicated on the Gantt chart.

Milestone	
Isolated Task	
Parent Task	
Exam/Holiday	

Detailed Program Schedule

The following four slides show the Program Schedule in detail, including *Competition Milestones, Academic Milestones and Holidays, Major Development Activities, Component/Hardware Procurement/Deliveries, and Major I&T Activities and Milestones*. Team members have been assigned to each task.

ID	Subject	Start date	Finish date	Relation type	ID	Subject	Category	Assignee
89	Electrical Schematic Finalised	15.10.2019	02.11.2019	parent of	93	Component Selection	Electrical	Conor Shore
89	Electrical Schematic Finalised	15.10.2019	02.11.2019	parent of	97	Schematic Design	Electrical	Conor Shore
93	Component Selection	15.10.2019	26.10.2019	parent of	94	CDH Selection	Electrical	Conor Shore
93	Component Selection	15.10.2019	26.10.2019	parent of	96	EPS Selection	Electrical	Marin Dimitrov
93	Component Selection	15.10.2019	26.10.2019	parent of	95	Sensor Selection	Electrical	George Amies
95	Sensor Selection	15.10.2019	26.10.2019	parent of	110	Select Pitot Tube/Pressure Sensors	Electrical	George Amies
96	EPS Selection	15.10.2019	26.10.2019	parent of	113	Battery Selection	Electrical	Marin Dimitrov
96	EPS Selection	15.10.2019	26.10.2019	parent of	114	Power System Design/Boost Converter	Electrical	Marin Dimitrov
94	CDH Selection	16.10.2019	26.10.2019	parent of	126	Other components	Electrical	Conor Shore
94	CDH Selection	16.10.2019	26.10.2019	parent of	125	Teensy 3.2 vs 4.0	Electrical	Marin Dimitrov
132	PDR Draft	17.10.2019	29.01.2020	parent of	134	CDH	Electrical	Conor Shore
132	PDR Draft	17.10.2019	29.01.2020	parent of	140	DC	Descent Control	Tim Chronis
132	PDR Draft	17.10.2019	29.01.2020	parent of	137	EPS	Electrical	Marin Dimitrov
132	PDR Draft	17.10.2019	29.01.2020	parent of	135	FSW	Electrical	Mihnea Romanovschi
132	PDR Draft	17.10.2019	29.01.2020	parent of	136	GCS	Electrical	Teja Potocnik
132	PDR Draft	17.10.2019	29.01.2020	parent of	141	I&T	Admin	Teja Potocnik
132	PDR Draft	17.10.2019	29.01.2020	parent of	139	Mech	Mechanical	Gaurav Jalan
132	PDR Draft	17.10.2019	29.01.2020	parent of	142	PM	Admin	Conor Shore
132	PDR Draft	17.10.2019	29.01.2020	parent of	138	Sensor	Electrical	George Amies
132	PDR Draft	17.10.2019	29.01.2020	parent of	214	Systems	Mechanical	May Ling Har
143	Initial Design Concept	18.10.2019	23.10.2019					
112	GCS Modular Design	23.10.2019	15.12.2019	parent of	145	Data CSV to graphs	Electrical	Teja Potocnik
112	GCS Modular Design	23.10.2019	15.12.2019	parent of	159	Data to Google Earth workflow	Electrical	Teja Potocnik
112	GCS Modular Design	23.10.2019	15.12.2019	parent of	158	Graph Generation Script	Electrical	Teja Potocnik
112	GCS Modular Design	23.10.2019	15.12.2019	parent of	160	Modify current GCS to work this year	Electrical	Teja Potocnik
112	GCS Modular Design	23.10.2019	15.12.2019	parent of	157	Serial Spitter	Electrical	Teja Potocnik

Detailed Program Schedule

ID	Subject	Start date	Finish date	Relation type	ID	Subject	Category	Assignee
97	Schematic Design	27.10.2019	02.11.2019	parent of	148	CanSat Addon Schmatic	Electrical	Marin Dimitrov
97	Schematic Design	27.10.2019	02.11.2019	parent of	147	CanSat Core Schmatic	Electrical	Conor Shore
332	Component/Hardware procurement	03.11.2019	29.11.2019				Admin	May Ling Har
81	Build PCB	03.11.2019	07.12.2019	parent of	109	Build CanSat Addon PCB	Electrical	Conor Shore
81	Build PCB	03.11.2019	07.12.2019	parent of	108	Build CanSat Core PCB	Electrical	Marin Dimitrov
81	Build PCB	03.11.2019	07.12.2019	parent of	103	Design CanSat Addon 2020	Electrical	Marin Dimitrov
81	Build PCB	03.11.2019	07.12.2019	parent of	102	Design CanSat Core PCB	Electrical	
81	Build PCB	03.11.2019	07.12.2019	parent of	107	Order Parts For CanSat Addon 2020	Electrical	Conor Shore
81	Build PCB	03.11.2019	07.12.2019	parent of	106	Order Parts for CanSat Core PCB	Electrical	Conor Shore
81	Build PCB	03.11.2019	07.12.2019	parent of	104	Order PCBs	Electrical	Conor Shore
81	Build PCB	03.11.2019	07.12.2019	parent of	105	Order Stencil From UoM PCB Lab	Electrical	Marin Dimitrov
90	CAD for Concept 1 and Concept 2	04.11.2019	22.12.2019	parent of	187	Auxiliary Electronics	Mechanical	May Ling Har
90	CAD for Concept 1 and Concept 2	04.11.2019	22.12.2019	parent of	116	Concept 1	Mechanical	Gaurav Jalan
90	CAD for Concept 1 and Concept 2	04.11.2019	22.12.2019	parent of	119	Concept 2	Mechanical	Richard Ryu
90	CAD for Concept 1 and Concept 2	04.11.2019	22.12.2019	parent of	166	PCB	Mechanical	May Ling Har
116	Concept 1	04.11.2019	22.12.2019	parent of	117	Container	Mechanical	May Ling Har
116	Concept 1	04.11.2019	22.12.2019	parent of	118	Payload	Mechanical	Gaurav Jalan
117	Container	04.11.2019	23.11.2019	parent of	163	Additional	Mechanical	May Ling Har
117	Container	04.11.2019	23.11.2019	parent of	162	Basic	Mechanical	May Ling Har
117	Container	04.11.2019	23.11.2019	parent of	208	Parachute	Descent Control	Tim Chronis
119	Concept 2	04.11.2019	20.12.2019	parent of	120	Container	Mechanical	May Ling Har

Detailed Program Schedule

ID	Subject	Start date	Finish date	Relation type	ID	Subject	Category	Assignee
119	Concept 2	04.11.2019	20.12.2019	parent of	121	Payload	Mechanical	Richard Ryu
120	Container	04.11.2019	23.11.2019	parent of	165	Additional	Mechanical	May Ling Har
120	Container	04.11.2019	23.11.2019	parent of	164	Basic	Mechanical	May Ling Har
120	Container	04.11.2019	23.11.2019	parent of	202	Parachute	Descent Control	Tim Chronis
166	PCB	04.11.2019	24.11.2019	parent of	168	Add-on	Mechanical	May Ling Har
166	PCB	04.11.2019	24.11.2019	parent of	167	Core	Mechanical	May Ling Har
118	Payload	13.11.2019	22.12.2019	parent of	189	Camera Mechanism	Mechanical	Richard Ryu
118	Payload	13.11.2019	22.12.2019	parent of	188	CCU	Mechanical	Richard Ryu
118	Payload	13.11.2019	22.12.2019	parent of	205	Elevator Design	Descent Control	Tim Chronis
118	Payload	13.11.2019	22.12.2019	parent of	191	Fuselage Structure	Mechanical	Richard Ryu
118	Payload	13.11.2019	22.12.2019	parent of	193	Integration	Mechanical	Gaurav Jalan
118	Payload	13.11.2019	22.12.2019	parent of	206	Parachute	Descent Control	Tim Chronis
118	Payload	13.11.2019	22.12.2019	parent of	190	Parachute Bay	Mechanical	Richard Ryu
118	Payload	13.11.2019	22.12.2019	parent of	204	Rudder Design	Descent Control	Tim Chronis
118	Payload	13.11.2019	22.12.2019	parent of	213	Tail	Mechanical	Gaurav Jalan
118	Payload	13.11.2019	22.12.2019	parent of	207	Winglet	Descent Control	Tim Chronis
118	Payload	13.11.2019	22.12.2019	parent of	192	Wing Structure	Mechanical	Gaurav Jalan
121	Payload	28.11.2019	20.12.2019	parent of	211	Camera Mechanism	Mechanical	May Ling Har
121	Payload	28.11.2019	20.12.2019	parent of	199	Elevator Design	Descent Control	Tim Chronis
121	Payload	28.11.2019	20.12.2019	parent of	196	Fuselage Structure	Mechanical	Gaurav Jalan
121	Payload	28.11.2019	20.12.2019	parent of	198	Integration	Mechanical	Richard Ryu
121	Payload	28.11.2019	20.12.2019	parent of	197	Parachute Bay	Mechanical	Gaurav Jalan
121	Payload	28.11.2019	20.12.2019	parent of	200	Parachute Size	Descent Control	Tim Chronis

Detailed Program Schedule

ID	Subject	Start date	Finish date	Relation type	ID	Subject	Category	Assignee
121	Payload	28.11.2019	20.12.2019	parent of	198	Integration	Mechanical	Richard Ryu
121	Payload	28.11.2019	20.12.2019	parent of	197	Parachute Bay	Mechanical	Gaurav Jalan
121	Payload	28.11.2019	20.12.2019	parent of	200	Parachute Size	Descent Control	Tim Chronis
121	Payload	28.11.2019	20.12.2019	parent of	195	Payload Deployment Mech	Mechanical	Richard Ryu
121	Payload	28.11.2019	20.12.2019	parent of	201	Rudder Design	Descent Control	Tim Chronis
121	Payload	28.11.2019	20.12.2019	parent of	212	Tail	Mechanical	May Ling Har
121	Payload	28.11.2019	20.12.2019	parent of	194	Wing Structure	Mechanical	Gaurav Jalan
210	Component Level Testing	30.11.2019	17.03.2020				Admin	Teja Potocnik
123	Prototype 1 Manufacture	07.12.2019	17.03.2020				Admin	Gaurav Jalan
228	Christmas Break	13.12.2019	13.01.2020					
115	Sponsorship Updates	16.12.2019	16.12.2019				Admin	May Ling Har
229	Semester 1 Exams	13.01.2020	24.01.2020					
82	PDR Submission	31.01.2020	31.01.2020				Admin	May Ling Har
314	CDR Draft	16.03.2020	08.05.2020	parent of	316	CDH	Electrical	Marin Dimitrov
314	CDR Draft	16.03.2020	08.05.2020	parent of	317	DC	Descent Control	Tim Chronis
314	CDR Draft	16.03.2020	08.05.2020	parent of	319	EPS	Electrical	Marin Dimitrov
314	CDR Draft	16.03.2020	08.05.2020	parent of	320	GCS	Electrical	Teja Potocnik
314	CDR Draft	16.03.2020	08.05.2020	parent of	322	I&T	Admin	Teja Potocnik
314	CDR Draft	16.03.2020	08.05.2020	parent of	323	ME	Mechanical	Gaurav Jalan
314	CDR Draft	16.03.2020	08.05.2020	parent of	325	PM	Admin	Conor Shore
314	CDR Draft	16.03.2020	08.05.2020	parent of	324	SE	Electrical	Marin Dimitrov
230	Easter Break	27.03.2020	20.04.2020					
326	Design revision and iteration	01.04.2020	05.06.2020				Admin	May Ling Har
327	Test Launch 1 (cancelled)	01.04.2020	01.04.2020				Admin	May Ling Har
87	CDR Submission (extended deadline)	08.05.2020	08.05.2020				Admin	May Ling Har
328	Test Launch 2 (cancelled)	10.05.2020	10.05.2020				Admin	May Ling Har
329	Semester 2 Exams (cancelled)	13.05.2020	03.06.2020					
331	Environmental testing	01.06.2020	06.06.2020				Admin	Teja Potocnik
330	AAS CanSat Competition Launch Weekend (cancelled)	12.06.2020	12.06.2020				Admin	May Ling Har

Detailed Program Schedule

CRITERIA	PERCENTAGE DONE
Project Analysis	100%
Mission Analysis	100%
System Concept	100%
Subsystem Design	100%
Procurement + Manufacturing	100%
Subsystem Testing	53%
System Integration	100%
Integrated Functional Level Testing	17%
PDR	100%
Environmental testing	-
Test Launches (0/2)	0%
Drop, vibration, thermal, dimensions	0%
Wind tunnel	0%
Design Iterations	70%
CDR	100%
Requirements compliance	100%
Prototype cloning	0%
OVERALL	**65%**

Shipping and Transportation

The team planned to assemble two fully functional CanSats, one of which will be shipped to Blacksburg, Virginia using an express courier service that can guarantee the delivery before the arrival of the full team in Blacksburg. The team will liaise with the competition officials to arrange this matter.

The team also planned to carry the exact same equipment for another two CanSats with them to ensure enough spares are available in case of a contingency. One fully assembled CanSat will be transported in a team member’s carry-on luggage, and a disassembled CanSat will be transported in another member’s carry-on luggage.

From an initial analysis, sending a 5 kg package worth £2000, the cost is approximately £100.

Should the team decide to not ship the CanSat, two team members will carry one fully assembled CanSat each in their carry-on luggage. The additional set of equipment for a third CanSat will be carried by a third member in their carry-on luggage. These members will be on separate flights, so that if in case of any flight delays and missed connections, at least one CanSat will arrive on time for the FRR.

Tools and equipment will be transported in checked-in luggage.

Conclusions

Major Accomplishments
• Design is well under weight limit without ballast. • Second revision of standardised PCB design manufactured and assembly started. • Foam cored carbon fibre structure successfully assembled and tested. • Majority of electrical components tested with success. • Significant funding attained, with more funding expected from Airbus had the launch weekend not been cancelled. • Inspired other UK Universities to join the 2020 UK CanSat Competition which was unfortunately cancelled, but are interested in joining next year's edition.

Major Unfinished Work
• First full prototype of CanSat. • Full systems test launches which have been cancelled, and various other tests (see below).

Testing to Complete
• Full systems test launches • Wind tunnel and other environmental tests • Some subsystems level tests

Flight Software Status
• In implementation phase, yet to be observed in full systems test launch